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Trade Barriers and the Relative Price Tradables*

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Abstract

In this paper I quantitatively address the role of trade barriers in explaining why prices of services relative to tradables are positively correlated with levels of development across countries. I argue that trade barriers play a crucial role in shaping the cross-country pattern of specialization across many heterogenous tradable goods. The pattern of specialization feeds into cross-country productivity differences in the tradables sector and is reflected in the relative price of services. I show that the existing pattern of specialization implies that the tradables-sector productivity gap between rich and poor countries is more than 80 percent larger than it would be under free trade. In turn, removing trade barriers would eliminate 64 percent of the disparity in the relative price of services between rich and poor countries, without systematically altering the cross-country pattern of the absolute price of tradables.

JEL codes: F1, O4

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1 Introduction

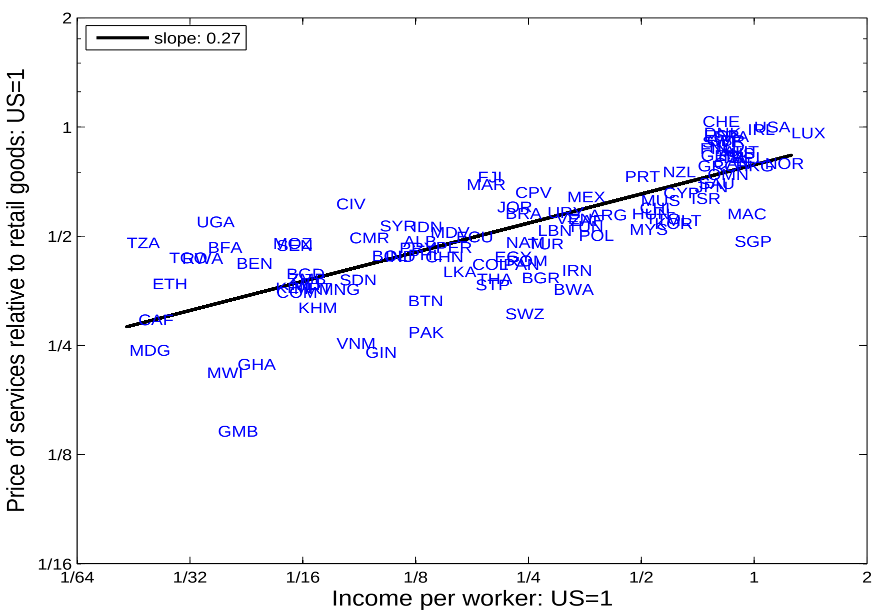
In this paper I investigate the role that trade barriers play in explaining why prices of services relative to tradables are positively correlated with levels of development across countries. My main message is that trade barriers are crucial in shaping the cross-country pattern of specialization across many heterogenous tradable goods. The pattern of specialization is key in determining cross-country productivity differences in the tradables sector, and these productivity differences are reflected in the relative price of services. I show that the existing pattern of specialization implies that the tradables-sector productivity gap between rich and poor countries is more than 80 percent larger than it would be if there were no barriers to trade. In turn, removing trade barriers would eliminate 64 percent of the disparity in the relative price of services between rich and poor countries. In particular, moving to free trade does not systematically alter the cross-country pattern in the price of tradables, but it does result in a large reduction in the gap in the price of services between rich and poor countries.

I construct aggregate prices for 103 countries for the year 2005 using detailed disaggregate price data from the 2005 International Comparison Program, World Bank Development Data Group (ICP from now on). I investigate country-specific PPPs at the retail level for 101 "Basic Headings" categories. I classify the Basic Heading categories into two groups: goods and services. Broadly speaking, goods correspond to merchandise, while services are intangible.

The ICP data are collected at the retail level which means that the observed prices include a distribution margin. Thus, within "goods" I distinguish between retail goods and tradable goods: retail goods are the products that result from combining tradable goods with a distribution margin from the local dock (if the good is imported) or from the factory gate (if the good is purchased domestically) to the final consumer. As a result, within each country, the price of retail goods is different from the price of purely tradable goods. For each country I construct two prices from Basic Headings data: one for services and one for retail goods. The 2005 Benchmark study of the Penn World Tables, which is based on ICP data, provides comparable prices across countries for a category called "Machinery and equipment". I take the price of Machinery and equipment to be my benchmark measurement for the price of purely tradable goods for two reasons. First, Machinery and equipment are highly traded and have a substantially smaller distribution margin than consumption goods (Burstein, Neves, and Rebelo, 2004). Second, I prefer to use a parameter-free measurement of the price of tradables as my benchmark. In section 4.2 I compare this proxy of the price of tradables to parametric alternatives that rely on stripping away the distribution margin from retail goods prices. By appealing to independent estimates of distribution margins in the literature I show that the parametric constructions also lead to aggregate prices of tradables that are uncorrelated with development.

Figure 1 plots the price of services relative to retail goods against income per worker for 103 countries. The elasticity of the price of services relative to retail goods with respect to income per worker is 0.27.[1] Prices of services co-vary more intensely with development than prices of retail goods do. The price elasticity of services is 0.49 while the price elasticity of retail goods is 0.22, see figure 2. The price elasticity of tradables (Machinery and equipment) is 0.02, and not significantly different from zero, see figure 3a. This implies that the elasticity of the price of services relative to tradables is 0.47, see figure 3b. Further empirical documentation of relative prices can be found in Kravis and Lipsey (1988), and Heston, Nuxoll, and Summers (1994). More recently, using disaggregate data, Marquez, Thomas, and Land (2012) show that prices of services tend to be highly correlated with levels of development, while prices of tradables have little-to-no correlation with development. They show that this observation remains robust even after removing goods and services that are "comparison resistant" across countries – for reasons that may stem from cross-country differences in quality for instance.

Figure 1: Price of services relative to retail goods. Prices are constructed for 103 countries using Basic Headings data from the 2005 International Comparison Program.



It is important to understand the fundamental sources of what causes differences in

[1]Throughout the paper, the elasticity of a price P with respect to income per worker y is the estimate of ρ from the following least squares regression across countries $i = 1, \ldots, I$: $\log(P_i) = a + \rho \log(y_i) + \epsilon_i$.

Figure 2: Prices of services and retail goods. Prices are constructed for 103 countries using Basic Headings data from the 2005 International Comparison Program.

(a) Price of services. (b) Price of retail goods.

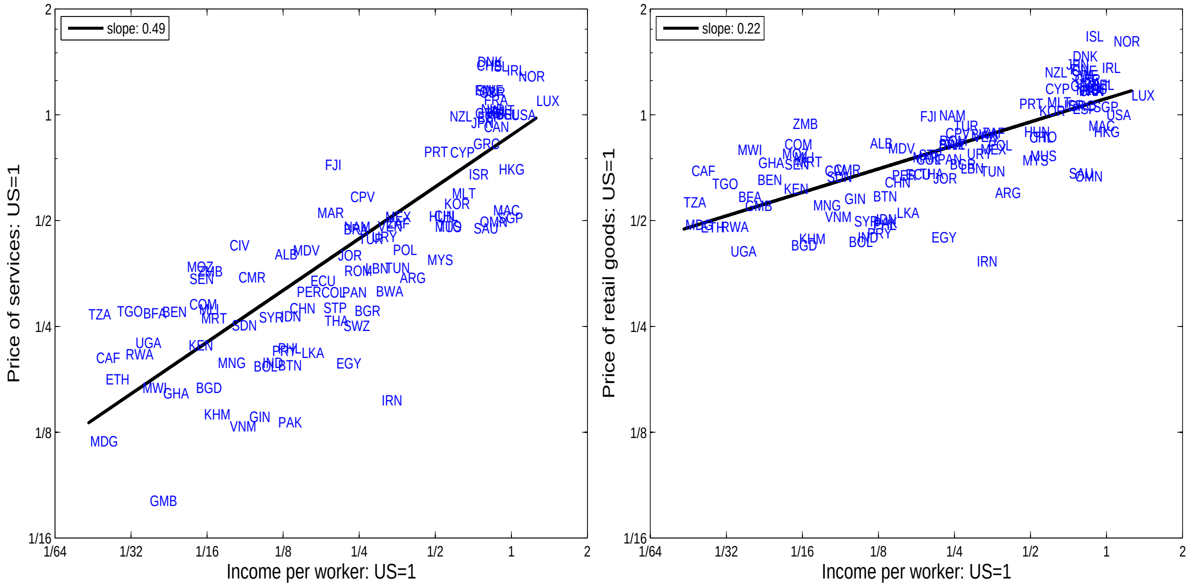
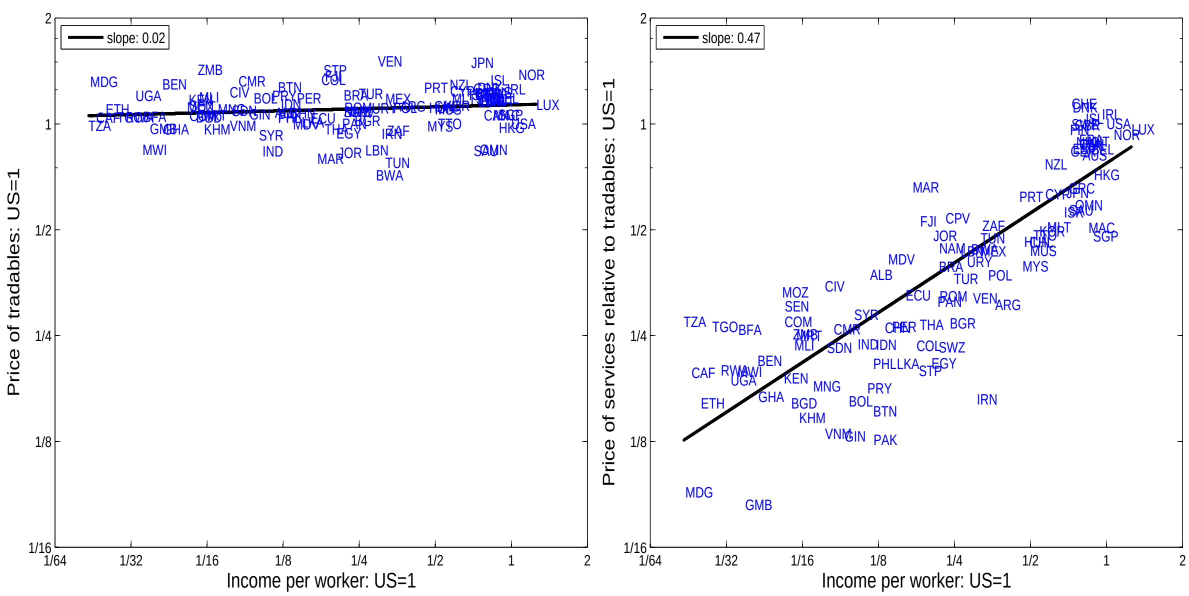


Figure 3: Price of tradables. I use the category "Machinery and equipment" from the 2005 ICP as a stand in for tradables.

(a) Price of tradables. (b) Price of services relative to tradables.



relative prices across countries for at least two reasons. First, relative prices lie at the heart of understanding real exchange rates (see for instance Burstein, Eichenbaum, and Rebelo, 2005). Second, relative prices play a crucial role in understanding income differences across countries (Restuccia and Urrutia, 2001; Eaton and Kortum, 2002; Hsieh and Klenow, 2007).

An early explanation as to why relative prices co-vary positively with development is due to Balassa (1964) and Samuelson (1964), the celebrated Balassa-Samuelson hypothesis. The theory implies that larger cross-country productivity differences in tradables than in nontradables result in larger cross-country differences in the price of nontradables than in the price of tradables. The intuition is as follows. Free trade and no arbitrage force the price of tradables to be equal across countries. Tradables-sector productivity is higher in rich countries than in poor countries resulting in higher wages in rich countries, and therefore, higher production costs. Mobility of homogeneous labor across sectors leads to higher production costs in rich countries' nontradables sector. This, coupled with small cross-country productivity differences in nontradables, results in a higher price of nontradables in rich countries than in poor countries. In particular, in each country, the relative price of nontradables is equal to the inverse of its relative productivity. Herrendorf and Valentinyi (2012) argue that the Balassa-Samuelson effect holds in a large cross section of countries: measured cross-country productivity differences are larger in tradables than in nontradables.

Bergin, Glick, and Taylor (2006) argue that the cross-country productivity gap is higher in tradables than in nontradables because more productive firms drive out less productive firms, and more productive firms tend to produce tradable goods. Buera, Kaboski, and Shin (2011) argue that financial frictions result in a misallocation of productive resources across sectors resulting in larger cross-country productivity differences in goods than in services. I argue that existing trade barriers result in a misallocation of the production of tradable goods and thus magnify the cross-country productivity gap in tradables. To this end, my paper encompasses the Balassa-Samuelson argument by providing a mechanism for which productivity differences in the tradables sector endogenously arise. However, my paper does not rely on the free trade assumption. In fact, I interact my model with data on bilateral trade in order to measure trade barriers, and the model in turn produces relative prices that are inline with the data in spite of, and more importantly as a result of, the fact that the calibrated trade barriers are nontrivial.[2]

A related strand of literature focusses exclusively on cross-country variation in the prices

[2] Waugh (2010) shows that that, in order to be simultaneously consistent with aggregate prices of tradable goods and the pattern of bilateral trade within a gravity framework, poor countries must face systematically larger barriers to export than rich countries. He then shows the implications that this particular pattern of trade barriers has for aggregate TFP and cross-country income differences.

of retail goods. Simonovska (2010) focuses on the positive correlation between prices of tradables (at the retail level) and levels of development. Using evidence from a particular apparel exporter, she shows that price discrimination across destinations is quantitatively important. Giri (2012) shows that incorporating distribution margins into a Ricardian model of trade with trade barriers can help explain the cross-sectional pattern of prices of retail goods across countries. Crucini and Yilmazkuday (2009) study retail price dispersion across international cities. They develop a two-sector, multi-city, general equilibrium model with a large number of goods and good-specific distribution margins. They use their model to estimate distribution margins for each good and quantify the importance of both trade costs and distribution costs on deviations from the law of one price.

I construct a multi-country model of trade with a continuum tradable goods. Each country has technologies for producing each tradable good, a composite good, nontradable services, and retail goods. Production of all tradables and services requires capital, labor, and intermediate inputs. Intermediate inputs consist of services and the composite good. Each country's level of efficiency for each tradable good is a random draw from a Fréchet distribution. Countries differ in their average efficiency across tradable goods and also face asymmetric bilateral trade barriers. Countries also differ in their services productivity. Each country purchases each tradable good from its least cost supplier, and all tradable goods are aggregated to form the composite good. Retail goods are constructed by applying a distribution margin, in the form of services, to the composite good. Finally, retail goods and services are used for final consumption. In equilibrium, each country produces only a subset of the tradable goods. Therefore, measured productivity in the tradables sector depends on the subset of goods produced, and the subset depends on the pattern of trade barriers.

I apply the model to a set of 103 countries for the year 2005. I quantitatively discipline the parameters of the model to be consistent with the observed pattern of bilateral trade and cross-country relative levels of development. Novel to the model is the feature that productivity in tradables depends crucially on the trade barriers. The calibration implies that poor countries face larger trade barriers than rich countries do. The resulting pattern of specialization leads to cross-country productivity differences in tradables that are twice as large as cross-country productivity differences in services.

The calibrated model reproduces the positive correlation between the prices of services and levels of development: the price elasticity of services (with respect to income per worker) is 0.59 in the model and is 0.49 in the data. The model replicates the distribution of the price of tradables almost perfectly: the price elasticity of tradables is 0.01 in the model and is 0.02 in the data. In the model, the price of retail goods is a geometric average of the price of services and the price of tradables, with the weight on the price of services equal to the distribution margin. Thus, the model slightly over-states the difference in the price of retail goods between rich and poor countries: the price elasticity of retail goods is 0.30 in the model and is 0.22 in the data.

Through counterfactuals I find that a complete removal of trade barriers would eliminate 64 percent of the difference in the price of services relative to tradables between rich and poor countries. Removing trade barriers has two effects. First, it results in identical prices of tradables across countries (PPP holds) so the price of tradables is uncorrelated with development both in the baseline and under free trade. Second, free trade leads to all countries reallocating resources towards the production of goods for which they have a comparative advantage, thereby changing the pattern of specialization and increasing measured productivity in the tradables sector. Since poor countries face larger trade barriers, their wages increase relative to wages in rich countries. Cross-sector labor mobility implies that the prices of services increase in poor countries relative to rich countries. As a result, the gap in the price of services relative to tradables between rich and poor countries declines when moving to free trade. Moreover, removing only the systematic differences in trade barriers across countries eliminates about half of the disparity in the difference in the relative price of services between rich and poor countries.

The remainder of the paper is laid out as follows. I describe the multi-country model in section 2 and discuss the qualitative mechanics of how trade barriers affect relative prices in section 3. Section 4 describes the calibration as well as the main quantitative results and counterfactual implications of removing trade barriers. In section 5 I consider departures from the baseline model and conclude in section 6.

2 Model

The model builds on the framework of Eaton and Kortum (2002), Alvarez and Lucas (2007), and Waugh (2010). There are I countries indexed by $i = 1, \ldots, I$. There are three sectors: tradable goods, retail goods, and services. The tradables sector is denoted by t, the retail goods sector is denoted by r, and the service is sector denoted by s. Each country i admits a representative household that is endowed with a measure N_i of workers. Each worker has a human capital level of h_i. Effective labor is denoted by $L_i = N_i h_i$. The representative household owns its country's capital stock, denoted by K_i. Both capital and labor are immobile across countries but perfectly mobile across sectors. Earnings from capital and labor are spent on consumption of retail goods and services.

Within the tradables sector there is a continuum of individual goods that are each potentially tradable across countries. Individual tradable goods are aggregated into a composite good. Each individual tradable good is produced using capital, labor, the composite good, and services. Services are produced using capital, labor, the composite good, and services as well. Services are combined with the composite good to construct retail goods. Neither retail goods nor services are tradable. From now on, where it is understood, country subscripts are omitted.

I choose world GDP to be the numéraire of the economy, i.e., $\sum_i w_i L_i + r_i K_i = 1$, where w_i and r_i denote the rental rates for labor and capital respectively in country i. Hence, all units are expressed in terms of world output.

2.1 Technologies

There is a continuum of individual tradable goods indexed by $x \in [0, 1]$, and each individual good is potentially tradable.

Composite intermediate good All individual tradable goods along the continuum are aggregated into a composite intermediate good T according to

$$T = \left(\int q_t(x)^{\frac{\eta-1}{\eta}} dx \right)^{\frac{\eta}{\eta-1}} .$$

where $q_t(x)$ denotes the quantity of good x.

Individual tradable goods Each country has access to technologies for producing each individual tradable good as follows

$$t_i(x) = z_i(x)^{-\theta} \left(K_{ti}(x)^{\alpha} L_{ti}(x)^{1-\alpha} \right)^{\nu_t} \left(S_{ti}(x)^{\sigma_t} T_{ti}(x)^{1-\sigma_t} \right)^{1-\nu_t} .$$

For each factor used in production, the subscript denotes the sector that uses the factor, and the argument in the parentheses denotes the index of the good along the continuum. For example, $K_{ti}(x), L_{ti}(x), S_{ti}(x)$, and $T_{ti}(x)$ respectively denote the amounts of capital, labor, services, and composite good that country i uses to produce tradable good x. The parameter $\nu_t \in [0, 1]$ determines the share of value added in gross production, $\sigma_t \in [0, 1]$ determines the share if services in intermediate inputs, while $\alpha \in [0, 1]$ determines capital's share in value added.

As in Alvarez and Lucas (2007), $z_i(x)$ represents country i's *cost* of producing good x, which is modeled as an independent random draw from an exponential distribution with parameter $\lambda_i > 0$ in country i. This implies that $z_i(x)^{-\theta}$, country i's level of efficiency in producing good x, has a Fréchet distribution. The expected value of $z_i(x)^{-\theta}$ is λ_i^{θ}, so average efficiency across the continuum of goods is λ_i^θ.[3] If $\lambda_i > \lambda_j$, then on average, country i is more efficient than country j. The parameter $\theta > 0$ governs the coefficient of variation in efficiency across the continuum. A larger θ implies more variation in efficiency levels, and hence, more room more specialization.

Since the index of the good x is irrelevant, from now on I follow Alvarez and Lucas (2007) and identify each individual good x by its vector of cost draws: $z = (z_1(x), z_2(x), \ldots z_I(x))$. I denote country i's density for cost draws by $\varphi_i(z)$.

Services Services are nontradable and are produced using capital and labor in addition to two intermediate inputs: services and the composite good.

$$S_i = A_{si} \left(K_{si}^{\alpha} L_{si}^{1-\alpha}\right)^{\nu_s} \left(S_{si}^{\sigma_s} T_{si}^{1-\sigma_s}\right)^{1-\nu_s}.$$

The term A_{si} denotes country i's productivity in the services sector.

Retail goods Retail goods are constructed by combining the composite good together with domestic services.

$$R_i = S_{ri}^{\sigma_r} T_{ri}^{1-\sigma_r}.$$

This technology makes explicit the idea that a domestic service margin is applied to tradable goods (the composite good) *after* trade has taken place. The parameter $\sigma_r \in [0, 1]$ corresponds to the distribution margin.

2.2 Preferences

The representative household derives utility from consuming retail goods and services as follows:

$$C_i = C_{si}^{\sigma_c} (C_{ri} - N_i \bar{c_r})^{1-\sigma_c}.$$

The terms C_s and C_r denote aggregate consumption of services and retail goods respectively. The term $\bar{c_r}$ denotes a subsistence level (per worker) for consumption of retail goods and is constant across countries.

2.3 International trade

Country i purchases each individual tradable good from its least cost supplier. The purchase price depends on the unit cost of the producer, as well as trade barriers.

[3] In equilibrium, each country produces only a subset of these goods and imports the rest. Therefore, average *measured* productivity is endogenous because it depends on the set of goods produced.

Barriers to trade are denoted by τ_{ij}, where $\tau_{ij} > 1$ is the amount of goods that country j must export in order for one unit to arrive in country i. As a normalization I assume that there are no barriers to ship goods domestically; that is, $\tau_{ii} = 1$ for all i. I also assume that the triangle inequality holds: $\tau_{ij}\tau_{jl} \geq \tau_{il}$.

2.4 Equilibrium

I focus on a competitive equilibrium. Informally, a competitive equilibrium is a set of prices and allocations that satisfy the following conditions: 1) The representative household maximizes utility, taking prices as given 2) firms maximize profits, taking prices as given, 3) domestic goods and factor markets clear and 4) trade is balanced in each country. In the remainder of this section I describe each condition from country i's point of view.

2.4.1 Household optimization

At the beginning of the time period, the capital stock is rented to domestic firms in each sector at the competitive rental rate r_i and labor is supplied domestically at the wage rate w_i. At the end of the period, factor income is spent on consumption of services and retail goods which have respective prices P_{si} and P_{ri}. Therefore the representative household faces the following budget constraint.

$$P_{si}C_{si} + P_{ri}C_{ri} = w_iL_i + r_iK_i.$$

Utility maximization implies that the representative household optimally allocates expenditures as follows:

$$\begin{aligned} P_{si}C_{si} &= \sigma_c(w_iL_i + r_iK_i - P_{ri}N_i\bar{c_r}) \\ P_{ri}C_{ri} &= (1-\sigma_c)(w_iL_i + r_iK_i - P_{ri}N_i\bar{c_r}) + P_{ri}N_i\bar{c_r}. \end{aligned}$$

I restrict the parameter $\bar{c_r}$ such that the representative household in each country has enough income to cover the subsistence requirement, i.e., $w_iL_i + r_iK_i > P_{ri}N_i\bar{c_r}$ for all i.

I define an optimal price for discretionary consumption, P_{ci}, such that: $P_{ci}C_i = P_{si}C_{si} + P_{ri}(C_{ri} - N_i\bar{c_r})$. I show in appendix C that

$$P_{ci} = B_cP_{si}^{\sigma_c}P_{ri}^{1-\sigma_c}, \tag{1}$$

where $B_c = (\sigma_c)^{-\sigma_c}(1-\sigma_c)^{\sigma_c-1}$.

2.4.2 Firm optimization

Denote the price for an individual tradable good z that was produced in country j and purchased by country i by $p_{tij}(z)$. Then, $p_{tij}(z) = p_{tjj}(z)\tau_{ij}$, where $p_{tjj}(z)$ is the marginal cost of producing good z in country j. Since each country purchases each individual good from its least cost supplier, the actual price in country i of good z is $p_{ti}(z) = \min_{j=1,\ldots,I} [p_{tjj}(z)\tau_{ij}]$.

The price of the composite good is

$$P_{ti} = \left(\int p_{ti}(z)^{1-\eta} \varphi(z) dz \right)^{\frac{1}{1-\eta}},$$

where $\varphi(z)$ is the joint density of cost draws across countries.

I explain how to derive the prices for each country in appendix C. Given the assumption on the country-specific densities, φ_i, the model implies that

$$P_{ti} = \gamma B_t \frac{u_{ti}}{\left(\frac{\lambda_i}{\pi_{ii}}\right)^{\theta}}, \tag{2}$$

where $u_{ti} = \left(r_i^{\alpha} w_i^{1-\alpha}\right)^{\nu_t} \left(P_{si}^{\sigma_t} P_{ti}^{1-\sigma_t}\right)^{1-\nu_t}$ is the unit cost for a factor bundle faced by producers of tradables in country i. The term $B_t = (\alpha\nu_t)^{-\alpha\nu_t}((1-\alpha)\nu_t)^{(\alpha-1)\nu_t}(\sigma_t\nu_t)^{-\sigma_t\nu_t}((1-\sigma_t)\nu_t)^{(\sigma_t-1)\nu_t}$ is constant across countries. Finally, the term $\gamma = \Gamma\left(1+\theta(1-\eta)\right)^{\frac{1}{1-\eta}}$ is also constant across countries, where $\Gamma(\cdot)$ is the Gamma function. I restrict parameters such that $\gamma > 0$. Note that the price in country i is the unit cost of inputs in country i, divided by country i's average productivity, multiplied by technological parameters that are constant across countries.[4]

The price of services is simply the unit cost of inputs, divided by productivity, scaled by technological parameters:

$$P_{si} = B_s \frac{u_{si}}{A_{si}}.$$

The term $u_{si} = \left(r_i^{\alpha} w_i^{1-\alpha}\right)^{\nu_s} \left(P_{si}^{\sigma_s} P_{ti}^{1-\sigma_s}\right)^{1-\nu_s}$ is the cost of a factor bundle faced by producers of services in country i and $B_s = (\alpha\nu_s)^{-\alpha\nu_s}((1-\alpha)\nu_s)^{(\alpha-1)\nu_s}(\sigma_s\nu_s)^{-\sigma_s\nu_s}((1-\sigma_s)\nu_s)^{(\sigma_s-1)\nu_s}$ is constant across countries.

Finally, producers of retail goods in country i apply a distribution margin to the composite good (the basket of tradables) by using domestic services. The result is that the price of retail goods takes the following form.

$$P_{ri} = B_r P_{si}^{\sigma_r} P_{ti}^{1-\sigma_r},$$

where $B_r = (\sigma_r)^{-\sigma_r}(1-\sigma_r)^{\sigma_r-1}$ and σ_r is the distribution margin.

[4] Average productivity in tradables is $(\lambda_i/\pi_{ii})^{\theta}$. This differs from average efficiency across the entire continuum of goods λ_i^{θ} since, in equilibrium, country i specializes in a subset of goods for which it is comparatively "good" at producing. The measure of such goods is captured by π_{ii}.

Trade flows Each country purchases each individual tradable good from its least cost supplier. The fraction of country i's expenditures on tradable goods from country j is given by:

$$\pi_{ij} = \frac{\left(u_{tj}\tau_{ij}\right)^{-1/\theta}\lambda_j}{\sum\limits_{l}\left(u_{tl}\tau_{il}\right)^{-1/\theta}\lambda_l}. \tag{3}$$

An alternative interpretation of π_{ij} is that it is the fraction of tradable goods that j supplies to i, or by the law of large numbers, π_{ij} is the probability that for any individual tradable good, country j is the least cost supplier to country i. I describe how to derive trade shares in appendix C.

Factor demands I first define total factor usage in the tradables sector in country i as follows:

$$K_{ti} = \int K_{ti}(z)\varphi(z)dz, \qquad L_{ti} = \int L_{ti}(z)\varphi(z)dz,$$
$$S_{ti} = \int S_{ti}(z)\varphi(z)dz, \qquad T_{ti} = \int T_{ti}(z)\varphi(z)dz,$$

where $K_{ti}(z), L_{ti}(z), S_{ti}(z)$, and $T_{ti}(z)$ refer to the amount of labor, capital, services, and composite good used in country i to produce the individual tradable good z. Note that each of $K_{ti}(z), L_{ti}(z), S_{ti}(z)$, and $T_{ti}(z)$ will be zero if country i imports good z. Thus, K_{ti}, L_{ti}, S_{ti}, and T_{ti} respectively denote the quantities of capital, labor, services and composite good used as inputs in the production of tradables goods in country i.

Aggregating over all producers of individual goods in each sector in country i, and using the fact that each producer minimizes costs, the derived factor demands at the sectoral level are described by

$$K_{si} = \frac{\alpha\nu_s P_{si}S_i}{r_i}, \qquad K_{ti} = \frac{\alpha\nu_t\sum_{j=1}^{I}P_{tj}T_j\pi_{ji}}{r_i},$$
$$L_{si} = \frac{(1-\alpha)\nu_s P_{si}S_i}{w_i}, \qquad L_{ti} = \frac{(1-\alpha)\nu_t\sum_{j=1}^{I}P_{tj}T_j\pi_{ji}}{w_i},$$
$$S_{si} = \frac{\sigma_s(1-\nu_s)P_{si}S_i}{P_{si}}, \qquad S_{ti} = \frac{\sigma_t(1-\nu_t)\sum_{j=1}^{I}P_{tj}T_j\pi_{ji}}{P_{si}}, \qquad S_{ri} = \frac{\sigma_r P_{ri}R_i}{P_{si}},$$
$$T_{si} = \frac{(1-\sigma_s)(1-\nu_s)P_{si}S_i}{P_{ti}}, \quad T_{ti} = \frac{(1-\sigma_t)(1-\nu_t)\sum_{j=1}^{I}P_{tj}T_j\pi_{ji}}{P_{ti}}, \quad T_{ri} = \frac{(1-\sigma_r)P_{ri}R_i}{P_{ti}}.$$

Country j's total spending on tradables is given by $P_{tj}T_j$, while π_{ji} denotes the fraction that is spent on goods from country i. Thus, $P_{tj}T_j\pi_{ji}$ is the total value of trade flows from country i to country j. Retail goods and services are not traded so foreign expenditures are zero.

2.4.3 Market clearing

The market clearing conditions for the raw factors of production (capital and labor) are:

$$K_{si} + K_{ti} = K_i \text{ and } L_{si} + L_{ti} = L_i.$$

The left-hand side of each of the previous equations is simply the factor usage by each sector, while the right-hand side is the factor availability.

The remaining country-specific resource constraints require that produced goods be equal to their uses.

$$\begin{aligned} S_{ri} + S_{si} + S_{ti} + C_{si} &= S_i, \\ T_{ri} + T_{si} + T_{ti} &= T_i, \\ C_{ri} &= R_i \end{aligned}$$

That is, the use of services as an intermediate in production plus final consumption of services must equal the amount of services available. Similar for tradables and retail goods.

2.4.4 Trade balance

To close the model I impose balanced trade country by country.

$$P_{ti} T_i \sum_{j \neq i} \pi_{ij} = \sum_{j \neq i} P_{tj} T_j \pi_{ji},$$

where the left-hand side denotes country i's imports, and the right-hand side denotes country i's exports.

This completes the description of a competitive equilibrium in the model. Next I discuss some important equilibrium implications of the theoretical model.

3 Qualitative implications for relative prices

I first discuss how relative prices are determined qualitatively and expose how the trade mechanism affects relative prices. Recall that the price of retail goods is $P_{ri} = B_r P_{si}^{\sigma_r} P_{ti}^{1-\sigma_r}$. Therefore, the price of services relative to retail goods is a simple transformation of the price of services relative to tradables: $\frac{P_{si}}{P_{ri}} = \left(\frac{1}{B_r}\right) \left(\frac{P_{si}}{P_{ti}}\right)^{1-\sigma_r}$. Since the term B_r is constant across countries, P_s/P_r is isomorphic to P_s/P_t as long as $\sigma_r < 1$. Thus, understanding the price of services relative to tradables is equivalent to understanding the price of services relative to retail goods with one key distinction; the price of services relative to retail goods includes the term $1 - \sigma_r$ in the exponent. This term accounts for the distribution margin in retail goods.

In particular, if there are no services required in distribute tradable goods to consumers, i.e., $\sigma_r = 0$ then this exponent is unity and the two relative prices are identical up to a constant of proportionality. A larger σ_r implies a larger share of services in the production of retail goods, thus the absolute price of retail goods will more closely resemble the absolute price of services.

I show in appendix C that the price of services relative to tradables is

$$\frac{P_{si}}{P_{ti}} = \Psi \times \left(\frac{\left[(\lambda_i/\pi_{ii})^\theta \right]^{\frac{\nu_s}{\nu_t}}}{A_{si}} \right)^{\frac{1}{1-\sigma_s(1-\nu_s)+\sigma_t(1-\nu_t)\nu_s/\nu_t}}, \tag{4}$$

where Ψ is a collection of terms that are constant across countries. Thus, the price of services relative to retail goods is

$$\frac{P_{si}}{P_{ri}} = \left(\frac{\Psi^{1-\sigma_r}}{B_r} \right) \left(\frac{\left[(\lambda_i/\pi_{ii})^\theta \right]^{\frac{\nu_s}{\nu_t}}}{A_{si}} \right)^{\frac{1-\sigma_r}{1-\sigma_s(1-\nu_s)+\sigma_t(1-\nu_t)\nu_s/\nu_t}}. \tag{5}$$

In order to interpret equations (4) and (5), note that they boil down to country i's productivity in tradables divided by country i's productivity in services (the second term in each expression). To see this recall that country i's average efficiency across all individual tradable goods is λ_i^θ. However, country i specializes in only a subset of the tradable goods. Therefore, its average *measured* productivity is its average efficiency, λ_i^θ, corrected by the share of goods that it actually produces, i.e., its home trade share, π_{ii}. The numerator is thus average measured productivity in tradables: $(\lambda_i/\pi_{ii})^\theta$. In the denominator is the productivity in services A_{si}. The remaining terms are common across countries and do not contribute to the cross-country variation. Thus, the model produces the classic Balassa-Samuelson effect endogenously: the price of nontradables (services), relative to tradables, is equal to the measured productivity in tradables, relative to the measured productivity in nontradables (services), corrected by the relevant input-output coefficients. The terms in the exponent adjust for the input-output structure since there is feed through across sectors: The price of services enters the price of tradables, and the price of tradables enters the price of services, since they are both used as intermediate inputs in production.

Novel to the model is that the average productivity in tradables depends on the endogenous term π_{ii}, country i's home trade share. The home trade share in country i reveals the set of goods that country i specializes in producing. The more specialized a country is, the smaller its home trade share is, and the higher its measured productivity in tradables will be. The degree of specialization depends on average efficiency, as well as the pattern of bilateral trade barriers.

4 Quantification

In this section I discuss the methodology for calibrating the model parameters. Then I discuss the implications of the calibrated model for explaining the distribution of prices across countries and assess the importance of trade barriers in generating the observed pattern of prices.

4.1 Data and calibration

I calibrate the model using data for a set of 103 countries for the year 2005 (see table D.2 in appendix D for the complete list of countries). This set includes both developed and developing countries and accounts for about 90 percent of the world GDP as computed from version 6.3 of the Penn World Tables (see Heston, Summers, and Aten, 2009, PWT63).

4.1.1 Data

With respect to the trade and production data used, the tradables sector corresponds to four-digit ISIC revision 2 categories 15**–37**. Trade data is reported at the four-digit SITC revision 2 level. I use a correspondence between production data (ISIC) and trade data (SITC) created by Affendy, Sim Yee, and Satoru (2010). The source for trade data is UN Comtrade, and I obtain production data from two sources: INDSTAT 4, 2010 (a databases maintained by UNIDO), and the World Bank's World Bank Development Indicators (for countries where data is not available through INDSTAT). The service sector accounts for the remainder of GDP that is not accounted for by value added in tradables. In the model there is a sector called retail goods. In terms of classification, I do not distinguish retail goods from tradables and there is no additional value added at the retail level. The interpretation is that retail goods are simply the tradable goods made available to final consumers by using domestic distribution services; some portion of the tradable goods are imported, and the remaining portion is purchased domestically.[5]

Construction of prices using ICP data I construct prices for services and retail goods using detailed Basic Headings data from the 2005 International Comparison Program, World Bank Development Data Group. The data I use is at the retail level for which there is no one-to-one link with ISIC categories, so I take a stand on which categories are closest to

[5] An example is a computer. Think of each component of a computer (processor, memory, disk, keypad, etc.) as an individual tradable good. Each country purchases each component from their least cost supplier. Once each component is purchased (some maybe imported, some purchased domestically) they are bundled into a composite good (a computer). Then the computer is sold to consumers by the domestic service sector (retail).

goods, and which are closest to services. There are 129 categories at the Basic Heading level, 53 of which I classify as retail goods, 48 as services, and the remaining 28 are unclassified (for example, the category "Change in inventories and valuables" is left unclassified) see table D.1 in appendix A for the complete list. The exact methodology I use to aggregate the Basic Headings prices into sectoral aggregate prices is in explained in appendix A.

4.1.2 Common parameters

I begin by describing the parameters which are common across countries and given in table 1. Following Alvarez and Lucas (2007), I set η equal to 2. This parameter is not quantitatively important for the question addressed in this paper, however, it must satisfy $1+\theta(1-\eta) > 0$.

Capital's share α is set at 1/3 as in Gollin (2002). This parameter is set so that labor's share in GDP is 2/3.

The parameters ν_s and ν_t, respectively, control the value added in services and tradable goods production. I compute both parameters by taking the average of the ratio of value added output to total output. For tradable goods I employ the manufacturing data from the INDSTAT 4, 2010 database, and for services I employ input-output tables for OECD countries.

The parameter σ_r corresponds to the distribution margin for retail goods.[6] Berger, Faust, Rogers, and Steverson (2012) argue that distribution margins in the US are on average between 0.50 and 0.70. Crucini and Yilmazkuday (2009) use micro data to construct estimates of distribution margins across a large number of retail items and cities. For a subset of their items that most closely correspond to my definition of retail goods, the median estimate of distribution margins is 0.42. They also state that the aggregate distribution margin, as measured from U.S. National Income and Product Accounts is 0.5, the same value that is used in Burstein, Neves, and Rebelo (2003). Since I aggregate all goods into one sector in my model, I set σ_r at 0.50, in line with the above evidence. At the end of the paper I check the sensitivity of the model's predictions over a range of values for the distribution margin.

The parameters σ_s and σ_t control the share of services (relative to tradables) as an input in intermediate uses. In particular, $1 - \sigma_t$ corresponds to the share of manufactures in total intermediate spending by producers of tradables. Using input-output tables for OECD countries I compute $\sigma_t = 0.17$. Finally, σ_s corresponds to the share of spending on services (including local distribution) in total intermediate spending by producers of services. I calculate $\sigma_s = 0.70$ from input-output tables for OECD countries.

[6]Specifically, distribution includes retail and wholesale trade, and local transport and storage, markups, and value-added taxes.

Next I discuss the calibration of preference parameters: σ_c and $\bar{c_r}$. σ_c is the share of services in the representative household's *discretionary* expenditures, while $\bar{c_r}$ is the per-worker subsistence level of retail goods consumption.[7] In my sample of 103 countries, the richest countries spend about 60 percent of their income on services. Since subsistence plays no role when income is high, I set $\sigma_s = 0.60$. The poorest countries in my sample spend about 20 percent of their total income on services. Thus, I set the value $\bar{c_r}$ such that the poorest countries spend 20 percent of their income on services. I introduce non-homothetic preferences to allow for the possibility that differences in relative prices are driven by differences in relative demand. However, it turns out that demand-side forces contribute next to nothing to the distribution of relative prices. If instead I set $\bar{c_r} = 0$ then all countries spend 60 percent of their income on services, while all of the implications for prices are essentially unaltered.

The parameter θ controls the dispersion in efficiency levels. I follow Alvarez and Lucas (2007) and set this parameter at 0.15. This value lies in the middle of the estimates in Eaton and Kortum (2002). My results hold up to other values including $\theta = 0.24$, the preferred estimate in Simonovska and Waugh (2010).

Table 1: Common parameters

Parameter	Description	Value
α	K's share in GDP	0.33
ν_t	K and L's share in production of tradables	0.31
ν_s	K and L's share in production of services	0.56
σ_r	service's share in retail goods production (distribution margin)	0.50
σ_s	service's share in intermediate component of services production	0.70
σ_t	service's share in intermediate component of tradables production	0.17
σ_c	share of services in final discretionary expenditures	0.60
$\bar{c_r}$	subsistence level for consumption of retail goods per worker	0.08
θ	variation in efficiency levels	0.15
η	elasticity of substitution in aggregator	2

Note: The subsistence level $\bar{c_r}$ implies that countries in the bottom decile of the income distribution allocate 20 percent of their total consumption expenditures to services.

4.1.3 Country-specific parameters

I take the labor force N from PWT63. To construct measures of human capital h, I follow Hall and Jones (1999) and Caselli (2005) by converting data on years of schooling from

[7] Discretionary expenditures refer to the representative household's expenditures in excess of spending on subsistence.

Barro and Lee (2010) into measures of human capital using Mincer returns. Effective labor is then $L = Nh$, see appendix A for details. I construct capital stocks K_i using the perpetual inventory method using investment data from PWT63, see appendix A for details.

The remaining parameters include the bilateral trade barriers τ_{ij}, the average efficiency parameters in the tradable sector, λ_i, and the productivity levels in the service sector, A_{si}. My strategy is to choose these parameters to be consistent with the pattern of bilateral trade and relative levels of development across countries.

Bilateral trade barriers From equation (3), the fraction of tradable goods that country i purchases from country j, relative to the fraction that i purchases domestically, is given by

$$\frac{\pi_{ij}}{\pi_{ii}} = \left(\frac{u_{tj}}{u_{ti}}\right)^{-1/\theta} \left(\frac{\lambda_j}{\lambda_i}\right) (\tau_{ij})^{-1/\theta}. \tag{6}$$

Since trade barriers are unobservable, I specify a parsimonious functional form that links trade barriers to observable data as follows

$$\log \tau_{ij} = ex_j + \gamma_{dist,k} dist_{ij,k} + \gamma_{brdr} brdr_{ij} + \gamma_{lang} lang_{ij} + \varepsilon_{ij}. \tag{7}$$

Here, ex_j is an exporter fixed effect dummy.[8] The variable $dist_{ij,k}$ is a dummy taking a value of one if two countries i and j are in the k'th distance interval. The six intervals, in miles, are [0,375); [375,750); [750,1500); [1500,3000); [3000,6000); and [6000,maximum). (The distance between two countries is measured in miles using the great circle method.) The variable $brdr$ is a dummy for common border and $lang$ is a dummy for common language. I assume that the residual, ε, is orthogonal to the previous variables and captures other factors which affect trade barriers. Each of these data, except for trade flows, are taken from the Gravity Data set available at http://www.cepii.fr. At the end of the paper I consider alternative approaches to estimating τ_{ij}. In particular, in one alternative specification I estimate trade barriers using measurements of bilateral transport costs and tariffs.

Taking logs on both sides of (6) and substituting in the parsimonious specification (7), I obtain an estimable equation:

$$\begin{aligned} \log\left(\frac{\pi_{ij}}{\pi_{ii}}\right) &= \underbrace{\log\left(u_{tj}^{-1/\theta}\lambda_j\right)}_{F_j} - \underbrace{\log\left(u_{ti}^{-1/\theta}\lambda_i\right)}_{F_i} \\ &\quad - \frac{1}{\theta}\left(ex_j + \gamma_{dist,k} dist_{ij} + \gamma_{brdr} brdr_{ij} + \gamma_{lang} lang_{ij} + \varepsilon_{ij}\right). \end{aligned} \tag{8}$$

[8] Waugh (2010) shows that a including a country-specific export effect for trade barriers is required in order to simultaneously be consistent with the prices of tradables across countries as well as the pattern of bilateral trade. In particular, I alternatively employed a specification with a importer fixed effect instead, and found that the model produced prices of tradables that were strongly negatively correlated with development, in addition to counterfactual prices of services across countries.

To compute the empirical counterpart to π_{ij}, I follow Bernard, Eaton, Jensen, and Kortum (2003), see appendix A. I estimate the coefficients for the parsimonious specification for trade barriers and recover the fixed effects F_i (country i's state of technology) as country specific fixed effects using Ordinary Least Squares. Observations for which the recorded trade flows are zero are omitted from the regression. The bilateral trade barrier for such observations is set to the maximum estimated barrier in the sample. There are 9,194 bilateral combinations with positive trade flows out of $I^2 - I = 10,506$ bilateral relationships.

The calibrated trade barriers τ_{ij} imply that poor countries face larger costs to export than rich countries do. Figure B.1a in appendix B plots the export-weighted trade barrier for each country i against income per worker. This is the result of poor countries facing larger exporter-specific component of trade costs. Countries in the bottom decile of the income distribution face an average exporter-specific component of 4.64, while countries in the top decile face an average exporter-specific component of 3.25, see figure B.1b in appendix B. Hummels (2001), Djankov, Freund, and Pham (2006), and Li and Wilson (2009) provide empirical evidence that it is more costly for poor countries to export goods than it is for rich countries.

Productivity in tradables and services In order to identify average efficiency in tradables, λ_i^θ, and productivity in services, A_{si}, I utilize information contained in the state of technology F_i from the regression of equation (8), in addition to data on income per worker. I normalize $\lambda_{US} = A_{US} = 1$.

I define income per worker, at PPP, as $y_i = (w_i L_i + r_i K_i)/(N_i P_{ci})$, where N_i is the number of workers in country i and P_{ci} is the optimal price for discretionary consumption given by equation (1). In appendix C I derive an expression for income per worker, y_i. The derived relationship implies that income per worker in country i, relative to the US, is given by the following expression:

$$\frac{y_i}{y_{US}} = \left(\frac{(\lambda_{ii}/\pi_{ii})^\theta}{(\lambda_{US}/\pi_{USUS})^\theta}\right)^{\frac{1}{\nu_t}} \left(\frac{\left[\frac{(\lambda_{ii}/\pi_{ii})^\theta}{(\lambda_{US}/\pi_{USUS})^\theta}\right]^{\frac{\nu_s}{\nu_t}}}{\frac{A_{si}}{A_{sUS}}}\right)^{-\frac{\sigma_t(1-\nu_t)/\nu_t+\sigma_r+\sigma_c(1-\sigma_r)}{1-\sigma_s(1-\nu_s)+\sigma_t(1-\nu_t)\nu_s/\nu_t}} \times \left(\frac{k_i}{k_{US}}\right)^\alpha \left(\frac{h_i}{h_{US}}\right)^{1-\alpha}. \tag{9}$$

Recall that π_{ii} is country i's home trade share, $k_i = K_i/N_i$ is country i's stock of capital per worker, and h_i is the average human capital of each worker in country i, each of which I have data for. I also have data for income per worker, Thus, there are only two unknowns in equation (9): λ_i and A_{si}.

Next, note that $F_i = \log(u_{ti}^{-1/\theta}\lambda_i)$. I obtain estimates of F_i from the regression equation (8). Therefore, the task will be to separate λ_i from $u_{ti}^{-1/\theta}$. To achieve this, recall that the unit cost of a factor bundle for producers of tradables in country i is $u_{ti} = \left(\frac{r_i}{w_i}\right)^{\alpha\nu_t}\left(\frac{w_i}{P_{ti}}\right)^{\nu_t}\left(\frac{P_{si}}{P_{ti}}\right)^{\sigma_t(1-\nu_t)} P_{ti}$ (§). Substituting equation (4) in for $\frac{P_{si}}{P_{ti}}$ in (§), and making the whole expression relative to the US, I obtain

$$\frac{\exp(F_i)}{\exp(F_{US})} = \left(\frac{r_i/w_i}{r_{US}/w_{US}}\right)^{-\frac{\alpha\nu_t}{\theta}} \left(\frac{w_i/P_{ti}}{w_{US}/P_{tUS}}\right)^{-\frac{\nu_t}{\theta}} \left(\frac{\left[\frac{(\lambda_{ii}/\pi_{ii})^{\theta}}{(\lambda_{US}/\pi_{USUS})^{\theta}}\right]^{\frac{\nu_s}{\nu_t}}}{\frac{A_{si}}{A_{sUS}}}\right)^{-\frac{\sigma_t(1-\nu_t)}{\theta\Omega}} \times \left(\frac{P_{ti}}{P_{tUS}}\right)^{-\frac{1}{\theta}} \left(\frac{\lambda_i}{\lambda_{US}}\right), \tag{10}$$

where Ω in the exponent of the third term on the right-hand side of equation (10) is a collection of constants: $\Omega = 1 - \sigma_s(1-\nu_s) + \sigma_t(1-\nu_t)\nu_s/\nu_t$.

The left-hand side of equation (10) is the estimated state of technology in country i, relative to the US. The right-hand side of equation (10) consists of 5 terms. The first term, $\frac{r_i}{w_i}$, is equal to $\frac{\alpha}{1-\alpha}\frac{L_i}{K_i}$, an object for which I have data on. The second term consists of w_i and P_{ti}. For w_i I use GDP per-effective worker at domestic prices from PWT63. For P_{ti}, I construct trade-based estimates of the price of tradables using the estimated states of technology and trade barriers from the gravity regression as in Eaton and Kortum (2001) as follows: $P_{ti} = \gamma B_t \left(\sum_j \exp(F_j)\tau_{ij}^{-1/\theta}\right)^{-\theta}$, where F_j and τ_{ij} are the estimates from the gravity regression.[9] For the third term on the right-hand side of equation (10) I plug in data on π_{ii}, while λ_i and A_{si} are unknown. The fourth term depends on the ratio of the price of tradables in country i relative to the US. I use the trade-based estimates $P_{ti} = \gamma B_t \left(\sum_j \exp(F_j)\tau_{ij}^{-1/\theta}\right)^{-\theta}$. Finally, the fifth (last) term consists of the unknown average efficiency in country i relative to the US. Thus, for each country i there are two unknowns in equation (10): λ_i and A_{si}.

Equations (9) and (10) provide two independent equations in to two unknowns, λ_i and A_{si}, for each country i. I recover these parameters by simultaneously solving the two nonlinear equations.

The calibrated average efficiency levels λ_i^{θ} are substantially larger in rich countries than in poor countries, see figure B.2a in appendix B. On average, countries in the top decile of the income distribution have an average efficiency level that is 2.61 times larger than countries in the bottom decile. The calibrated productivity levels A_{si} are only slightly larger in rich

[9] In appendix C I show that $P_{ti} = \gamma B_t \left(\sum_j (u_j\tau_{ij})^{-1/\theta}\lambda_j\right)^{-\theta}$, and the gravity regression implies that $\exp(F_j) = u_j^{-1/\theta}\lambda_j$. Thus, $P_{ti} = \gamma B_t \left(\sum_j \exp(F_j)\tau_{ij}^{-1/\theta}\right)^{-\theta}$.

countries than in poor countries, see figure B.2b in appendix B. On average, countries in the top decile of the income distribution have a productivity level that is only 1.64 times larger than that of countries in the bottom decile of the income distribution.

4.1.4 Model fit

I used data on the pattern of bilateral trade and cross-country income differences to calibrate productivity levels and trade barriers. The model matches the pattern of bilateral trade well: the regression from equation (8) produces an R^2 of 0.80. Income per worker in the model is very close to the data, the correlation between the model and the data is 0.99, see figure B.4 in appendix B.

Next I assess the model's ability to explain the prices in the data, and then measure the contribution of trade barriers in accounting for the systematic patterns in prices across countries. At the end of the paper I discuss the implications of using alternative specifications for calibrating the trade barriers, as well as the model's sensitivity to various values of the distribution margin.

4.2 Quantitative results

This section discusses the quantitative implications for relative prices and assesses the quantitative role of trade barriers in explaining the pattern of relative prices across countries. I will report elasticities of prices with respect to income per worker, and from now on I omit the term "with respect to income per worker".

Neither the trade data nor the production data include domestic service margins that are applied after trade takes place. Since the parameters of the model are disciplined by trade and production data, the prices of tradables that are generated by the model correspond to prices at the local dock (if imported) or at the factory gate (if purchased domestically), i.e., they do not include a distribution margin. Consider the benchmark ICP category called "Machinery and equipment". This category contains the smallest distribution margin among all tradable goods (Burstein, Neves, and Rebelo, 2004). Therefore, the price of Machinery and equipment is a reasonable proxy for the price of pure tradables. In the data, the price elasticity of tradables is 0.02, and the model produces a corresponding price elasticity of 0.01, see figure 4. That is, even in the presence of large and asymmetric trade barriers, the prices of tradables do not vary systematically with development. This does not imply that each individual tradable good's price is uncorrelated with development. In fact, the prices for each individual good along the continuum are indeed different, however, the price of the composite tradable good is uncorrelated with development. Mutreja, Ravikumar, Riezman, and Sposi (2012) discuss aggregate price equalization in the presence of trade barriers for the case of capital goods prices.

One potential concern is my proxy for the price of tradables. Since I used the price of machinery and equipment as a stand in for the price of tradables, how can I be certain how the price of tradables varies with development? Here I present further evidence to shed light on this. First, Waugh (2010) relies on the fact that the price of tradables is at best only weakly correlated with development in order to argue for the use of exporter-fixed effects over importer-fixed effects in the calibration of trade barriers. Second, imagine the price of retail goods in country i, P_{ri}, as being the geometric average of the price of purely tradable goods (inclusive of trade costs), P_{ti}, and the price of local distribution services, P_{si}. In particular, $P_{ri} = P_{si}^{\sigma} P_{ti}^{1-\sigma}$ where σ corresponds to the distribution margin. The ICP provides values for P_{ri} and P_{si}. Thus, once I take a stance on the value of the distribution margin, σ, I can compute values for the price of tradables in each country i: $P_{ti} = \frac{P_{ri}^{\frac{1}{1-\sigma}}}{P_{si}^{\frac{\sigma}{1-\sigma}}}$ (†). In light of this fact I ask the following question: what value of σ is required so that the price elasticity of tradables with respect to income per worker is exactly zero? It turns out that this occurs when $\sigma = 0.46$, very close to 0.50 – the value I used in the calibration based on existing evidence in the literature. If I instead compute the price of tradables in (†) using the value of $\sigma = 0.50$, then the resulting price elasticity of tradables in the data is -0.04.

Table 2: Price elasticities w.r.t. income per worker (95% confidence band in parentheses).

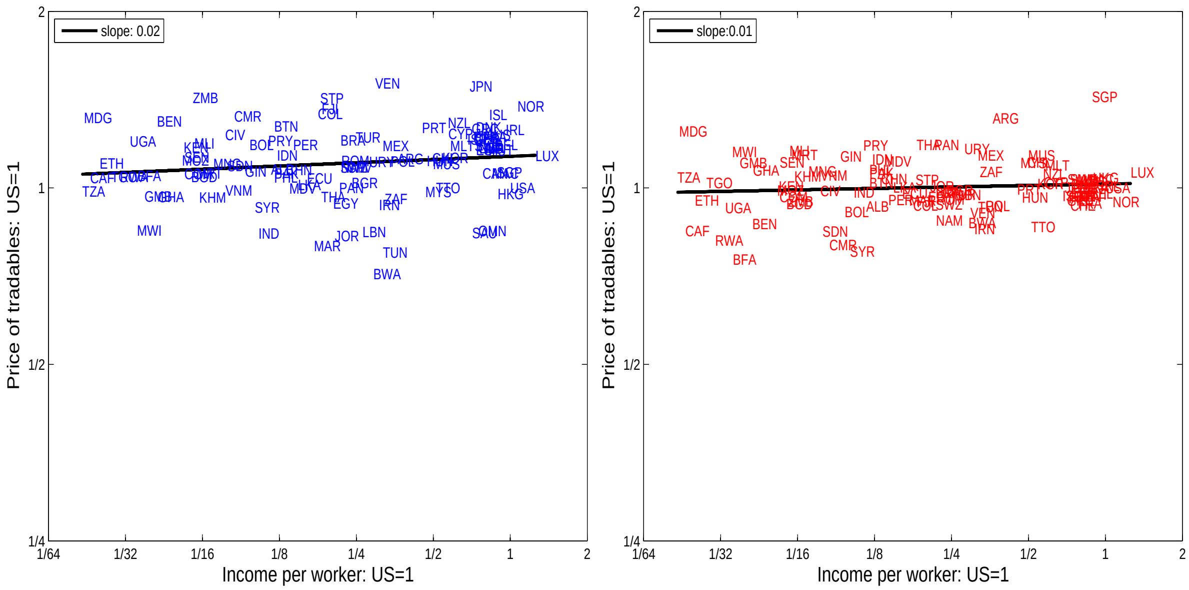
Variable	Data	Model
Price of services	0.49 (0.42–0.56)	0.59 (0.51–0.68)
Price of retail goods	0.22 (0.18–0.26)	0.30 (0.26–0.34)
Price of services relative to retail goods	0.27 (0.22–0.31)	0.29 (0.25–0.34)
Price of tradables	0.02 (-0.01–0.04)	0.01 (-0.01–0.03)
Price of services relative to tradables	0.47 (0.41–0.53)	0.58 (0.49–0.68)

Note: I use data on the price of Machinery and equipment from the 2005 benchmark classification of the ICP as a stand in for the price of tradables.

Table 2 reports summary statistics on how the model-predicted prices perform relative to the data. The model slightly over-predicts the price elasticity of services (0.59 in the model compared to 0.49 in the data). However, the model matches the price elasticity of tradables quite well (0.01 in the model compared to 0.02 in the data). The price of retail goods in the model is a geometric average of the price of services and the price of tradables, thus, the model slightly over-predicts the price elasticity of retail goods (0.30 in the model compared to 0.22 in the data). Taken together, the model overstates the elasticity of the

Figure 4: Price of tradables: data and model. I use data on the price of Machinery and equipment from the 2005 benchmark classification of the ICP as a stand in for the price of tradables.

(a) Price of tradables (data). (b) Price of tradables (model).



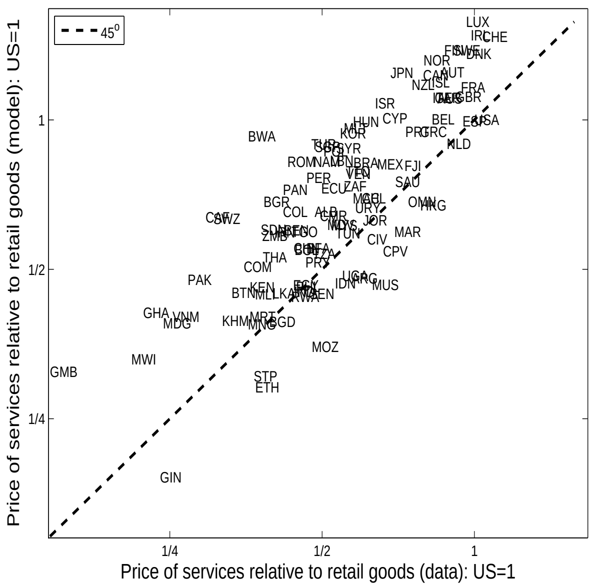
price of services relative to tradables (0.58 in the model compared to 0.47 in the data), but replicates the elasticity of the price of services relative to retail goods (0.29 in the model compared to 0.27 in the data).

Figure 5a plots the model-predicted price of services relative to retail goods against the corresponding relative price in the data. The countries line up well with the 45-degree line, indicating that the model captures the systematic differences in relative prices across countries. Figure 5b plots the model-predicted price of services relative to tradables against the corresponding relative price in the data. Again, the data are grouped around the 45-degree line. Figure 6 shows a similar picture for both the absolute price of services as well as the absolute price of retail goods.

Figure B.3 in appendix B plots average productivity in the tradables sector, $(\lambda_i/\pi_{ii})^{\theta}$, against income per worker. Average productivity in the tradables sector differs by a factor of 3.20 between countries in the top decile of the income distribution and countries in the bottom decile. Productivity in the services sector, A_{si}, differs by a factor of 1.64 (see table D.2 in appendix D for a complete list of productivity levels across countries). Together the calibrated model implies that the productivity gap in tradables between rich and poor

Figure 5: Relative price of services: model vs data.

(a) Price of services relative to retail goods.



(b) Price of services relative to tradables.

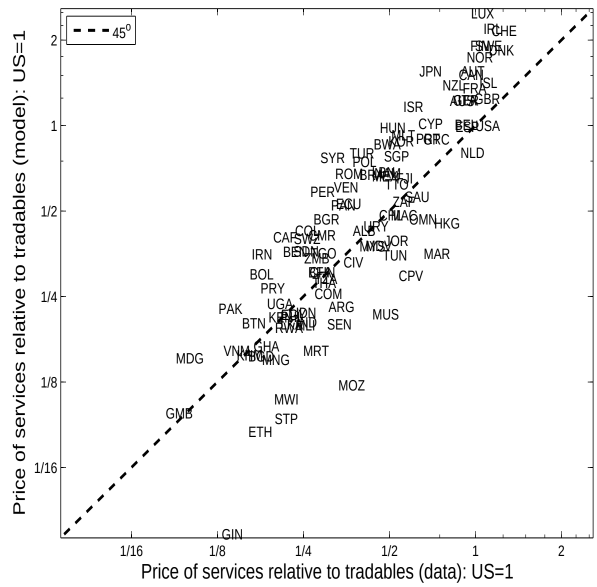
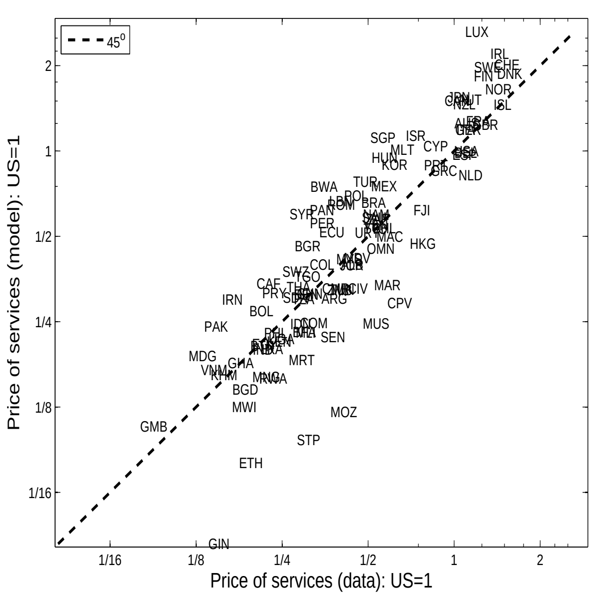
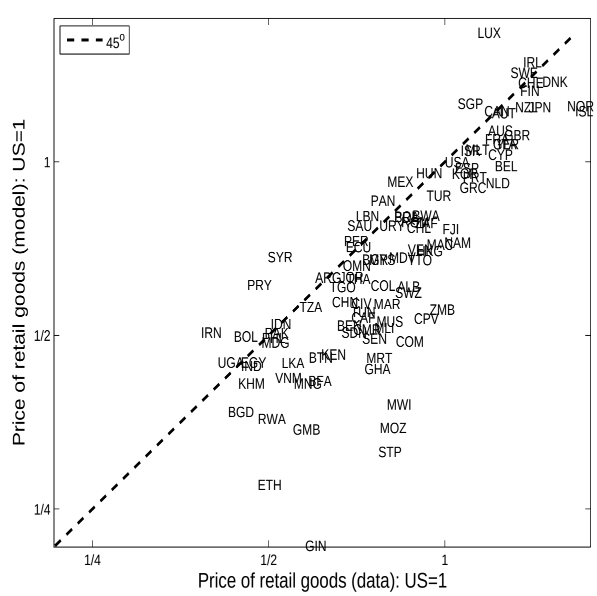


Figure 6: Prices of services and retail goods: model vs data.

(a) Price of services.



(b) Price of retail goods.



countries is about twice as large as the productivity gap in services. What's more is that measured productivity in the tradables sector in country i depends on the pattern of specialization through the home trade share π_{ii}. Therefore, any policy that alters the set of goods that a country produces will imply a different average productivity measurement in the tradables sector.

Labor is more costly in rich countries due to higher productivity in both sectors. Since there are smaller cross-country productivity differences in the services sector than in the tradables sector, prices of services are higher in rich countries. Crucini, Telmer, and Zachariadis (2005) argue that this matters primarily to the extent that the share of nontradable inputs (capital, labor, and services) is sufficiently large. If the share of nontradable inputs in the production of services was small, then most of the cross-country variation in the price of services would be due to variation in the price of tradables, which is approximately equal across countries. In the model, the share of nontradable inputs in the production of services is indeed large: $\nu_s + \sigma_s(1-\nu_s) = 0.87$.

A subtle but important implication of my results is that the nontradable input margin in the production of tradables matters quantitatively only if it occurs *after* trade has taken place. If the nontradable margin is applied to tradables after trade occurs (distribution services in the destination country), then countries where the price of nontradables is high will systematically face a higher price of retail goods; this effect is discussed in Giri (2012). On the other hand, if the nontradable margin is applied to production before trade takes place, i.e., in the producer's country, then that country's trading partners will alter their import shares, and the systematic effect on the composite price of tradables across countries will be negligible. In the model, the nontradable input margin before trade is $\nu_t + \sigma_t(1-\nu_t) \cong 0.43$, while the share of nontradable inputs after trade is $\sigma_r = 0.50$; both numbers are similar in magnitude. However, there is no systematic variation in the composite price of tradables across countries, while there is substantial systematic variation in the price of retail goods.

The model slightly over-predicts the price elasticity of services. At least part of the over-prediction for the price of services can be explained. Consider how I classified goods as either retail goods or services. The Basic Heading category called "Maintenance and repair of the dwelling" contains both goods (materials for repair) and services (services for repair), but I classified this category as services since I can not disaggregate it any further. There are a few other Basic Headings categories that pose the same issue. Since retail goods have a lower price elasticity than services, the price elasticity of services that I measured in the data is likely a lower bound for the true price elasticity of services. It is not possible to completely avoid this issue so I experimented with other reasonable classifications and I found that the measured cross-country distributions of prices are practically identical across various classifications.

This measurement issue likely does not explain all of the gap between the model-predicted price elasticity of services and that in the data. One can also think of other distortions that affect the prices of domestic goods differently in rich versus poor countries. My focus is on the quantitative role of trade barriers. As such, with only productivity differences and asymmetric trade barriers, the model is able to capture a bulk of the systematic variation in the price data.

My calibration did not use price data to impose any quantitative discipline on the model, only production and trade data. Thus, the prices generated by the model are a function of the observed trade and production data. Therefore, I am in a position to ask how relative prices would look under different distributions of trade barriers, and hence, different patterns of trade and specialization. This is what I do next.

4.3 Counterfactuals

In the remainder of this section I quantify the importance of trade barriers on relative prices by examining the implications of changing the pattern of bilateral trade barriers.

Free trade How much of the systematic variation in prices is due to trade barriers? To answer this I set $\tau_{ij} = 1$ for all bilateral combinations and keep all other parameters at their baseline values and examine the model's implications for prices. Table 3 provides a summary of the changes in the price elasticities.

Table 3: Price elasticities w.r.t. income per worker.

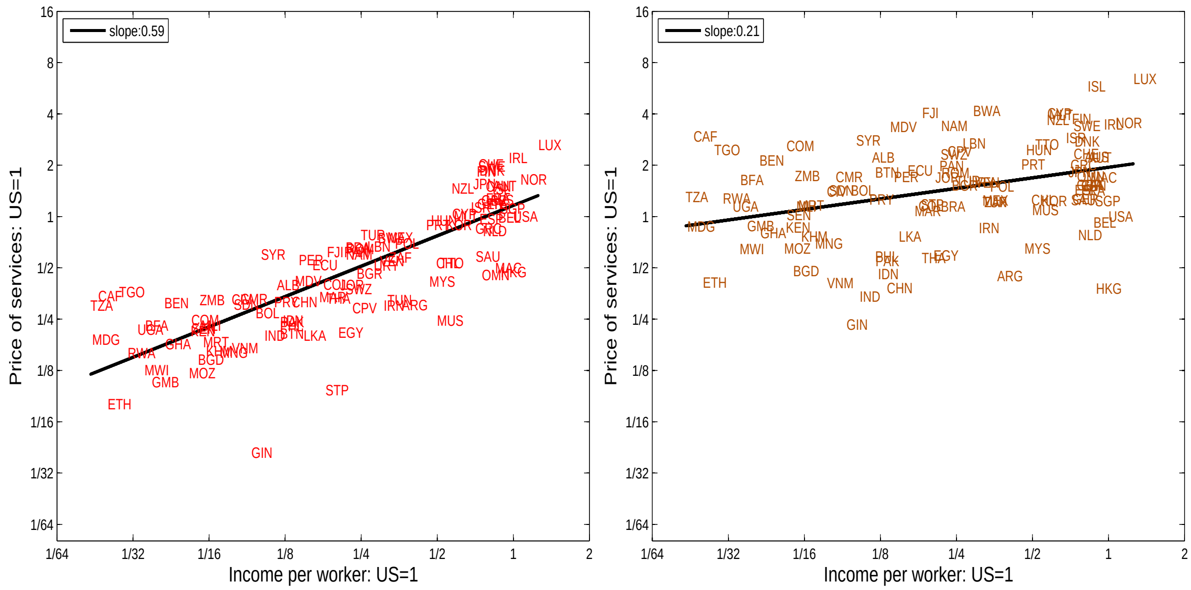
Variable	Baseline	CF1	CF2
Price of services	0.59	0.21	0.29
Price of retail goods	0.30	0.10	0.12
Price of services relative to retail goods	0.29	0.11	0.17
Price of tradables	0.01	0.00	−0.04
Price of services relative to tradables	0.58	0.21	0.33

Note: The column called Baseline refers to the implications of the calibrated model. CF1 refers to the free trade counterfactual where $\tau_{ij} = 1$ for all (i, j). Finally, CF2 refers to the counterfactual in which each countries' exporter-fixed effect component of trade barriers is set equal to the US value: $ex_j = ex_{USA}$ in equation (7).

The price elasticity of services declines significantly (0.59 to 0.21), see figure 7. Moving to free trade increases measured productivity in the tradables sector in all countries by allowing countries to reallocate resources towards the goods for which they have a comparative

Figure 7: Price of services: baseline and free trade.

(a) Price of services (baseline). (b) Price of services (free trade).



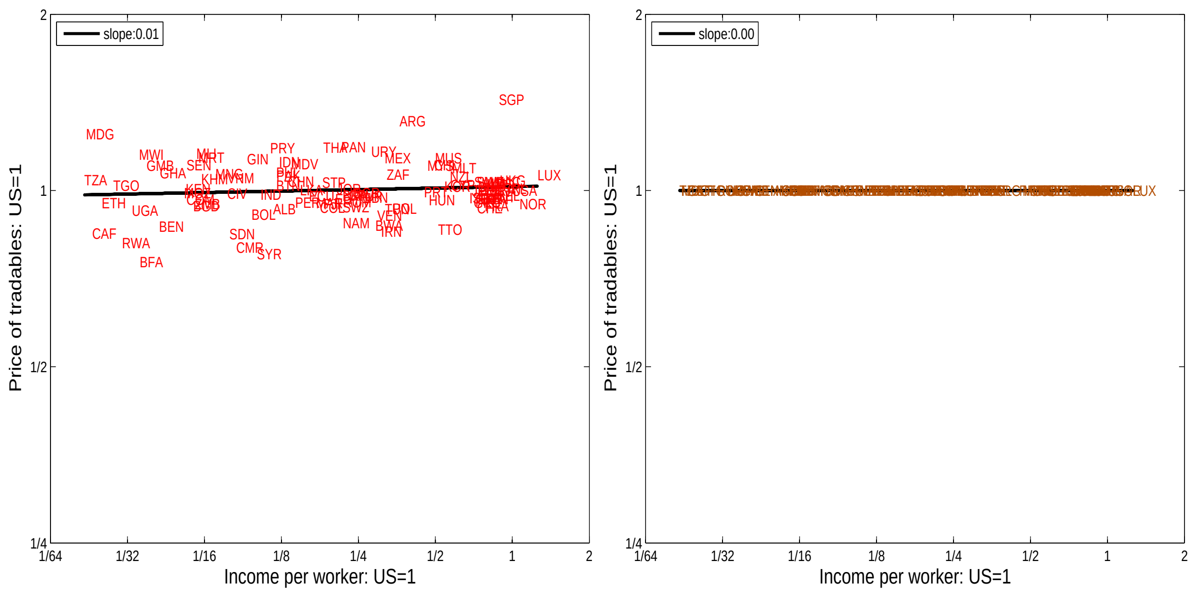
advantage. This increases the wage rate, and thus increases the price of services. Since poor countries face larger trade barriers than rich countries do, prices of services increase more in poor countries than in rich countries. In the free trade counterfactual the 90-10 ratio for average productivity in tradables is 1.81, while in the baseline model the 90-10 ratio is 3.20, a magnification of about 80 percent.

PPP holds in the tradables sector since the law of one price applies good by good. Thus, the price of tradables is equalized across countries and the price elasticity barely changes (0.01 to 0.00), see figure 8. Notice that although the price elasticity of tradables is essentially the same in baseline specification and in the free trade counterfactual, in the case of free trade, tradables prices are identical across countries whereas in the baseline specification, prices differ across countries but the variation is not systematically related to development. That is, existing trade barriers do not generate systematic differences in the aggregate price of tradables across countries. Taken together, the elasticity of the price of services relative to tradables decreases from 0.58 to 0.21, a reduction of 64 percent.

The change in the price elasticity of retail goods is a weighted average of the change in the price elasticity of services and the change in the price elasticity of tradables ($\Delta\rho_r = \sigma_r\Delta\rho_s + (1-\sigma_r)\Delta\rho_t$, where ρ is the elasticity). The price elasticity of retail goods decreases from 0.30 to 0.10.

Figure 8: Price of tradables: baseline and free trade.

(a) Price of tradables (baseline). (b) Price of tradables (free trade).



A complete removal of trade barriers is not meant to be practical: distance cannot be changed, and there is always going to be a cost associated with geography. However, this exercise is meant to speak to the role that the mere presence of trade barriers plays in explaining differences in relative prices. According to the specification that I use to estimate trade barriers, all of the asymmetry in trade barriers is governed by the exporter-specific component ex_j. This suggests that some impediments to trade are indeed specific to each country and are likely the result of policy or infrastructure, and therefore can potentially be removed. Next I discuss the implications of removing cross-country differences in the exporter-specific component only.

Removal of exporter-specific component of trade barriers Recall the parsimonious specification for trade costs given by (7): $\log \tau_{ij} = \gamma_{ex} ex_j + \gamma_{dis,k} dis_{ij,k} + \gamma_{brd} brd_{ij} + \gamma_{lang} lang_{ij} + \varepsilon_{ij}$. The purpose of this exercise is to quantify the importance of the asymmetric component of the trade barrier that is generated by the exporter-specific fixed effect. The fact that the exporter-specific fixed effect varies systematically with levels of development suggests that some component of trade barriers is due to factors other than geography. It is therefore important to quantify the importance of this channel as it can likely be manipulated by policy. Next I ask, how would relative prices look if the asymmetric component of trade barriers was removed?

To run this counterfactual I set the exporter fixed effect in all countries equal to the US value, $ex_j = ex_{USA}$, and recompute trade barriers for all bilateral combinations. The elasticity of the price of services relative to tradables decreases from 0.58 to 0.33, see table 3. That is, eliminating asymmetry in export costs alone would shave away almost half of the difference in relative prices between rich and poor countries. The mechanism that generates this result is the same as discussed in the free trade counterfactual above. In particular, all of the action is embedded in the price of services; the distribution of the price of tradables is not systematically altered.

5 Robustness

In this section I examine the implications of tweaking the baseline model. The first issue is regarding the value of the distribution margin σ_r. The second issue deals with the estimates of the bilateral trade barriers τ_{ij}.

5.1 Sensitivity to the distribution margin

I argued that a reasonable value for the distribution margin in my model is 0.50. Here I report results for prices for values of the distribution margin ranging from 0.30–0.60. For each value of σ_r, I re-calibrate λ_i, A_{si}, and τ_{ij} and solve for the new equilibrium prices. As can be seen in table 4, the price elasticity of tradables is remarkably robust: the price of tradables is uncorrelated with development in each situation. The price of services is always positively correlated with development, but tends to be a bit stronger with lower values of σ_r. The price elasticity of retail goods is affected substantially. A larger distribution margin puts more weight on the domestic price of services. Since prices of services are higher in rich countries, and prices of tradables are approximately equal across countries, a larger distribution margin increases the price elasticity of retail goods. However, part of this effect is dampened by the fact that the price elasticity of services becomes smaller with larger values of the distribution margin.

5.2 Alternative measurements of trade barriers

I explore the implications of employing alternative estimates of trade barriers. The key difference from the baseline is in the exact specification that I employ to relate unobservable trade barriers with observable data. Instead of using data on distance, common language and common border to proxy for geography and costs of trading, I use measurements of

Table 4: Price elasticities w.r.t. income per worker: Re-calibrated model with different distribution margin, σ_r.

Variable	data	$\sigma_r = 0.30$	$\sigma_r = 0.40$	$\sigma_r = 0.50$	$\sigma_r = 0.60$
Price of services	0.49	0.64	0.62	0.59	0.57
Price of retail goods	0.22	0.20	0.25	0.30	0.34
Price of tradables	0.02	0.01	0.01	0.01	0.01

Note: $\sigma_r = 0.50$ corresponds to the baseline.

transport costs and tariffs. I employ the following specification:

$$\log\left(\frac{\pi_{ij}}{\pi_{ii}}\right) = F_j^{asym} - F_i^{asym} - \frac{1}{\theta}\underbrace{\beta\log(1 + trf_i + tc_{ij})}_{\log\tau_{ij}^{asym}}.$$

I measure transport costs from country j to country i, tc_{ij}, by dividing the trade flows in manufactured goods (from j to i) reported at $c.i.f.$ by the value reported at $f.o.b.$, both of which come from the Direction of Trade Statistics maintained by the IMF. That is, $tc_{ij} = \frac{X_{ij}^{cif}}{X_{ij}^{fob}} - 1$. I measure tariffs using applied tariff rate measurements for manufactured goods for each country i, trf_i, from the World Development Indicators database at the World Bank.[10],[11] This specification clearly leads to different estimates of the trade barriers, but also different estimates productivity through the fixed effects F_i.

The implications for prices in this specification are given in table 5. The price elasticity of services is 0.67, higher than the baseline model (0.59), as well as the data (0.49). Moreover, the price elasticity of tradables is -0.08, which is further from the data (0.02) compared to the predictions of the baseline model (0.01). However, the general pattern is a qualitatively consistent description of the data: a high elasticity of the price of services, and a low (closer to zero) elasticity of the price of tradables.

In the baseline specification, estimating the matrix of trade barriers requires $I + 8$ coefficients: I country-specific exporter fixed effects, 6 effects from distance intervals, 1 for common language, and 1 for common border. In this alternative specification estimating the trade barrier matrix requires only 1 parameter: the parameter on the sum of tariffs and transport costs. Not surprisingly, the baseline specification out-performs the alternative specification, mainly because there are more degrees of freedom in matching the trade data.

[10] The tariff variable for each country i is an average across four different tariff measurements for manufactured goods: 1) simple mean, most favored nation, 2) weighted mean, most favored nation, 3) simple mean, all nations, and 4) weighted mean, all nations. Using any one of these tariff measurements individually produces similar results.

[11] If I simply use the tariff and transport cost data directly to compute trade barriers (i.e, $\tau_{ij}^{asym} = 1 + trf_i + tc_{ij}$ (i.e., impose $\beta = 1$) then the resulting trade barriers will be far to small to reconcile the observed volume of trade across countries – my estimate of β is 2.04.

Table 5: Price elasticities w.r.t. income per worker: Re-calibrated model with alternative estimates for trade barriers.

Variable	Data	Baseline	Alternative
Price of services	0.49	0.59	0.67
Price of retail goods	0.22	0.30	0.29
Price of tradables	0.02	0.01	−0.08

Note: The column called Baseline refers to the calibration in which $\log \tau_{ij} = ex_j + \gamma_{dist,k} dist_{ij,k} + \gamma_{brdr} brdr_{ij} + \gamma_{lang} lang_{ij} + \varepsilon_{ij}$. The column called Alternative uses the following specification for trade barriers: $\log \tau_{ij} = \beta \log(1 + trf_i + tc_{ij})$.

In turn, the model's ability to translate the pattern of trade into country-specific prices speaks to the strength of the model: the closer the calibrated model gets to the trade data, the closer the model also gets to the price data.

6 Conclusion

I argue that trade barriers are a quantitatively important component in explaining the cross-country distribution of the relative price of services. The price of services relative to tradables is determined by the inverse of relative productivity between these two sectors. Trade barriers help determine the pattern of specialization across multiple, heterogeneous, tradable goods, which in turn determines measured productivity in the tradables sector.

To formalize this argument I construct a multi-country model of trade with many tradable goods. Each country's level of efficiency for each good is a random draw from a country-specific distribution. Countries differ in their average efficiency across the entire basket of goods and also face asymmetric bilateral trade barriers. The subset of goods that each country produces is a function of both average efficiency and trade barriers. Measured productivity in the tradables sector in turn depends on the set of goods produced.

I calibrate the model to match the observed pattern of bilateral trade as well a cross-country relative levels of development. The calibration implies three important features: 1) there are small cross-country productivity differences in services, 2) there are large cross-country productivity differences in average efficiency in tradables, and 3) poor countries face larger trade barriers than rich countries do. Larger barriers in poor countries magnify the disparity in tradables-sector productivity between rich and poor countries, which translates into large cross-country differences in relative prices. To this end, the model quantitatively replicates the observed distributions of prices: systematically higher prices of services in rich countries than in poor countries, and the apparent similarity in prices of tradables across countries. Removing trade barriers eliminates 64 percent of the relative price disparity between rich and poor countries: the disparity of the price of services between rich and poor countries shrinks while the disparity of the price of tradables between rich and poor countries is unchanged.

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A Data

This section describes my data sources as well as how I map the model to the data.

Categories I identify tradables with categories 15**-37** according to the four-digit ISIC revision 3 classification (see http://unstats.un.org/unsd/cr/registry/regcst.asp?cl=2). I interpret retail goods as the same inherent goods as tradables, the difference being that retail goods are the transformation of tradable goods from the dock to the final consumer.

Prices and expenditures I use detailed retail data collected by the ICP at the Basic Headings level for the year 2005. I classify each Basic Headings category as either services or goods by using my own correspondence given in table D.1 in appendix D (recall that retail goods are the same as tradable goods; retail goods just include a distribution margin). Some categories are labeled as N/A as they do not pertain to any particular type of good, i.e., the category called "Gross operating surplus". The ICP records prices and expenditures in local currency for a common basket of goods across countries at the retail level. I construct country-specific prices for retail goods and services for each country as follows. Let B denote a basket of Basic Heading categories, either retail goods or services. Each element $b \in B$ is a Basic Heading category. The ICP provides data on expenditures in local currency on each category b, which I convert into 2005 US dollars using the nominal exchange rate. I denote country i's total expenditures in US dollars as EXP_{bi}^{dom}. Similarly, the ICP provides prices in local currency for each category b. For each country i I convert the price of each category b into US dollars using the exchange rate and denote this price as PPP_{bi}. I construct country i's expenditures in international dollars for each category b as $EXP_{bi}^{int} = \frac{EXP_{bi}^{dom}}{PPP_{bi}}$. I compute the aggregate PPP price in country i for the entire basket B by dividing expenditures in US dollars by expenditures in international dollars: $P_{bi} = \frac{\sum_{b \in B} EXP_{bi}^{dom}}{\sum_{b \in B} EXP_{bi}^{int}}$.

Human Capital I use data on years of schooling from Barro and Lee (2010) to construct human capital measures. I take average years of schooling for the population age 25 and up and convert into measures of human capital using $h = \exp(\phi(s))$, where ϕ is piecewise linear in average years of schooling s. This method is identical to the one used by Hall and Jones (1999) and Caselli (2005).

National Accounts Real income per worker is taken directly from PWT63 as the variable `rgdpwok`. The size of the workforce is constructed using PWT63 data as follows: number of workers equals 1000*`pop`*`rgdpl`/`rgdpwok`. I use the perpetual inventory method to construct aggregate stocks of capital:

$$K_{t+1} = I_t + (1-\delta)K_t,$$

where I_t is aggregate investment in PPP and δ is the depreciation rate. I_t computed from PWT63 as `rgdpl*pop*ki`. The initial capital stock K_0 is computed as $I_0/(g+\delta)$, where I_0 is the value of the investment series in the first year it is available, and g is the average geometric growth rate for the investment series between the first year with available data and 1975 (for some countries the first year with available data is after 1975, In which case, the geometric growth rate for first 5 years with available data is calculated). Following the literature, δ is set to 0.06.

Production Data on tradables production is taken from INDSTAT4, a database maintained by UNIDO at the four-digit ISIC revision 3 level. I compute gross production as the sum of gross output over all tradable categories.

Trade barriers Trade barriers are assumed to be a function of distance, common language, and shared border; each of which are taken from Centre D'Etudes Prospectives Et D'Informations Internationales (http://www.cepii.fr/welcome.htm).

Trade Flows Data on bilateral trade flows are obtained from UN Comtrade for the year 2005 (http://comtrade.un.org/). All trade flow data is at the four-digit SITC revision 2 level, and then aggregated into total trade flows. In order to link trade data to production data I employ the correspondence provided by Affendy, Sim Yee, and Satoru (2010) which links ISIC revision 3 to SITC revision 2 at the 4 digit level.

Construction of Trade Shares The empirical counterpart to the model variable π_{ij} is constructed following Bernard, Eaton, Jensen, and Kortum (2003) (recall that this is the fraction of country i's spending on tradables that was purchased from country j). I divide the value of country i's imports of tradables from country j, by i's gross production of tradables minus i's total exports of tradables (to the rest of the world) plus i's total imports of tradables (from only countries in my sample) to arrive at the bilateral trade share.

B Additional figures

This appendix provides additional figures that are referenced in the main body of the text.

Figure B.1: Trade barriers.

(a) Export-weighted trade barrier: $\frac{\sum_{j\neq i} \tau_{ji} X_{ji}}{\sum_{j\neq i} X_{ji}}$.

(b) Exporter-fixed effect component: $\exp(ex_i)$.

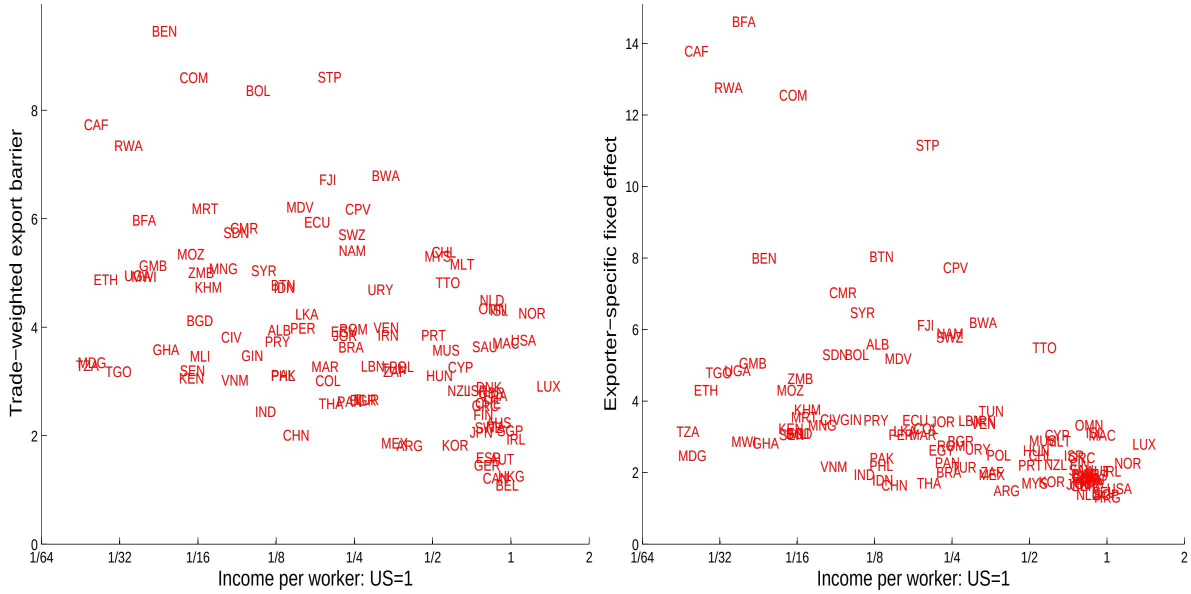


Figure B.2: Distribution of productivity.

(a) Average efficiency in tradables: λ_i^θ.

(b) Productivity in nontradables: A_{si}.

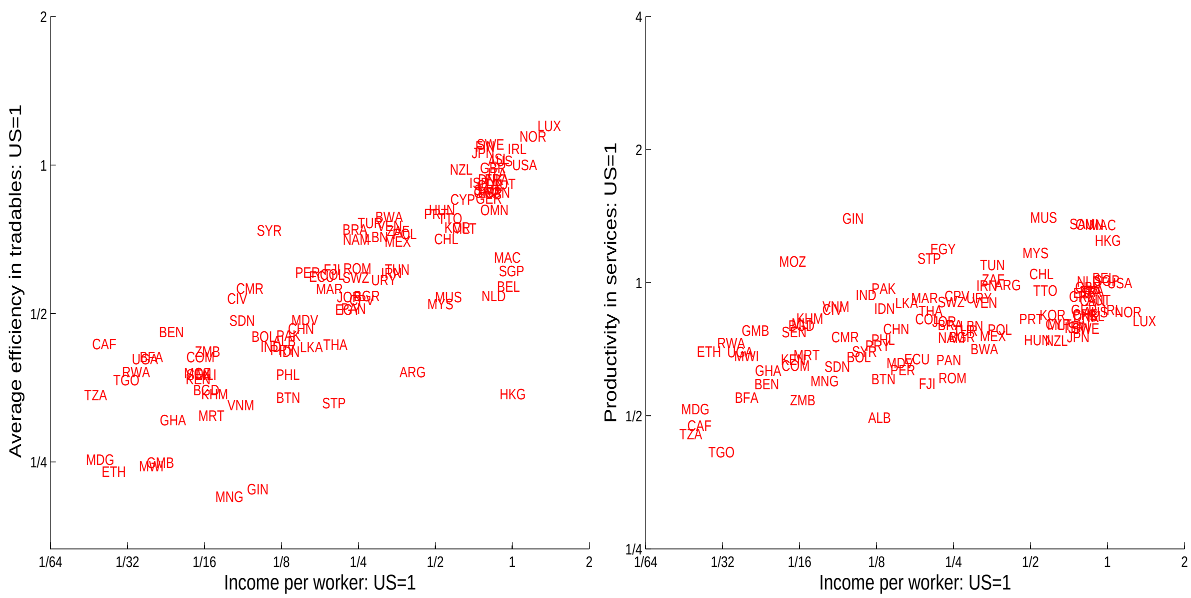


Figure B.3: Average productivity in tradables: $\left(\frac{\lambda_i}{\pi_{ii}}\right)^{\theta}$.

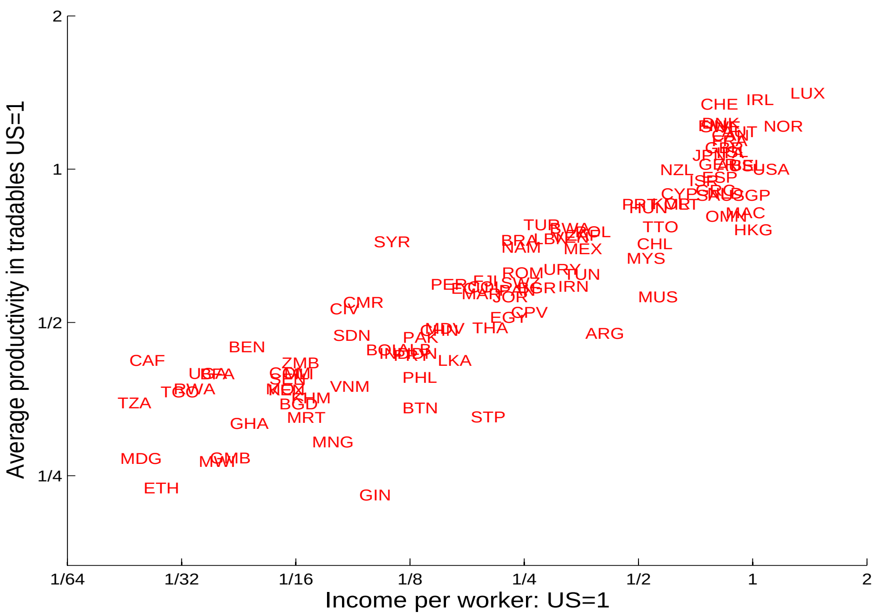
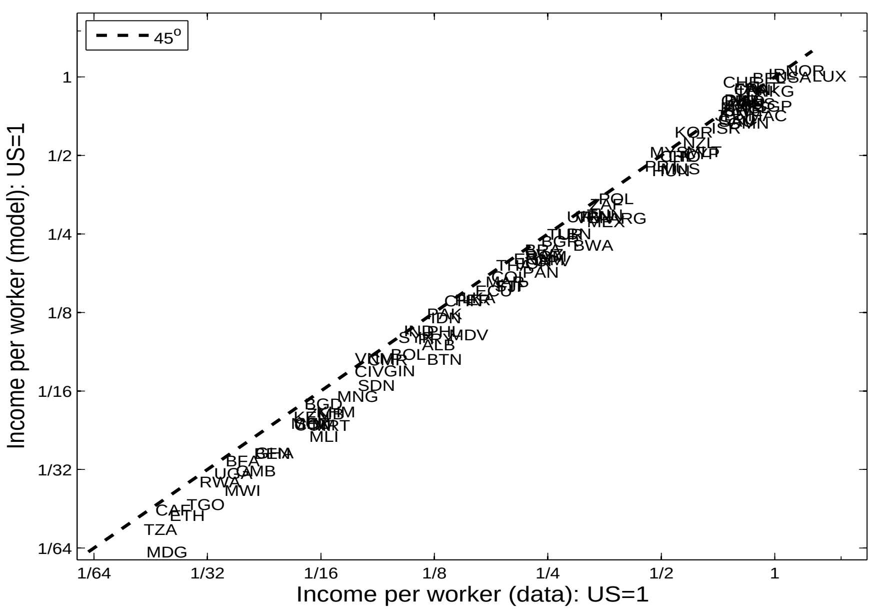


Figure B.4: Income per worker: model vs data. The only margin of error for income per worker between the model and the data comes from the difference in home trade shares, π_{ii}, between the model and the data – I did not directly target home trade shares.



C Derivations

C.1 Price indices and trade shares

I show how to derive analytical expressions for prices and trade shares. The following derivations rely on three properties of the exponential distribution.

1) $u \sim \exp(\mu)$ and $k > 0 \Rightarrow ku \sim \exp(\mu/k)$.

2) $u_1 \sim \exp(\mu_1)$ and $u_2 \sim \exp(\mu_2) \Rightarrow \min\{u_1, u_2\} \sim \exp(\mu_1 + \mu_2)$.

3) $u_1 \sim \exp(\mu_1)$ and $u_2 \sim \exp(\mu_2) \Rightarrow \Pr(u_1 \leq u_2) = \frac{\mu_1}{\mu_1+\mu_2}$.

Price indices Here I derive the price for the composite tradable good, P_{ti}. Cost minimization by producers of tradable good z implies a unit cost of an input bundle used in sector t, which is denoted by u_{ti}.

Perfect competition implies that the price in country i of the individual tradable good z, when purchased from country j, equals unit cost in country j times the trade barrier

$$p_{tij}(z) = B_t u_{tj} \tau_{ij} z_j^{\theta},$$

where B_t is a collection of constant terms. The trade structure implies that country i purchases each intermediate good z from the least cost supplier, so the price of good z, in country i, is

$$p_{ti}(z)^{1/\theta} = (B_t)^{1/\theta} \min_j \left[(u_{tj}\tau_{ij})^{1/\theta} z_j \right].$$

Since $z_j \sim \exp(\lambda_j)$, it follows from property 1 that

$$(u_{tj}\tau_{ij})^{1/\theta} z_j \sim \exp\left((u_{tj}\tau_{ij})^{-1/\theta} \lambda_j \right).$$

Then, property 2 implies that

$$\min_j \left[(u_{tj}\tau_{ij})^{1/\theta} z_j \right] \sim \exp\left(\sum_j (u_{tj}\tau_{ij})^{-1/\theta} \lambda_j \right).$$

Lastly, appealing to property 1 again,

$$p_{ti}(z)^{1/\theta} \sim \exp\left(B_t^{-1/\theta} \sum_j (u_{tj}\tau_{ij})^{-1/\theta} \lambda_j \right). \tag{C.1}$$

Recall that $P_{ti}^{1-\eta} = \int p_{ti}(z)^{1-\eta}\varphi(z)dz$. Let $\mu_i = (B_t)^{-1/\theta} \sum_j (u_{tj}\tau_{ij})^{-1/\theta} \lambda_j$, then

$$P_{ti}^{1-\eta} = \mu_i \int x^{\theta(1-\eta)} \exp(-\mu_i x)\, dx.$$

Apply a change of variables so that $\omega_i = \mu_i x$ and obtain

$$P_{ti}^{1-\eta} = (\mu_i)^{\theta(\eta-1)} \int \omega_i^{\theta(1-\eta)} \exp(-\omega_i) d\omega_i.$$

Let $\gamma = \Gamma(1 + \theta(1-\eta))^{1/(1-\eta)}$, where $\Gamma(\cdot)$ is the Gamma function. Therefore,

$$\begin{aligned} P_{ti} &= \gamma (\mu_{ti})^{-\theta} \\ &= \gamma B_t \left(\sum_j (u_{tj}\tau_{ij})^{-1/\theta} \lambda_j \right)^{-\theta}. \end{aligned} \tag{C.2}$$

Trade shares Now I derive the trade shares π_{ij}, the fraction of i's total spending on tradable goods that is obtained from country j. Due to the law of large numbers, the fraction of goods that i obtains from j is also the probability, that for any good z, country j is the least cost supplier. Mathematically,

$$\begin{aligned} \pi_{ij} &= \Pr \left\{ p_{tij}(z) \leq \min_l \left[p_{til}(z) \right] \right\} \\ &= \frac{(u_{tj}\tau_{ij})^{-1/\theta} \lambda_j}{\sum_l (u_{tl}\tau_{il})^{-1/\theta} \lambda_l}, \end{aligned} \tag{C.3}$$

where I have used equation (C.1) along with properties 2 and 3.

Using equations (C.2) and (C.3), the the price of tradables can be stated as

$$P_{ti} = \gamma B_t \frac{u_{ti}}{\left(\frac{\lambda_i}{\pi_{ii}}\right)^{\theta}}. \tag{C.4}$$

C.2 Relative prices and income per worker

Here I show how to derive expressions for the price of services relative to tradables and the price of services relative to retail goods. In addition I show how to derive an expression for income per worker. I begin by deriving a few important relationships that will be used for the following derivations.

The unit cost for a factor bundle by producers of tradables is

$$\begin{aligned} u_{ti} &= \left(r_i^{\alpha} w_i^{1-\alpha} \right)^{\nu_t} \left(P_{si}^{\sigma_t} P_{ti}^{1-\sigma_t} \right)^{1-\nu_t} \\ &= \left(\frac{r_i}{w_i} \right)^{\alpha\nu_t} \left(\frac{w_i}{P_{ti}} \right)^{\nu_t} \left(\frac{P_{si}}{P_{ti}} \right)^{\sigma_t(1-\nu_t)} P_{ti}. \end{aligned} \tag{C.5}$$

Substitute (C.5) into (C.4) and rearrange to solve for $\frac{w}{P_t}$ as

$$\frac{w_i}{P_{ti}} = \left(\frac{\left(\frac{\lambda_i}{\pi_{ii}}\right)^{\theta}}{\gamma B_t} \right)^{\frac{1}{\nu_t}} \left(\frac{P_{si}}{P_{ti}} \right)^{\frac{-\sigma_t(1-\nu_t)}{\nu_t}}. \tag{C.6}$$

Relative prices I first solve for the price of services relative to tradables. The unit cost for a factor bundle by producers of services is

$$\begin{aligned} u_{si} &= \left(r_i^{\alpha} w_i^{1-\alpha}\right)^{\nu_s} \left(P_{si}^{\sigma_s} P_{ti}^{1-\sigma_s}\right)^{1-\nu_s} \\ &= \left(\frac{r_i}{w_i}\right)^{\alpha\nu_s} \left(\frac{w_i}{P_{ti}}\right)^{\nu_s} \left(\frac{P_{si}}{P_{ti}}\right)^{\sigma_s(1-\nu_s)} P_{ti}. \end{aligned} \tag{C.7}$$

Substitute (C.7) into the price of services to obtain

$$\begin{aligned} P_{si} &= \left(\frac{B_s}{A_{si}}\right) u_{si} \\ &= \left(\frac{B_s}{A_{si}}\right) \left(\frac{r_i}{w_i}\right)^{\alpha\nu_s} \left(\frac{w_i}{P_{ti}}\right)^{\nu_s} \left(\frac{P_{si}}{P_{ti}}\right)^{\sigma_s(1-\nu_s)} P_{ti} \\ \Rightarrow \frac{P_{si}}{P_{ti}} &= \left(\frac{B_s}{A_{si}}\right)^{\frac{1}{1-\sigma_s(1-\nu_s)}} \left(\frac{r_i}{w_i}\right)^{\frac{\alpha\nu_s}{1-\sigma_s(1-\nu_s)}} \left(\frac{w_i}{P_{ti}}\right)^{\frac{\nu_s}{1-\sigma_s(1-\nu_s)}}. \end{aligned} \tag{C.8}$$

Finally, substitute equation (C.6) for $\frac{w}{P_t}$ into (C.8) to obtain the price of services relative to tradables

$$\frac{P_{si}}{P_{ti}} = \left(\frac{\left[\frac{(\lambda_i/\pi_{ii})^{\theta}}{\gamma B_t}\right]^{\frac{\nu_s}{\nu_t}}}{\frac{A_{si}}{B_s}}\right)^{\frac{1}{1-\sigma_s(1-\nu_s)+\sigma_t(1-\nu_t)\frac{\nu_s}{\nu_t}}} \tag{C.9}$$

As pointed out in the text, the price of services relative to retail goods is pinned down by the price of services relative to tradables:

$$\frac{P_{si}}{P_{ri}} = \left(\frac{1}{B_s}\right) \left(\frac{P_{si}}{P_{ti}}\right)^{1-\sigma_r} \tag{C.10}$$

Income per worker I define income per worker at PPP, in country i, as the factor income per worker, deflated by the price of final consumption: $y_i = \frac{w_i L_i + r_i K_i}{N_i P_{ci}}$.[12] P_{ci} is the optimal price of discretionary consumption which satisfies: $P_{ci}C_i = P_{si}C_{si} + P_{ri}(C_{ri} - N_i\bar{c}_r)$, where $C_i = C_{si}^{\sigma_c}(C_{ri} - N_i\bar{c}_r)^{1-\sigma_c}$ is aggregate discretionary consumption. Therefore,

$$\begin{aligned} P_{ci} &= B_c P_{si}^{\sigma_c} P_{ri}^{1-\sigma_c} \\ &= B_c \left(\frac{P_{si}}{P_{ri}}\right)^{\sigma_c} P_{ri} \end{aligned} \tag{C.11}$$

where $B_c = (\sigma_c)^{-\sigma_c}(1-\sigma_c)^{\sigma_c - 1}$. Next, $w_i L_i + r_i K_i = \frac{w_i L_i}{1-\alpha}$ implies that $y_i = \left(\frac{w_i}{P_{ci}}\right)\left(\frac{h_i}{1-\alpha}\right)$. I will now show how to solve for $\frac{w_i}{P_{ci}}$. Start by subbing in equation (C.11) for the price of

[12] Recall that $L_i = N_i h_i$ is the effective labor force, i.e., the number of workers times the average human capital of each worker.

consumption,

$$\frac{w_i}{P_{ci}} = \left(\frac{1}{B_c}\right)\left(\frac{P_{si}}{P_{ri}}\right)^{-\sigma_c}\left(\frac{w_i}{P_{ri}}\right)$$
$$= \left(\frac{1}{B_c}\right)\left(\frac{P_{si}}{P_{ri}}\right)^{-\sigma_c}\left(\frac{w_i}{P_{ti}}\right)\left(\frac{P_{ti}}{P_{si}}\right)\left(\frac{P_{si}}{P_{ri}}\right).$$

I have already solved for $\frac{w_i}{P_{ti}}$ in terms of $\frac{P_{si}}{P_{ti}}$ (equation (C.6)) and I have already solved for the relative prices in terms of productivity and home trade shares (equations (C.9) and (C.10)). Thus, the expression for income per worker is

$$y_i = \left(\frac{1}{B_c}\right)\left(\frac{1}{B_r}\right)^{1-\sigma_c}\left(\frac{1}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha} \times \left(\frac{(\lambda_i/\pi_{ii})^{\theta}}{\gamma B_t}\right)^{\frac{1}{\nu_t}}\left(\frac{\left[\frac{(\lambda_i/\pi_{ii})^{\theta}}{\gamma B_t}\right]^{\frac{\nu_s}{\nu_t}}}{\frac{A_{si}}{B_s}}\right)^{-\frac{\sigma_t(1-\nu_t)/\nu_t+\sigma_r+\sigma_c(1-\sigma_r)}{1-\sigma_s(1-\nu_s)+\sigma_t(1-\nu_t)\nu_s/\nu_t}} k_i^{\alpha} h_i^{1-\alpha}, \quad \text{(C.12)}$$

where $k_i = \frac{K_i}{N_i}$ is capital stock per worker.

D Additional tables

This appendix provides additional tables listing the names and isocodes of the countries included in my sample, as well as the classification of goods and services that I used to construct prices.

Table D.1: Basic Heading classification

Code	Name	Classification
1101111	Rice	Goods
1101112	Other cereals and flour	Goods
1101113	Bread	Goods
1101114	Other bakery products	Goods
1101115	Pasta products	Goods
1101121	Beef and veal	Goods
1101122	Pork	Goods
1101123	Lamb, mutton and goat	Goods
1101124	Poultry	Goods
1101125	Other meats and preparations	Goods
1101131	Fresh or frozen fish and seafood	Goods
1101132	Preserved fish and seafood	Goods
1101141	Fresh milk	Goods
1101142	Preserved milk and milk products	Goods
1101143	Cheese	Goods
1101144	Eggs and egg-based products	Goods
1101151	Butter and margarine	Goods
1101153	Other edible oils and fats	Goods
1101161	Fresh or chilled fruit	Goods
1101162	Frozen, preserved or processed fruits	Goods
1101171	Fresh or chilled vegetables	Goods
1101172	Fresh or chilled potatoes	Goods
1101173	Frozen or preserved vegetables	Goods
1101181	Sugar	Goods
1101182	Jams, marmalades and honey	Goods
1101183	Confectionery, chocolate and ice cream	Goods
110119	Food products n.e.c.	Goods
110121	Coffee, tea and cocoa	Goods
110122	Mineral waters, soft drinks, fruit and vegetable juices	Goods
1102111	Spirits	Goods
1102121	Wine	Goods
1102131	Beer	Goods
110220	Tobacco	Goods
1103111	Clothing materials and accessories	Goods
1103121	Garments	Goods
1103141	Cleaning and repair of clothing	Services
1103211	Footwear	Goods
1103221	Repair and hire of footwear	Services
110410	Actual and imputed rentals for housing	Services
110430	Maintenance and repair of the dwelling	Services
110440	Water supply and miscellaneous services relating to the dwelling	Services
110442	Miscellaneous services relating to the dwelling	Services
110451	Electricity	Services
110452	Gas	Goods
110453	Other fuels	Goods
110511	Furniture and furnishings	Goods

Table D.1 – Continued

Code	Name	Classification
110512	Carpets and other floor coverings	Goods
110513	Repair of furniture, furnishings and floor coverings	Services
110520	Household textiles	Goods
110531	Major household appliances whether electric or not	Goods
110532	Small electric household appliances	Goods
110533	Repair of household appliances	Services
110540	Glassware, tableware and household utensils	Goods
110551	Major tools and equipment	Goods
110552	Small tools and miscellaneous accessories	Goods
110561	Non-durable household goods	Goods
1105621	Domestic services	Services
1105622	Household services	Services
110611	Pharmaceutical products	Goods
110612	Other medical products	Goods
110613	Therapeutical appliances and equipment	Goods
110621	Medical Services	Services
110622	Dental services	Services
110623	Paramedical services	Services
110630	Hospital services	Services
110711	Motor cars	Goods
110712	Motor cycles	Goods
110713	Bicycles	Goods
110722	Fuels and lubricants for personal transport equipment	Goods
110723	Maintenance and repair of personal transport equipment	Services
110724	Other services in respect of personal transport equipment	Services
110731	Passenger transport by railway	Services
110732	Passenger transport by road	Services
110733	Passenger transport by air	Services
110734	Passenger transport by sea and inland waterway	Services
110735	Combined passenger transport	Services
110736	Other purchased transport services	Services
110810	Postal services	Services
110820	Telephone and telefax equipment	Goods
110830	Telephone and telefax services	Services
110911	Audio-visual, photographic and information processing equipment	Goods
110914	Recording media	Goods
110915	Repair of audio-visual, photographic and information processing equipment	Services
110921	Major durables for outdoor and indoor recreation	Goods
110931	Other recreational items and equipment	Goods
110933	Gardens and pets	Services
110935	Veterinary and other services for pets	Services
110941	Recreational and sporting services	Services
110942	Cultural services	Services
110943	Games of chance	Goods
110950	Newspapers, books and stationery	Goods
110960	Package holidays	Services
111000	Education	Services

Table D.1 – Continued

Code	Name	Classification
111110	Catering services	Services
111120	Accommodation services	Services
111211	Hairdressing salons and personal grooming establishments	Services
111212	Appliances, articles and products for personal care	Goods
111220	Prostitution	Services
111231	Jewelery, clocks and watches	Goods
111232	Other personal effects	Goods
111240	Social protection	Services
111250	Insurance	Services
111261	FISIM	Services
111262	Other financial services n.e.c	Services
111270	Other services n.e.c.	Services
111300	Net purchases abroad	N/A
130221	Compensation of employees	N/A
130222	Intermediate consumption	N/A
130223	Gross operating surplus	N/A
130224	Net taxes on production	N/A
130225	Receipts from sales	N/A
130421	Compensation of employees	N/A
130422	Intermediate consumption	N/A
130423	Gross operating surplus	N/A
130424	Net taxes on production	N/A
130425	Receipts from sales	N/A
140111	Compensation of employees	N/A
140112	Intermediate consumption	N/A
140113	Gross operating surplus	N/A
140114	Net taxes on production	N/A
140115	Receipts from sales	N/A
150110	Metal products and equipment	Goods
150120	Transport equipment	Goods
150210	Residential buildings	Services
150220	Non-residential buildings	Services
150230	Civil engineering works	Services
150300	Other products	Services
160000	Change in inventories and valuables	N/A
180000	Balance of exports and imports	N/A

Table D.2: List of countries and productivities (US = 1)

Isocode	**Country**	$\left(\frac{\lambda_i/\pi_{ii}}{\lambda_{US}/\pi_{US\,US}}\right)^{\theta}$	$\frac{A_{si}}{A_{s\,US}}$
ALB	Albania	0.44	0.50
ARG	Argentina	0.48	0.99
AUS	Australia	1.02	0.86
AUT	Austria	1.19	0.91
BEL	Belgium	1.02	1.02
BEN	Benin	0.45	0.59
BFA	Burkina Faso	0.40	0.55
BGD	Bangladesh	0.35	0.80
BGR	Bulgaria	0.58	0.75
BOL	Bolivia	0.44	0.68
BRA	Brazil	0.72	0.80
BTN	Bhutan	0.34	0.61
BWA	Botswana	0.77	0.71
CAF	Central African Republic	0.42	0.47
CAN	Canada	1.17	0.91
CHE	Switzerland	1.34	0.85
CHL	Chile	0.71	1.05
CHN	China Version 1	0.48	0.79
CIV	Cote d'Ivoire	0.53	0.87
CMR	Cameroon	0.55	0.75
COL	Colombia	0.59	0.83
COM	Comoros	0.40	0.65
CPV	Cape Verde	0.52	0.93
CYP	Cyprus	0.89	0.81
DNK	Denmark	1.23	0.84
ECU	Ecuador	0.58	0.67
EGY	Egypt	0.51	1.19
ESP	Spain	0.97	0.95
ETH	Ethiopia	0.24	0.70
FIN	Finland	1.22	0.80
FJI	Fiji	0.60	0.59
FRA	France	1.14	0.96
GBR	United Kingdom	1.10	0.98
GER	Germany	1.02	0.87
GHA	Ghana	0.32	0.63
GIN	Guinea	0.23	1.40
GMB	Gambia, The	0.27	0.78
GRC	Greece	0.91	0.93
HKG	Hong Kong	0.76	1.25
HUN	Hungary	0.84	0.74
IDN	Indonesia	0.43	0.87
IND	India	0.43	0.94
IRL	Ireland	1.37	0.87
IRN	Iran	0.59	0.99
ISL	Iceland	1.08	0.84
ISR	Israel	0.95	0.79
ITA	Italy	1.08	0.95
JOR	Jordan	0.56	0.82
JPN	Japan	1.07	0.75
KEN	Kenya	0.37	0.67
KHM	Cambodia	0.36	0.83
KOR	Korea, Republic of	0.86	0.85
LBN	Lebanon	0.73	0.80
LKA	Sri Lanka	0.42	0.90
LUX	Luxembourg	1.41	0.82
MAC	Macao	0.82	1.35
MAR	Morocco	0.57	0.92
MDG	Madagascar	0.27	0.52
MDV	Maldives	0.49	0.66
MEX	Mexico	0.70	0.76
MLI	Mali	0.40	0.81
MLT	Malta	0.85	0.81
MNG	Mongolia	0.29	0.60
MOZ	Mozambique	0.37	1.12

Table D.2 – Continued

Isocode	**Country**	$\left(\frac{\lambda_i/\pi_{ii}}{\lambda_{US}/\pi_{USUS}}\right)^{\theta}$	$\frac{A_{si}}{A_{sUS}}$
MRT	Mauritania	0.33	0.69
MUS	Mauritius	0.56	1.40
MWI	Malawi	0.27	0.68
MYS	Malaysia	0.67	1.17
NAM	Namibia	0.70	0.75
NLD	Netherlands	0.90	1.01
NOR	Norway	1.21	0.86
NZL	New Zealand	1.00	0.74
OMN	Oman	0.81	1.35
PAK	Pakistan	0.47	0.97
PAN	Panama	0.58	0.67
PER	Peru	0.59	0.63
PHL	Philippines	0.39	0.74
POL	Poland	0.75	0.78
PRT	Portugal	0.85	0.83
PRY	Paraguay	0.43	0.72
ROM	Romania	0.63	0.61
RWA	Rwanda	0.37	0.73
SAU	Saudi Arabia	0.89	1.36
SDN	Sudan	0.47	0.65
SEN	Senegal	0.39	0.77
SGP	Singapore	0.89	1.01
STP	Sao Tome and Principe	0.33	1.13
SWE	Sweden	1.21	0.79
SWZ	Swaziland	0.60	0.90
SYR	Syria	0.72	0.70
TGO	Togo	0.36	0.41
THA	Thailand	0.49	0.86
TTO	Trinidad &Tobago	0.77	0.96
TUN	Tunisia	0.62	1.10
TUR	Turkey	0.78	0.78
TZA	Tanzania	0.35	0.45
UGA	Uganda	0.40	0.70
URY	Uruguay	0.64	0.92
USA	United States	1.00	1.00
VEN	Venezuela	0.73	0.90
VNM	Vietnam	0.37	0.88
ZAF	South Africa	0.74	1.02
ZMB	Zambia	0.42	0.54