The Missing Food Problem

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Abstract

Poor countries have low labour productivity in agriculture relative to other sectors, yet predominantly consume domestically produced food. The existing literature on cross-country agricultural and aggregate productivity differences abstracts from open economy considerations – leaving open the question of *why* poor countries import so little food. I propose an answer: high trade barriers and low relative input costs (wages) in developing-country agriculture. With a modified Eaton-Kortum trade model, I show these distortions reconcile the cross-country productivity data with observed trade flows. Through various counterfactual exercises, I find these distortions contribute to cross-country productivity differences and future work should ascertain their underlying causes.

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1 Introduction

The difference in aggregate income and productivity between rich and poor countries is primarily due to differences within the agricultural sector.[1] Agriculture in the poorest countries accounts for the majority of employment and labour productivity is nearly seventy times lower than in the richest countries while the gap for nonagricultural sectors is barely seven.[2] Evidence is also beginning to accumulate that productivity variation (both in terms of labour productivity and total factor productivity) in industry is lower than agriculture (Duarte and Restuccia, 2010; Herrendorf and Valentinyi, 2012). These productivity data alone imply developing countries should be massive importers of food. This is in stark contrast to observed trade flows: the poorest countries import only 2% of their food while the richest countries import over half.[3] Existing research abstracts from international trade and focuses on domestic distortions within closed-economy frameworks.[4] Higher food imports would allow workers in domestic agriculture to move towards more productive activities, resulting in potentially large aggregate gains.

In this paper, I reconcile the cross-country productivity data and observed trade flows. I propose a theory where two distortions lead poor countries to heavily rely on domestic food production despite low relative productivity. The first distortion, import barriers, increase the cost of imported goods and lead consumers to opt for lower productivity domestic producers. The second distortion, low relative input costs (wages) in agriculture, decrease domestic agricultural prices and also lead consumers to opt for lower productivity domestic producers. Without these distortions, a country could conceivably reallocate factors to manufactured goods - say, garments - and import the necessary food. Development accounting exercises by Caselli (2005) suggest that if countries could achieve an agricultural labour share equal to the US, cross-country aggregate productivity

[1] Research to understand agriculture's massive productivity gap has a long history - since at least Schultz (1953) coined this issue the Food Problem.

[2] Calculations based on means within top and bottom deciles of countries by GDP/Capita for 138 countries following Caselli (2005) and Restuccia et al. (2008). Details in Section 3.2.

[3] Data sources and other details are described in Section 3.1.

[4] See, e.g., Hayami and Ruttan (1970); Kuznets (1971); Kawagoe et al. (1985); Hayami and Ruttan (1985); Rao (1993); Gollin et al. (2004); Cordoba and Ripoll (2006); Gollin et al. (2007); Adamopoulos (2011); Vollrath (2009); Adamopoulos and Restuccia (2011); Duarte and Restuccia (2010); Lagakos and Waugh (2010).

variation would decline to almost one-quarter of its current level. Through various counterfactual exercises using a modified Eaton-Kortum trade model, I find the two distortions indeed contribute to cross-country aggregate productivity differences.

To infer the existence and magnitude of these distortions from data, I rely on relationships between productivity, trade flows, and input costs implied by the model. Overall, I find the poorest 10% of countries in my sample have import costs are over 70 percentage points higher than in the richest 10%, conditional on standard observable determinants of trade costs. The input costs (such as wages) in agriculture are over 90% lower than in nonagriculture for the poorest countries but one-third lower in the richest. The independent evidence for both distortions is well established. Wages in agriculture relative to nonagriculture, for instance, increase strongly with aggregate income. This holds over time (Caselli and Coleman, 2001) and across countries (Vollrath, 2009; Lagakos and Waugh, 2011; Gollin et al., 2011b). Regarding the trade distortion, tariff rates reported by the WTO show, on average, poorer countries have MFN tariffs on the order of 20% for agricultural imports (with bound rates over 80%) and approach 120% for the average South Asian country. Variation across commodities is also revealing, as meat, dairy, vegetables, grains, and other general food categories have higher tariff rates than commodities such as spices, oils, coffee, nuts, and the like (Gibson et al., 2001).

The specific procedure I use to estimate the distortions is novel and a brief discussion of the details is warranted. Within a model of trade and production, within-sector trade and heterogeneous firm productivity implies imports shut down low productivity producers – increasing average productivity. Within a given sector, a country's labour productivity is a function of the spending allocated to domestic producers (the country's "home-bias") and of underlying technology. Taking sectoral productivity and home-bias from data, technological parameters are thus recovered. The model further relates a country's competitiveness with technology and input costs of production. Competitiveness can be recovered through a fairly standard gravity regression. Given technology and competitiveness, inputs costs are recovered. Finally, technology, input costs, and trade costs together determine a country's home-bias. Given observable determinants of trade costs, the model requires additional import costs that are decreasing with aggregate income to match observed home-biases across countries.

As an illustrative exercise, I quantify the potential aggregate gains of sectoral labour reallocation by eliminating the two distortions in the model. To endogenize labour allocations and wages, I expand the model by embedding it into a dual-economy (agriculture and nonagriculture) model of structural change.[5] I model non-homothetic preferences as in Kongsamut et al. (2001), where households must satisfy a minimum food intake requirement before allocating income across goods according to their preference weights. To capture the input cost distortion, I incorporate wage wedges similar to Restuccia et al. (2008), where farm workers face a tax to switch into nonagricultural activities. With the expanded model, I examine counterfactual allocations of labour, and the implied change in aggregate productivity, under various scenarios ranging from removal of observable WTO tariffs to complete frictionless trade.

The results of these counterfactual exercises are dramatic. Removal of observed tariffs rates lower agriculture's share of employment by nearly ten percentage points in the poorest countries (from three-quarters to two-thirds). Lowering the model-implied import costs to the average level of rich countries lowers the typical poor country's agricultural employment share to less than 60%. Frictionless trade in agricultural goods lowers the employment share to below 45%. These reallocations generate substantial reductions in the aggregate labour productivity ratio of the richest relative to the poorest countries – currently 33. Without tariffs the counterfactual ratio is 25 and by lowering the model-implied costs it is 20.[6] My results, however, do not provide concrete policy prescriptions or identify particular market distortions in need of eliminating. Instead, these results emphasize the importance of future work explaining the source of high agricultural import costs and low relative agricultural wages.

I contribute to a large literature in international macroeconomics examining agricultural and

[5]This modeling exercise builds on a more theoretical treatment of structural change in an open economy by Yi and Zhang (2010).

[6]These reallocations resulting from food imports may be found historically. Stokey (2001) finds food imports account for much of the United Kingdom's increased manufacturing output between 1780 and 1850. More recently, Teignier (2010) demonstrates a similar pattern in South Korea since the 1960s.

aggregate productivity differences across countries. Unlike this paper, the literature has previously focused on causes of low agricultural productivity using closed economy frameworks. Explanations include inefficient farm sizes (Adamopoulos and Restuccia, 2011), poor domestic transportation infrastructure (Adamopoulos, 2011; Gollin and Rogerson, 2010), comparatively low quality farm workers (Lagakos and Waugh, 2010), barriers to labour or intermediate inputs (Restuccia et al., 2008), or simply over-counting farm workers in the data (Gollin et al., 2004). In this paper, high trade barriers contribute to low import levels but are not likely the *cause* of extremely low agricultural productivity in poor countries. The richest-10% of countries allocate approximately 43% of expenditures to domestically produced food while the poorest-10% allocate over 98%. Arkolakis et al. (2012) find that for all new-trade models the gains from trade are fully captured by the fraction of spending allocated to domestically produced goods. Using their result, the import differences alone would generate a ratio between rich and poor country productivity of only 1.18 to 1.09 – nowhere near the factor of 70 difference observed.[7] That is, differences in import levels can explain less than 5% of the total gap in agricultural productivity. My contribution is not to explain agriculture's low relative productivity but to address why import levels are so low in spite of that low relative productivity.

The remainder of the paper begins with a model of production and trade in Section 2. I use this model in Section 3 to reconcile productivity and trade flows with high trade costs and low input costs in developing country agriculture. Household preferences and market clearing conditions are not necessary to estimate these distortions. They are necessary, however, to endogenize labour allocations and wages so counterfactual exercises can be undertaken. To that end, I develop a model full in Section 4. I use the full model to illustrate the effect these distortions have on aggregate productivity. I conclude in Section 5.

[7]Details of the relationship between import patterns and productivity are provided in Section 3.

2 A Multi-Sector Ricardian Trade Model

To ensure key features and assumptions are clear, I present the model in two parts. First, in this section, I develop the production and trade components of the model. Estimates of trade costs and input costs are fully independent of consumer preferences and market clearing conditions. Second, to gauge the effect of high import costs and differential sectoral input costs on aggregate productivity, sectoral labour allocations and wages must be endogenized. Preferences and market clearing conditions are incorporated in Section 4.

Prior to providing details, a few brief and general notes on the overall model structure is in order. There are N countries each with three sectors: agriculture (a), manufacturing (m), and services (s). Agriculture and manufacturing are composite goods composed of individually tradable and horizontally differentiated varieties. Each variety is sourced from the lowest cost producer, whether at home or abroad, which introduces within-sector trade (exporting a subset of varieties to import others).

2.1 Production Technology

I model N-by-N bilateral trade flows with two differentiated tradable goods, agriculture and manufacturing, similar to Eaton and Kortum (2002). Goods are composed of a continuum of differentiated varieties, available for firms in any country to produce. Each firms may produce an individual product variety, denoted z, with linear technology[8]

$$y_{ik}(z) \quad = \quad A_{ik}(z)L_{ik}(z),$$

where $A_{ik}(z)$ is the labour productivity for variety-z in country-i and sector-k. Markets are perfectly competitive, which implies the producer price will equal marginal costs, $\frac{w_{ik}}{A_{ik}(z)}$. More specifically, each variety is a contestable market with zero barriers to firm entry or exit; any price deviation from

[8]Incorporating intermediate inputs into this production function is another standard formulation, which increase gains from trade since imported input prices decline following liberalization.

marginal cost will result in a new entrant supplanting the incumbent firm. Productive technologies for each firm/variety are independent random draws from a Frechet distribution specific to each country-i and sector-k,[9] such that

$$Pr(A_{ik}(z) \leq x) = F_{ik}(x) \quad = \quad e^{-(x/A_{ik})^{-\theta_k}},$$

where θ_k governs productivity dispersion and A_{ik} the overall level of productivity ($A_{ik} \propto E\left[A_{ik}(z)\right]$). Lower θ implies greater variability in productivity across firms (and countries) and higher A implies greater average productivity. These productivity differences across producers provides the incentive to trade: low productivity domestic producers may be shut down in favour of an import. The incentive to trade, and the gain from doing so, is inversely related to θ.

Let $\tilde{y}_{ik}(z)$ be the quantity of variety-z in country-i for good-k, either imported or produced domestically. A domestic firm aggregates these into composite goods through a CES technology with an elasticity of substitution of ρ,

$$Y_{ik} \quad = \quad \left[\int_0^1 \tilde{y}_{ik(z)}^{1-1/\rho} dz\right]^{\rho/(\rho-1)}.$$

Finally, nontradable services are produced with a similar linear production technology, $Y_{is} = A_{is}L_{is}$.

2.2 International Prices and Trade Patterns

Firms producing the composite manufactured and agricultural goods purchase individual varieties from the lowest cost source - at home or abroad. Trade costs are iceberg, where $\tau_{ijk} > 1$ sector-k

[9]The Frechet distribution enables an analytic solution to each country's aggregate price index of tradables. Beyond that, the assumption may be reasonable since *any* underlying distribution of firm productivity that follows a power law (such as Pareto, student's t, lorentzian, log gamma, and double Pareto, to name a few) will converge to a Frechet distribution. There is much evidence that firm size in the United States closely follows a Pareto distribution (see, e.g., Axtell (2001)). There are also strong theoretical reasons to expect the underlying distribution of ideas, in the specific sense of Jones (2005), follows a Pareto distribution. Jones (2005) demonstrates that, with this distributional assumption, Leontief plant technologies aggregate to Cobb-Douglas production with labour-augmenting technical change. Kortum (1997) demonstrates that a Pareto distribution of underlying ideas is required for exponential growth in such a model.

goods are shipped per unit delivered to country-i from country-j. To avoid shipments through third-party countries, the triangle inequality holds: $\tau_{ij} < \tau_{ih}\tau_{hj}$, for any country h. Consequently, the price of variety-z in country-i for good-k is the lowest price charged by producers, $\frac{w_{jk}}{A_{jk}(z)}$, adjusted for transport costs, τ_{ijk}:

$$p_{ik}(z) \quad = \quad \min_{j\in\{1,..,N\}} \left[\frac{\tau_{ijk}w_{jk}}{A_{jk}(z)}\right]. \tag{1}$$

Each country's price for tradable good-k, is therefore $P_{ik} = \left[\int_0^1 p_{ik}(z)^{1-\rho}dz\right]^{1/(1-\rho)}$. Given the distribution of productivity across varieties, and assuming import costs and wages are not variety-specific, this index reduces to

$$P_{ik} \quad = \gamma \quad \left[\sum_{j=1}^{N}\left(\frac{\tau_{ijk}w_{jk}}{A_{jk}}\right)^{-\theta_k}\right]^{-1/\theta_k}, \tag{2}$$

where $\gamma = \Gamma\left(1+\frac{1-\rho}{\theta_k}\right)^{\frac{1}{1-\rho}}$.[10] Notice, Equation 2 is the price paid by consumers in country-i for the aggregate good-k and no knowledge of individual variety sources is necessary.

The share of country-i expenditures purchased from country-j captures trade patterns in the model. This share, in turn, depends on the fraction of varieties produced in j that have the lowest price of all producers in any other country, from the perspective of country-i consumers. This share can be represented by

$$\pi_{ijk} \quad = \quad \frac{\psi_{ijk}}{\sum_{j=1}^{N}\psi_{ijk}}, \tag{3}$$

where $\psi_{ijk} = \tau_{ijk}^{-\theta_k}\left(A_{jk}/w_{jk}\right)^{\theta_k}$ is the product of trade costs and competitiveness of country-j from the perspective of country-i consumers. A_{jk}/w_{jk} is a country's competitiveness, which rises with technological productivity A_{jk} and falls with labour costs w_{jk}.

[10] $1+\theta_k > \rho$ must hold for a well defined Gamma-function. I set ρ (which plays no role in the quantitative analysis that follows) such that $\gamma = 1$.

3 Reconciling Cross-Country Productivity and Trade Patterns

With the production and trade components of the model now established, I investigate what parameter values are necessary to match both trade and productivity flows. In particular, I demonstrate high trade costs *and* low relative input costs in agriculture are required. All estimates and exercises are based on a sample of 138 countries for which year 2000 data on trade (from Feenstra et al. (2005)), aggregate productivity (from PWT 6.3), sectoral GDP (from the World Bank), and agricultural labour shares (from the FAO) are available. The list of sample countries, and selected estimates of sectoral labour productivity, import shares, and the two distortion measures is in Appendix C: Table 6.

3.1 Productivity and Trade Costs

The share of country-i expenditure imported from country-j – from Equation 3 – can be expressed as

$$\pi_{ijk} = P_{ik}^{\theta}\left(\frac{A_{jk}}{\tau_{ijk}w_{jk}}\right)^{\theta} = P_{ik}^{\theta}\left(\frac{T_{jk}}{\tau_{ijk}}\right)^{\theta},$$

where $T_{jk} = A_{jk}/w_{jk}$ is a country's competitiveness, which rises with technological productivity A_{jk} and falls with labour costs w_{jk}. Domestic spending shares are similar: $\pi_{iik} = P_{ik}^{\theta}\left(A_{ik}/w_{ik}\right)^{\theta} = P_{ik}^{\theta}T_{ik}^{\theta}$. The ratio of π_{ijk} to π_{iik} is a normalized import share that depends only on competitiveness measures and trade costs:

$$ln\left(\frac{\pi_{ijk}}{\pi_{iik}}\right) = \theta ln\left(T_{jk}\right) - \theta ln\left(T_{ik}\right) - \theta ln\left(\tau_{ijk}\right).$$

To estimate this expression, proxy trade costs with various bilateral characteristics and an importer-specific trade barrier, B_{ik}. The bilateral costs include distance between capitals and indicators for shared border, common (ethnographic) language, and trade agreement status (from Fieler (2011)).

The precise empirical specification I use, for each sector-k, is:

$$\begin{aligned} ln\left(\frac{\pi_{ijk}}{\pi_{iik}}\right) &= \beta_{1k} ln\left(Distance_{ijk}\right) + \beta_{2k} Border_{ijk} + \beta_{3k} Language_{ijk} \\ &\quad + \beta_{4k} Agreement_{ijk} + \eta_{jk} + \iota_{ik} + \nu_{ijk}, \end{aligned} \tag{4}$$

where η_{jk} is the exporter fixed-effect, ι_{ik} the importer fixed-effect, and ν_{ijk} the random component.

To fit trade shares π_{ijk} to data, I construct trade share measures similar to Eaton and Kortum (2001), Bernard et al. (2003), and Waugh (2010). Specifically, I take the ratio of country-i imports from country-j relative to country-i's output less net exports

$$\hat{\pi}_{ijk} = \frac{Import_{ijk}}{SectoralOutput_{ik} - Exports_{ik} + Imports_{ik}}$$

I infer sectoral output from World Bank GDP shares. Bilateral trade data for 2000 is from the NBER-UN Trade Database, which disaggregates by 4-digit SITC code (Feenstra et al., 2005). Agricultural trade flows are all bilateral flows classified with an SITC (revision 2) 1-digit code of 0.[11] I report in Table 1 the average share purchased from domestic producers ($\pi_{iik} = 1 - \Sigma_{i \neq j} \pi_{ijk}$). A lower value reflects greater imports from abroad while a higher value indicates the opposite - a home-bias. The poorest 10% of countries in the sample, despite their relatively low productivity in agriculture, import almost none of their food consumption.[12] The basic gravity-specification implied by the theory captures the trade data well. The parameter estimates are listed in Table 3, with 6,235 observed trade pairs in agriculture and 9,172 in manufacturing.[13] The model parameter

[11] I exclude from all analysis trade flows related to SITC 1-digit code 9. This includes gold, military items, and other special or not elsewhere classified transactions.

[12] Using this method, certain countries in my sample (such as Belgium, Finland, and the Netherlands) have total exports larger than output, which generates a negative home share. I exclude from the quantitative analysis any country for which $\pi_{iik} \notin [0,1]$ for either agricultural or nonagricultural trade. The analysis does not change if, for those countries beyond the unit interval, $ln(\frac{\pi_{ijk}}{\pi_{iik}})$ is set equal to the closest country within the interval. As an alternative, I ensure results regarding home bias in poor countries are robust to using bilateral agricultural trade data linked to agricultural gross output from the FAO production data, though on a smaller set of countries for which the FAO provides bilateral trade data.

[13] Often, countries do not trade with every other country, leaving zeros in the data for those pairs. I estimate the above specification only on the pairs with positive trade with OLS. The results are robust when, following (Eaton and Kortum, 2001) to handle this left-censoring, I estimate a Tobit model with the minimum observed π_{ij} for each country-i serving as the lower limit.

estimates are derived from coefficient estimates as: $\hat{T}_{ik} = e^{\hat{\eta}_{ik}/\theta}$, $\hat{B}_{ik} = e^{-(\hat{\iota}_{ik}+\hat{\eta}_{ik})/\theta}$, and $\hat{P}_{ik} = \left[\sum_{j=1}^{N}\left(\hat{\tau}_{ijk}^{-1}\hat{T}_{jk}\right)^{\theta}\right]^{-1/\theta}$ from Equation 2.

To evaluate these expressions, a value for the cost-elasticity of trade (θ) is necessary. This parameter governs the productivity dispersion across producers within (and between) regions and determines how sensitive trade flows are to trade costs (higher θ implies a lower cost-elasticity of trade flows). This parameter is the subject of much research and I set $\theta = 7$ in both sectors. Alvarez and Lucas (2007) set $\theta = 6.67$, Eaton and Kortum (2002) set $\theta = 8.3$, and Anderson and van Wincoop (2004) reviews the literature and argues for $\theta \in [5, 10]$. Between rich and poor countries, Waugh (2010) finds $\theta = 7.9$ for OECD countries and $\theta = 5.5$ for non-OECD countries. Most recently, Simonovska and Waugh (2011) find $\theta = [2.5, 5.5]$. For internal trade within colonial India, Donaldson (2010) finds $\theta = 3.8$ with the 17 agriculture varieties for which he has data, but $\theta = 5.2$ with the entire sample of 85 commodities. Lower θ increases the scope for comparative advantage and, therefore, increases predicted international trade flows; higher trade costs are required to match data. Gains from trade are also higher for lower θ. In this sense, my results are conservative when $\theta = 7$. The overall conclusions of this paper are robust to these wide range of values and I report results for alternative values in various footnotes as needed.

3.2 Sectoral Competitiveness and Input Costs

Real labour productivity, by sector, are constructed for a large set of countries following the procedures of Caselli (2005) and Restuccia et al. (2008) for the year 2000. Detailed accounts of agricultural net production values at international prices are available from the UN Food and Agricultural Organization.[14] Measuring agricultural and non-agricultural output using international prices avoids inferring productivity differences from distortions in domestic agricultural prices. FAO agricultural prices are also farm-gate (producer) prices, which exclude distribution and marketing costs, making output aggregated with FAO data useful for productivity compar-

[14]FAO Statistics are publicly available at: http://faostat.fao.org

isons across countries.[15] Non-agricultural labour productivity is inferred using Penn-World Table (version 6.3) data on cross-country PPP adjusted GDP per worker. Specifically, for each country-i, since FAO data gives agriculture's labour productivity (y_{ia}) and share of total employment (l_{ia}) and the PWT data gives aggregate labour productivity (y_i), non-agricultural productivity (y_{in}) is given by $(y_i - y_{ia}l_{ia})/l_{in}$.[16] I report the results of this exercise in Table 1, based on my sample of 138 countries. The cross-country differences in agricultural labour productivity dwarf non-agriculture. Agricultural productivity among the poorest 10% of countries is nearly 70 times lower than among the richest 10% while the comparable figure in nonagriculture is less than 7.[17]

In the model, average sectoral labour productivity reflects the underlying productivity of producers with positive output, $E\left[A_{ik}(z) \mid z \in \{y_{ik}(z) > 0\}\right]$. One can solve for this productivity analytically by rearranging a country's expression for home-bias ($\pi_{iik} = P_{ik}^{\theta}\left(A_{ik}/w_{ik}\right)^{\theta}$) to find real wages in sector-k ($w_{ik}/P_{ik} = \pi_{iik}^{-1/\theta}A_{ik}$). Given labour as the only factor of production, labour productivity (y_{ik}) equals real wages,

$$y_{ik} = \pi_{iik}^{-1/\theta}A_{ik}. \tag{5}$$

Imports, which lower the share of varieties purchased from domestic sources, cause average productivity to grow as inefficient producers shut-down. Absent a very low π_{iik}, measured labour productivity will closely reflect A_{ik}. In autarky, the two will equal. With real labour productivity and domestic shares of consumer expenditures known from data, autarky productivity can be inferred from observed productivity net of trade gains; that is, $A_{ik} = y_{ik}\pi_{iik}^{1/\theta}$. I report average values for countries in various income categories in Table 1. The results suggest labour productivity dif-

[15]The quality and price of distribution services, and of services generally, varies systematically with a country's level of development (Summers and Heston, 1991; Adamopoulos, 2011).

[16]Net agricultural output is rescaled uniformly such that the US share of GDP from agriculture using FAO data matches that from the WDI. The difference exists since the price normalizations for PPP adjustments differ between the PWT and the FAO. See Caselli (2005) for further details regarding this adjustment.

[17]Details on data availability and sample selection are in Section 3. There are 176 countries for which this sectoral productivity analysis is possible. These include all countries for which PWT6.3 GDP/Worker data exists for 2000, with 3 exceptions due to lack of FAO data: Taiwan, Hong Kong, Macao. For this set of countries, the agricultural gap between the top and bottom 10% of countries is 70.4 in agriculture and 6.6 - nearly identical to the restricted set of 138 countries.

ferences largely reflect underlying technological differences rather than selection across firms due to variation in import penetration.

My estimates of sectoral competitiveness, $\hat{T}_{ik}$, imply rich countries have a comparative advantage in manufacturing and an absolute advantage in both sectors while poor countries have a comparative advantage in agriculture. I report means for the richest and poorest countries in Table 2. On average, rich country competitiveness in manufacturing is 2.4 times poor country competitiveness but only 1.6 times more in agriculture. For all countries, I plot the competitiveness estimates $\hat{T}_{ik}$ in Figures 1e and 1f. Given these, and the autarky productivity parameter (A_{ik}), input costs by sector (w_{ik}) can be backed out as $w_{ik} = A_{ik}/\hat{T}_{ik}$.

I report the results of this exercise in Table 1.[18] Poor countries have substantially lower relative input costs in agriculture than richer countries. The magnitudes are substantial: the cost of inputs in agriculture are only 6% of the cost in nonagriculture for poor countries. For rich countries, this figure is an order of magnitude large at 64%. Low relative unit costs in poor countries, by increasing competitiveness relative to trading partners, substantially compensate for low labour productivity. This will reduce household incentives to import. An alternative specification for trade costs would assume exporter-specific trade costs instead of importer-specific (Waugh, 2010). Under this specification, competitiveness is identified off the importer fixed effect as $\hat{T}_{ik} = e^{-\hat{\imath}_{ik}/\theta}$. The result still hold in this case, with relative agricultural input costs less than 0.05 in poor countries and nearly 0.4 in rich.

This estimate provides no information about what is actually behind these cost differentials but it is not a new observation. Recent research examining relative agricultural wages, to take one particular input as an example, often assumes a barrier to workers moving off the farm (see, e.g., Caselli and Coleman, 2001; Restuccia et al., 2008; Herrendorf and Teixeria, 2011). More recently, Lagakos and Waugh (2011) develop a framework where agricultural wages are much lower than nonagriculture without explicit barriers but through worker heterogeneity and selection. At this stage, I need not take a stand on what is behind input cost differentials but emphasize that they

[18] Varying the cost-elasticity of trade (θ) does not substantially change the results. For $\theta \in [5, 10]$, relative agricultural unit costs vary between 0.05 and 0.06 for the poorest countries and between 0.54 and 0.81 for the richest.

are necessary to reconcile productivity and trade data. In the quantitative exercises, however, I will treat labour as the only input of production and assume a barrier to farm workers switching to nonagricultural activities and compare the resulting wage differentials with selected data.[19]

3.3 International Trade Costs

Figure 1 displays the trade cost estimates for both sectors. I separately plot the overall measure (trade weighted across import sources) and the importer-specific fixed effect. The typical country in my sample has average trade costs (trade-weighted across export partners) of 219% in agriculture and 235% in manufacturing. For the richest 10% of countries, these figure are 100% and 89%, and for the poorest they are 334% and 386%. Expressed relative to the cross-country mean, the importer-specific component of trade costs average 28% for poor countries and 44% for rich countries in agriculture. This implies that imports are typically 28% more expensive in the poorest 10% of countries relative to the average country, conditional on the bilateral trade cost components. For comparison, using a similar method of reporting the country-specific component, Waugh (2010) finds a -62% fixed-effect for the United States' manufacturing goods trade while I find -53% for US manufacturing and -71% for US agriculture.[20]

An importer-specific trade barrier is a reduced-form approach to capture all import costs such as tariffs, non-tariff barriers, health regulations, or information asymmetries, among many others, into a single number.[21] I cannot identify the underlying cause of high trade barriers but, as with differential input costs, I demonstrate higher barriers in poor countries is necessary to reconcile productivity and trade data. That being said, I compare the estimated import barriers with two import tariff measures. Figure 2 illustrates, for various geographic regions, the average difference

[19]Gollin et al. (2011a) incorporate a more detailed labour market structure into a dual-economy model with trade.

[20]That poor countries have higher trade costs than richer countries is robust to the particulars of this framework. I show in Appendix B, using a new approach developed by Novy (2011), that this conclusion holds within a wide variety of new-trade models, including Eaton and Kortum (2002), Anderson and van Wincoop (2003), Redding and Venables (2004), Melitz (2003), Melitz and Ottaviano (2008), or Chaney (2008).

[21]The importer costs I back out using gravity-regression fixed-effects are *net* of internal, within-country, trade costs (τ_{iik}). With internal costs, one can show $e^{-(\hat{\iota}_{ik}+\hat{\eta}_{ik})/\theta} = \tilde{B}_{ik}/\tau_{iik}$. So, the estimate $\hat{B}_{ik}$ from above is an underestimate of the true import cost ($\tilde{B}_{ik}$), if $\tau_{iik} > 1$.

between the estimated import barrier relative to the United States' value. African countries, on average, have 80 percentage points higher estimated import barriers than does the United States. Using tariff data from the WTO, I also report the average bound and most-favoured nation import tariff rates for agricultural goods. The difference between tariff rates in Africa and the United States is over 70 percentage points using bound tariff rates and nearly 30 percentage points using MFN. At least some fraction of the higher estimated import barriers seems to be higher explicit import tariff rates.

To illustrate the effect of importer-specific trade costs on trade patterns, consider counterfactual trade flows if productivity, input costs, and bilateral trade costs were the *only* determinants of trade. With trade costs decomposed into bilateral costs and importer-specific barriers ($\tau_{ijk} = \delta_{ijk}B_{ik}$), a country's home bias can be expressed as

$$\hat{\pi}_{iik} \quad = \quad \left[1+\Sigma_{j\in J}\left(\frac{T_{jk}}{\delta_{ijk}B_{ik}T_{ik}}\right)^{\theta}\right]^{-1},$$

by rearranging the expression for trade shares (Equation 3) for $j = i$. As before, let $\hat{T}_{ik} = e^{\hat{\eta}_{ik}/\theta}$ and $\hat{\delta}_{ijk} = \hat{\beta}'X$ from regression equation 4, where X is the vector of bilateral components of trade costs. In a world where $B_i = 1$ for all i, the agricultural home bias for the poorest and richest countries will be 93% and 88%, respectively. The B_{ik} that minimizes the deviation between model-implied normalized trade shares and data requires higher B_i for poor countries (to increase home-bias) and lower B_i for rich countries (to decrease home-bias). With the importer-specific costs implied by the regression approach, home bias in the poorest countries is 99% and in the richest countries is 57% - both much closer to data. To summarize, to reconcile productivity and trade flows, poor countries must have lower agricultural input costs (relative to nonagriculture) and higher import costs than rich countries.

4 The Effect of Distortions on Aggregate Productivity

If agricultural import barriers were relaxed, labour would reallocate towards nonagricultural activities and imports would be an additional source to meet subsistence requirements. Gains arise from two channels: (1) greater food imports increase agricultural productivity, as domestic producers concentrate on a smaller set of more productive varieties; and (2) labour moves off the farm towards higher productivity nonagricultural activities. To illustrate the potential magnitude of the gains from agricultural trade liberalization, labour allocations and equilibrium sectoral wages must be endogenously determined in the model. To that end, I incorporate a standard household sector and market clearing conditions to the previous production and trade framework. I then use this full model to illustrate the quantitative importance of the two key distortions in poor countries: high trade costs and low relative agricultural wages. One important caveat is in order: these exercises do not reflect actual policy experiments but serve to illustrate the importance of the two distortions.

4.1 Model with Endogenous Wages and Labour Allocations

I incorporate standard dual-economy features found in the macroeconomics literature: (1) non-homothetic preferences and (2) a barrier to labour movement from agriculture to nonagriculture. This preference structure captures Engel's law, with food expenditure shares declining with income. Market clearing conditions include trade balance across both tradable sectors. Positive net exports in agriculture, for example, allows negative net exports of manufactured goods.

4.1.1 Household Problem

Each country-i is populated by a household of size L_i. Labour is allocated between three sectors, denoted $k \in \{a, m, s\}$, representing agriculture, manufacturing, and services. Preferences are non-homothetic as there exists a subsistence food requirements within a Stone-Geary type utility function.[22] Given prices, P_{ik}, and wage, w_{ik}, in country-i and sector-k, each household selects consumption and labour allocations to maximize

$$\max_{\{C_{ik},L_{ik}\}_{k\in\{a,m,s\}}} U(C_{ia},C_{im},C_{is}) = \varepsilon_a ln(C_{ia}-\bar{a})+\varepsilon_m ln(C_{im})+\varepsilon_s ln(C_{is}) \tag{6}$$

$$\text{s.t.} \sum_{k\in\{a,m,s\}} L_i P_{ik} C_{ik} = \sum_{k\in\{a,m,s\}} w_{ik} L_{ik} \tag{7}$$

Preference weights $\{\varepsilon_a, \varepsilon_m, \varepsilon_s\}$ determine the fraction of disposable income allocated to each type of good. Consumer demands are standard: $C_{ia} = \bar{a}+\varepsilon_a \tilde{M}_i P_{ia}^{-1}$, $C_{im} = \varepsilon_m \tilde{M}_i P_{im}^{-1}$, $C_{is} = \varepsilon_s \tilde{M}_i P_{is}^{-1}$, where $\tilde{M}_i$ is consumer income after subsistence spending, $\left(\sum_{k\in\{a,m,s\}} w_{ik}\frac{L_{ik}}{L_i}\right) - P_{ia}\bar{a}$. As food subsistence requirements increase (through a higher $\bar{a}$) food's share of total expenditures increases.

Trade shares (from Equation 3) combine with household demand to determine each country's total sales. Country-j spends π_{jik} fraction of its total consumer demand on output of good-k from country-i, which implies total foreign demand is $\sum_{j\neq i} L_j P_{ik} C_{ik} \pi_{jik}$. Since country-$i$ spends π_{iik} fraction on its own output, total demand for country-i output of good-k is then $\sum_{j=1}^{N} L_j P_{ik} C_{ik} \pi_{jik}$. With labour as the only productive input, total sectoral revenue from all sources - foreign and domestic - equals labour income by sector for each country:

$$w_{ia}L_{ia} = P_{ia}Y_{ia} = \sum_{j=1}^{N}\left[L_j(P_{ja}\bar{a}+\varepsilon_a\tilde{M}_j)\pi_{jia}\right], \tag{8}$$

$$w_{im}L_{im} = P_{im}Y_{im} = \sum_{j=1}^{N}\left[L_j\varepsilon_m\tilde{M}_j\pi_{jim}\right], \tag{9}$$

$$w_{is}L_{is} = P_{is}Y_{is} = \varepsilon_s\tilde{M}_iL_i. \tag{10}$$

Labour demand by producers of each tradable variety, $L_{ik}(z)$, aggregates to sectoral labour

[22] With non-homothetic preferences and an elasticity of substitution equal to one, structural change is generated through income effects alone. Recent results by Herrendorf et al. (2011) suggest when modeling expenditure categories as final expenditures, income effects and nonhomotheticities match data well. In this paper, expenditure categories are expressed in value-added form. In this case, they argue homothetic preferences used by Ngai and Pissarides (2007), which generate structural change through relative price effects instead of income effects, matches data best. The data requirements to implement the consumption value-added approach, however, limits its use in the cross-country analysis of this paper. One would need to extract the consumption component of each sector's value-added, which requires data on sectoral distribution costs. Detailed input-output data is also required. As a final note, Herrendorf et al. (2011) investigate post-war US data, where agriculture's share of employment never exceeds 10%, and they conclude that future work extending the analysis to a larger set of countries would be of interest.

$L_{ik} = \left[\int_0^1 L_{ik}(z)dz\right]$. Across all sectors, the labour market must clear for each country:

$$\sum_{k\in\{a,m,s\}} L_{ik} \quad = \quad L_i. \tag{11}$$

The input cost distortion is modeled as a barrier to labour movement from agriculture to nonagriculture. Specifically, I consider a labour market barrier identical to Restuccia et al. (2008), where an implicit tax of ξ_i is levied on any farm worker in country-i who switches to a nonagricultural activity. Consequently, equilibrium sectoral wages will be $w_{ia} = \xi_i w_i$ and $w_{im} = w_{is} = w_i$.[23]

The sectoral revenue and labour earnings conditions imply international trade balances for each country. Specifically, combine Equations 8 to 10 with labour market clearing Equation 11 and $\tilde{M}_i + P_{ia}\bar{a} = \left(\sum_{k\in\{a,m,s\}} w_{ik}\frac{L_{ik}}{L_i}\right)$ to yield

$$L_i(P_{ia}\bar{a} + (\varepsilon_a + \varepsilon_m)\tilde{M}_i) \quad = \quad \sum_{j=1}^{N} L_j[(P_{ja}\bar{a} + \varepsilon_a\tilde{M}_j)\pi_{jia} + \varepsilon_m\tilde{M}_j\pi_{jim}]. \tag{12}$$

Country-i appears on both the left and right side, so this equation is identical to imports equaling exports. Alternatively, this condition states that total spending on tradable goods by country-i consumers will equal total global spending on tradable goods produced by country-i firms.[24]

4.1.2 Equilibrium Definition

A competitive equilibrium in this framework is a set of prices $\{P_{ia}, P_{im}, P_{is}\}_{i=1}^N$, wages $\{w_i\}_{i=1}^N$, consumption allocations $\{C_{ia}, C_{im}, C_{is}\}_{i=1}^N$ and labour allocations $\{L_{ia}, L_{im}, L_{is}\}_{i=1}^N$ such that (1) given prices and wages, households solve Equation 6; (2) given wages, price aggregates are consistent with Equation 2; (3) given wages, prices, and labour allocations, international trade balances through Equation 12; and (4) labour markets clear through Equation 11.

[23]The revenue from this tax is destroyed. However, since it applies to switching sectors and there is no incentive for agents to deviate from equilibrium allocations, there will be no tax revenue in equilibrium.

[24]More generally, countries with current account deficits would have higher estimated wages, increasing the estimated productivity dispersion if rich countries have current account deficits. For poor countries, the impact will be negligible, given their low import shares. Dekle et al. (2007) finds most wage estimates under imbalanced trade are within 10% of the balanced-trade case.

4.1.3 Calibration of the Full Model

The model parameters are calibrated either to reflect generally accepted values in the literature, to match trade and productivity patterns, or so the model matches other key moments in the data. I describe the calibration of each parameter in the following paragraphs. The various model parameters, their values, and calibration targets, are listed in Table 2. See Figure 3 for a comparison between the model outcomes and data.

First, the preference parameters are set to $\varepsilon_a = 0.01$, $\varepsilon_m = 0.24$, and $\varepsilon_s = 0.75$ (as in Caselli and Coleman, 2001). These parameters govern the equilibrium labour shares as a country's level of income grows large. Next, the Frechet dispersion parameters are set to $\theta_a = \theta_m = 7$, as before. Total employment is inferred from PWT6.3 as the ratio of total GDP to GDP/Worker.

To match trade and productivity data, competitiveness (T_{ik}) and trade costs (τ_{ijk}) are determined through the bilateral trade regression of Section 3.1. With these, prices are determined from Equation 2 and trade shares from Equation 3. Given prices and trade shares, international disposable income levels $\tilde{M}_i$ are selected to balance trade in Equation 12. Given income and prices, wages and labour allocations are determined through Equations 8 and 10. The product of competitiveness and wages, as before, pins down sectoral technology parameters (A_{ik}) in the tradable sectors. I set service sector labour productivity, A_{is}, so the model implied aggregate labour productivity matches data.[25] Finally, each country's labour market distortion, ξ_i, is adjusted so agriculture's labour productivity relative to nonagriculture matches data. Productivity implied by the model calibrated in this way reflect the data well.

The remaining parameter, food's subsistence consumption level $\bar{a}$, is set to 0.0025 to match agriculture's share of employment among the poorest economies. This parameter is an important driver of agriculture's high employment and spending shares in low income countries; households, after all, need to exceed the minimum food requirement. This implies an average value of subsistence spending, $P_a\bar{a}$, of nearly 30% of aggregate expenditures for the poorest countries and less

[25] Aggregate productivity is PPP adjusted, with details of this procedure provided in Appendix A. Wage levels and labour allocations are independent of service-sector labour productivity. They depend only on trade balance and household expenditure patterns.

than 0.5% among the richest. For comparison, Hoyos and Lessem (2008) report food expenditure shares of approximately two-thirds in the poorest countries. Although this estimate captures food spending broadly (including processing and services components), rather than spending on agricultural goods directly. For the United States in 1880, Caselli and Coleman (2001) find one-third of spending on raw agricultural goods consumption.

4.2 Results of Various Counterfactual Exercises

The trade cost estimates backed-out from the model represent a black box. A host of trading difficulties exist for poor countries that increase trade costs: explicit tariffs, non-tariff barriers, contracting costs and insecurity, information gathering costs, currency controls, local content regulations, or health regulations in the case of food. These quantitative exercises remain agnostic about the ultimate cause of the trade and input market distortions but serve to illustrate the importance for cross-country productivity differences of future research investigating these areas. Results for each exercise are provided in Table 4. Results are listed with and without the input cost distortion, although the former case will be the focus.

Lower Importer Barriers to Rich-Country Level

Importer-specific barriers to trade are expressed only relative to other countries. Since there are no particular levels, the first experiment sets all barriers – whatever they may be – to the average of the richest-10% of countries: $\tilde{\tau}_{ija} = \delta_{ija} min(B_{ia}, E\left[B_{ia}|y_i \geq y^{90^{th}}\right])$, where $y^{90^{th}}$ is the 90^{th}-percentile of GDP per capita. Importer barriers are significantly higher in poor countries and this experiment lowers those barriers, on average, by just over 70 percentage points. In response, households in poor countries allocate a significantly higher share of spending to imports, from 2% of spending to over 60%. This facilitates a decline in agriculture's share of employment by over 16 percentage points, to 57%. Aggregate labour productivity rises by 58%, lowering the gap between the richest and poorest countries from 32 to almost 20.

Remove WTO Tariffs

As a more policy-relevant exercise, I also quantify the model's predicted change in productivity from lowering agricultural trade costs by the tariff rates reported by the WTO. On average, poorer countries have tariffs on the order of 20% for agricultural imports under MFN and with over 80% bound rates. Counterfactual trade flows and labour allocations when $\tilde{\tau}_{ija} = \tau_{ija}/(1+tariff_{ia})$ lead to significant gains, even when using MFN rates. While the bound rate may not actually be applied, as it is just the permitted limit under WTO rules for each country, variation in rates across product categories may lead to degrees of trade restrictiveness larger than MFN rates alone would suggest (Kee et al., 2008, 2009). Moreover, non-tariff barriers such as quotas, border wait times, and other factors, increase restrictiveness further still. I thus consider the bound rate to illustrate the effect of a broader indicator of trade barriers. Following removal of tariffs, agriculture's employment share declines by nearly ten percentage points. Aggregate labour productivity in the poorest countries grows by nearly one-third and the rich-poor gap falls to 25.

Other Counterfactuals

The estimated total agricultural trade cost (τ_{ija}) between the United States and Chile, for example, are 24% when the US is the importer but are 147% when Chile is the importer. The differences are less extreme between developed countries but is still present. Imports by Canada from the US face an estimated 14% cost while the reverse flow faces less than 3% costs. Whatever the source of these differences may be, harmonizing trade policies between countries may result in substantial gains. Following Waugh (2010), who investigates trade cost asymmetries exhaustively, I simulate the model using the minimum trade cost each trade partner: $\tilde{\tau}_{ija} = min(\tau_{ija}, \tau_{jia})$. The effect on productivity is dramatic, with the poorest countries more than doubling average labour productivity and reducing the rich-poor gap to almost 15.

The final liberalization experiment involves completely frictionless trade between countries. This would remove from the model all sources of trade frictions, including distance, resulting in $\tilde{\tau}_{ija} = 1$ for all (i, j). This is clearly not an achievable policy goal but illustrates the behaviour of the model and the magnitude of the greatest possible gains in this framework. The share of employment in agriculture falls to less than half, lowering the gap between the rich and poor countries from 32 to 14.

5 Conclusion

This paper examines the relationship between the international food trade and differences in aggregate labour productivity between rich and poor countries. A large literature finds labour productivity differences within the agricultural sector, where most developing country employment concentrates, accounts for nearly the entire productivity gap. Agricultural productivity in the poorest countries is seventy times lower than in the richest but nonagricultural productivity is only seven times lower. If one were to consider trade flows implied by these productivity data alone, the prediction is clear: developing countries should be massive importers of food. This is in stark contrast to data, where the share of food spending imported by the richest countries is an order of magnitude larger than for the poorest countries. Existing studies abstract from this puzzle and focus explaining productivity differences within closed-economy frameworks. Instead, I describe and exploit a general equilibrium model of international trade to reconcile the productivity data with observed trade patterns.

I find two distortions can lower imports in poor countries despite their low relative agricultural productivity: (1) high import barriers and (2) low relative input costs (wages) in agriculture. Trade barriers increase import prices and low farm wages decrease domestic food prices. Both distortions lead consumers to opt for lower productivity domestic producers. With lower import costs, some low productivity domestic producers exit and the resulting labour reallocation increases aggregate productivity in poor countries. I quantify this effect of distortions on cross-country aggregate productivity differences and find they are large. Future research to uncover the underlying cause of these distortions would provide much insight about international income and productivity differences.

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Table 1: Cross-Country Productivity, Employment, and Trade Data

(a) Summary Statistics from Data

GDP / Capita Percentiles	Value-Added per Worker		Relative Agricultural Productivity	Agriculture's Employment Share	Home Bias (π_{iik})	
	Agriculture	Nonagriculture			Agriculture	Nonagriculture
<10th	276	8,658	0.05	0.77	0.98	0.80
<25th	476	11,045	0.08	0.69	0.97	0.81
25th-50th	1,106	14,690	0.11	0.41	0.92	0.82
50th-75th	3,145	21,063	0.17	0.21	0.89	0.71
>75th	11,002	44,017	0.24	0.08	0.59	0.49
>90th	19,161	55,372	0.35	0.04	0.43	0.42

(b) Inferred Technology and Cost Parameters

GDP / Capita Percentiles	Autarky Productivity (A_{ik})		Implied Input Costs (w_{ik})		Relative Agricultural Input Costs	Trade Costs ($\bar{\tau}_{ik}$), %	
	Agriculture	Nonagriculture	Agriculture	Nonagriculture		Agriculture	Nonagriculture
<10th	276	8,398	321	8,403	0.06	334	386
<25th	474	10,759	550	10,002	0.11	315	323
25th-50th	1,088	14,224	1,193	11,321	0.15	230	261
50th-75th	3,085	19,976	3,199	14,083	0.27	204	228
>75th	9,903	38,875	7,975	21,270	0.43	123	124
>90th	16,799	48,205	11,691	20,909	0.64	100	89

Reports cross-country simple averages within each aggregate GDP/Capita categories for 138 countries. Value-added per worker calculations are PPP adjusted using FAO and PWT6.3 data for 2000. Share of employment in agriculture from FAO data, also for 2000. Calculations follow Caselli (2005) and Restuccia et al. (2008). Home bias represents domestic purchases relative to domestic absorption, by sector. Trade costs are trade-weighted average across export partners. Details in text.

Table 2: Model Calibration and Baseline Fit

(a) Values for Common Model Parameters

Parameters	Target	Value
$\{\theta_a, \theta_m\}$	Cost-Elasticity of Trade Flows	$\{7, 7\}$
$\{\varepsilon_s, \varepsilon_m, \varepsilon_a\}$	Long-Run US Employment Shares	$\{0.75, 0.24, 0.01\}$
$\bar{a}$	Sectoral Employment Data (Panel C)	0.0025

(b) Mean Values for Selected GDP/Worker Deciles

	Model		Data	
	Lowest Decile	Highest Decile	Lowest Decile	Highest Decile
Employment (millions), L_i	7.76	27.89	7.76	27.89
*Relative Ag Wages, ξ_i	0.17	0.40	0.32	0.73
Agricultural Import Costs, $\hat{B}_{ia}$	28%	-44%		
Manufacturing Import Costs, $\hat{B}_{im}$	30%	-36%		
Agricultural Competitiveness, $\hat{T}_{ia}$	0.87	1.29		
Manufacturing Competitiveness, $\hat{T}_{im}$	1.01	2.46		

(c) Sectoral Employment Shares, Model and Data

	Model		Data	
	Lowest Decile	Highest Decile	Lowest Decile	Highest Decile
Employment Shares				
Agriculture†	0.74	0.05	0.76	0.04
Manufacturing	0.06	0.23	0.06	0.29
Services	0.20	0.72	0.18	0.67

Lists calibrated model parameters, their targets, and values. Summarizes various moments of the model's output compared to data. The importer-specific costs (B_{ik}) are expressed relative to the average country. $*$ denotes only limited data available for comparison: 3 countries with ILO wage data within lowest decile and 5 countries within highest. † denotes fitted to approach the typical share in poor countries, conditional on all countries being within [0,1].

Table 3: Main Estimation Results

	Agriculture	Manufacturing
	(1)	(2)
Ln(Distance)	-1.040	-1.384
	(0.029)***	(0.023)***
Shared Border	0.577	0.451
	(0.104)***	(0.097)***
Shared Language	0.66	0.586
	(0.061)***	(0.052)***
Trade Agreement	0.348	-.287
	(0.123)***	(0.122)**
Exporter FEs	Yes	Yes
Importer FEs	Yes	Yes
Observations	6235	9172
R^2	0.971	0.971

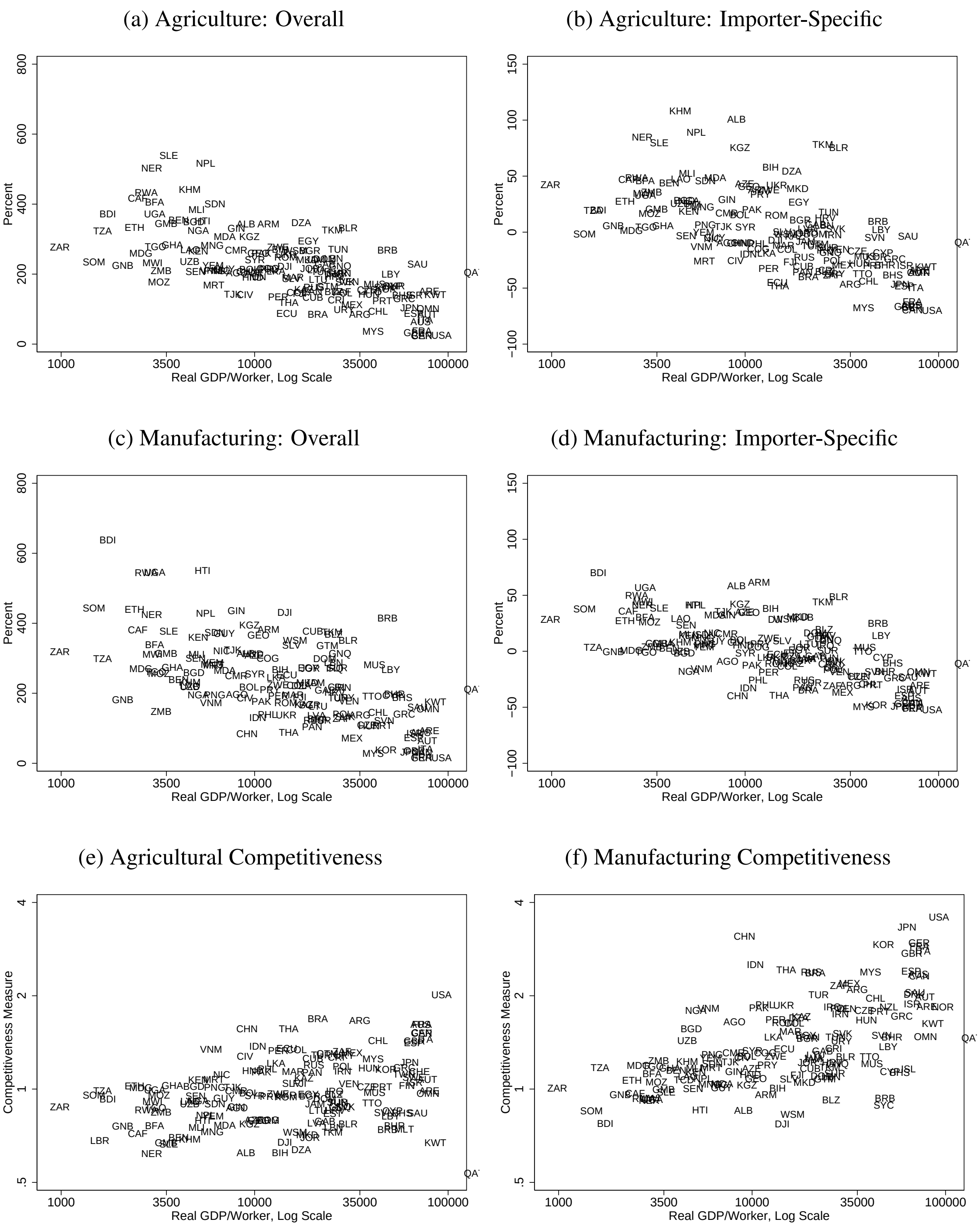
The OLS esimates of Equation 4. The dependent variable is the normalized import share, for importer-exporter pairs from the NBER-UN trade database, for each traded sector. Data on distance, borders, and language from CEPII; trade agreement indicator from Fieler (2010).

Table 4: Quantitative Evaluation of Agricultural Trade Costs and Sectoral Wage Differences

		Aggregate Labour Productivity Richest/Poorest 10%	Agriculture's Share of Total Employment in Poorest 10%	Average % Change in Aggregate Productivity of Poorest 10%
	Baseline (Data)	32.9 (32.9)	0.74 (0.76)	-
Counterfactual Scenarios, Holding Sectoral Wage Wedge Fixed				
(1)	Lower Import Costs	20.6	0.57	58%
(2)	Symmetric Trade Cost	15.1	0.40	114%
(3)	Remove WTO Tariffs	25.1	0.65	31%
(4)	Frictionless Trade	14.2	0.44	138%
Counterfactual Scenarios, Removing Sectoral Wage Wedge				
(5)	Remove Sectoral Wedge	12.5	0.28	184%
(6)	Lower Import Costs	9.8	0.13	256%
(7)	Symmetric Trade Cost	9.4	0.08	277%
(8)	Remove WTO Tariffs	10.5	0.16	238%
(9)	Frictionless Trade	8.5	0.05	322%

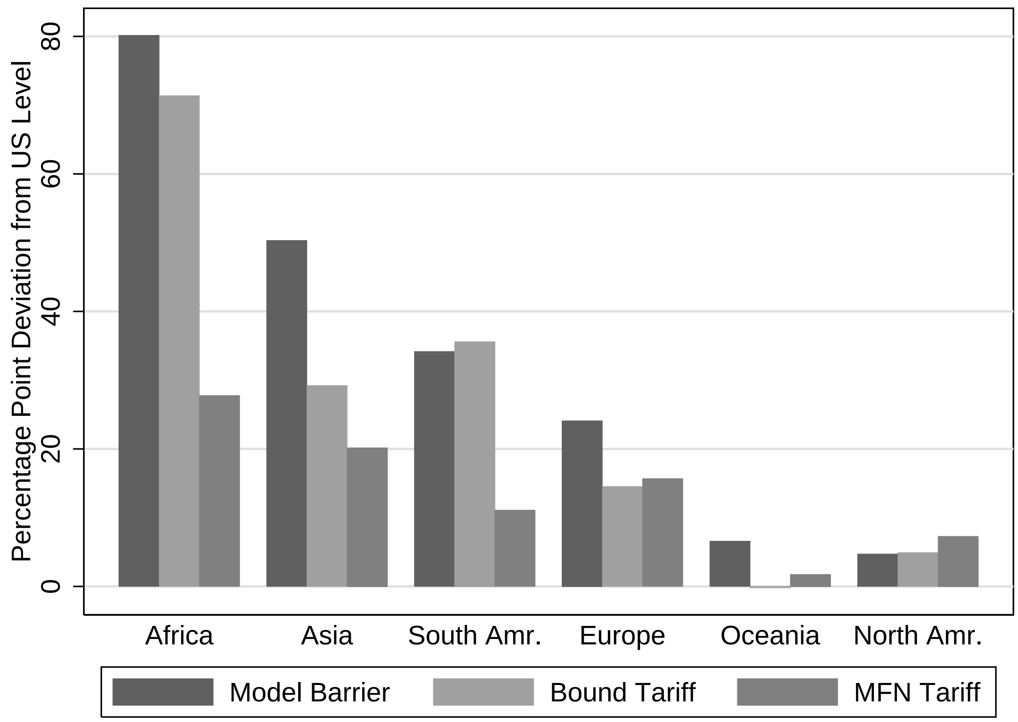
Displays the difference in average aggregate labour productivity among the richest 10% of countries relative to the poorest under various counterfactual experiments. The average share of employment and the average percentage change in aggregate labour productivity among the poorest countries is also reported. Experiments adjust agricultural trade costs parameters only. The top panel holds the labour market barrier (ξ_i)fixed while the lower panel allows wage equalization across sectors ($\xi_i = 1$ for all i).

Figure 1: Trade Cost Estimates for Agricultural Goods



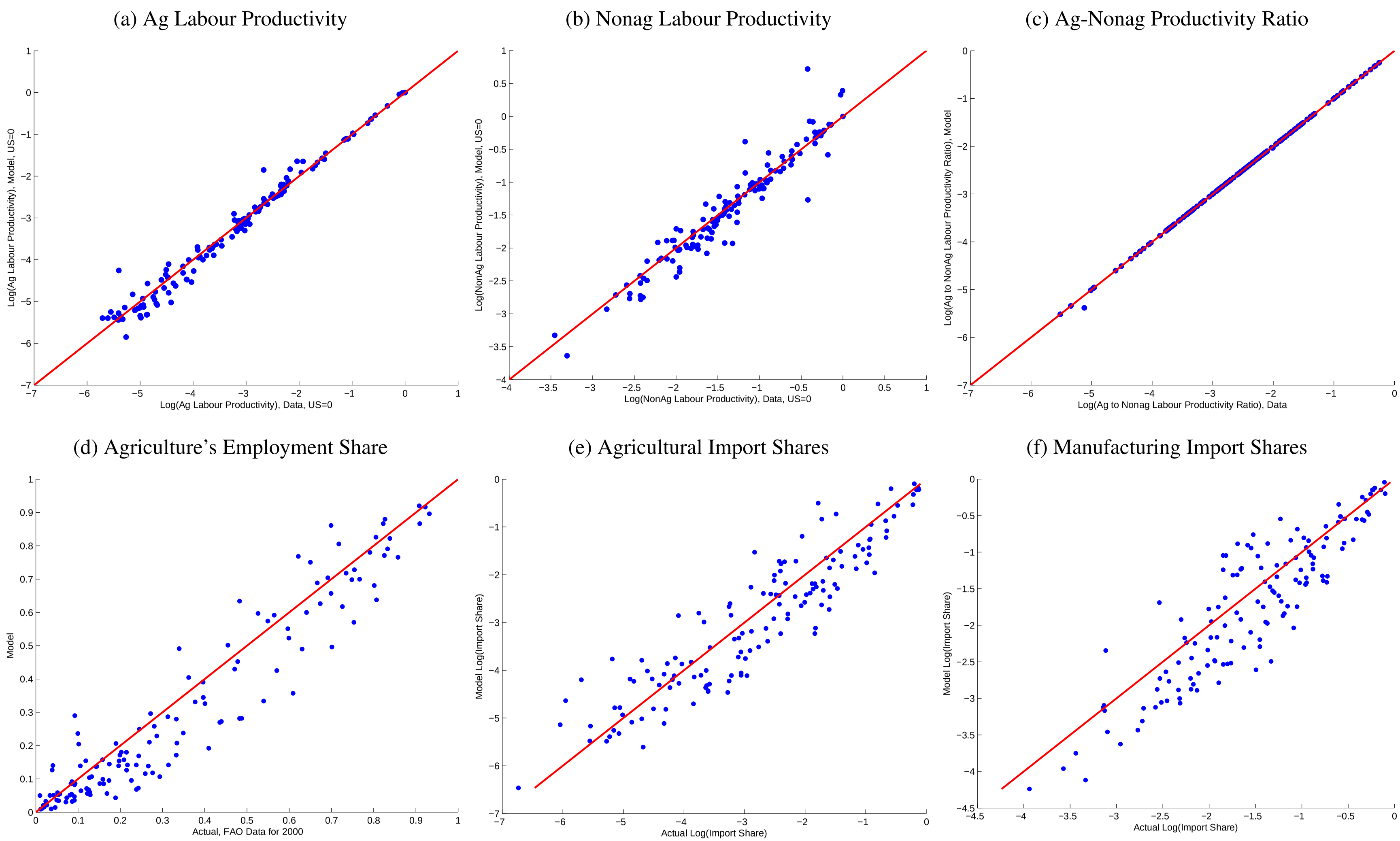
Displays trade costs and competitiveness (productivity to input cost ratios) measures implied by a regression of normalized trade shares on measures of bilateral trade costs and separate importer and exporter fixed effects. Details regarding the mapping of fixed effects to trade costs and competitiveness can be found in section 3.1. The reported overall trade costs are a trade-weighted average total trade cost between each importing country and the export partners.

Figure 2: Model Import Barrier Compared to WTO Tariff Data



Compares WTO tariff data (both bound and MFN rates on agricultural goods for 2007) to estimated importer-specific barriers for various geographic regions. For comparability, levels are plotted as percentage point differences with the United States level. Values are GDP-weighted across countries within each continent (trade-weighting yields similar patterns). Africa displays 80 percentage points higher import barriers than the United States, 71 percentage points higher bound tariff rates, and 28 percentage points higher MFN tariff rates.

Figure 3: Comparing Baseline Model to Data



Provides a comparison of model output to data. Sectoral labour productivities, employment, and trade patterns closely match. Imperfect matches for relative agricultural labour productivity are Djibouti and Iraq.

Appendix A: PPP Adjustments for Cross Country Comparisons

I construct PPP-adjusted aggregate productivity in the model following similar procedures as in the data. Given the three-sector structure of the model, PPP-adjusted GDP/Worker is total nominal consumer expenditures deflated by a country-specific Geary-Khamis price index. This procedure follows the World Bank's International Comparisons Program and represents how Penn-World Table measures of GDP/Worker comparable across countries would be constructed in a world with only three goods (Heston et al., 2009). To begin, find international prices of each good-k and purchasing power parities for each country-i that solve the following system:

$$\begin{aligned} IP_k &= \sum_{i=1}^{N} \frac{P_{ik}}{PPP_i} \gamma_{ik}, \\ PPP_i &= \frac{\sum_{k \in \{a,m,s\}} L_i P_{ik} C_{ik}}{\sum_{k \in \{a,m,s\}} IP_k C_{ik}}. \end{aligned}$$

PPP_i is country-i's purchasing power parity exchange rate and $\gamma_{ik} = \frac{L_i C_{ik}}{\sum_{j=1}^{N} L_j C_{jk}}$ is a quantity (of total consumption) weight for country-i and good-k. The common set of international prices to value consumption is essentially a weighted-average of goods prices across countries. The model's PPP-adjusted GDP/Worker for country-i is then $Y_i/L_i = PPP_i^{-1} \sum_{k \in \{a,m,s\}} P_{ik} C_{ik}$.

Unfortunately, the model is unable to analytically produce PPP-adjusted estimates of sectoral labour productivity since individual variety producer-prices and production quantities are unknown. To provide proper comparisons with data, I simulate the model on a set of 25,000 products for each sector and country. Within the simulation, I track individual producer prices and quantities to construct PPP adjustment-factors following the World Bank procedures. Overall, productivity estimates from Equation 5, rescaled by each sector's international price (IP_k), match appropriate PPP-adjusted estimates very well. Overall, the correlation between the two measures are 0.997 in agriculture and 0.987 in manufacturing.

Appendix B: A Flexible Measure of Cross-Country Trade Costs

New micro-founded international trade models imply similar gravity relationships between bilateral trade flows. Equivalent gravity relationships hold under Armington assumptions, such as in Anderson and van Wincoop (2003); monopolistic competition, as in Redding and Venables (2004); heterogeneous firm-level models, such as Melitz (2003); Melitz and Ottaviano (2008) and Chaney (2008); or Ricardian models, as in Eaton and Kortum (2002). These theories yield trade relationships that depend on trade costs and source- and destination-specific characteristics. Novy (2011) demonstrates a certain manipulation of *any* of these can reduce to a measure of trade costs between the pair. Specifically,

$$\tau_{ij} = \left(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}}\right)^{\frac{1}{2}} - 1 \quad = \quad \left(\frac{\pi_{iik}\pi_{jjk}}{\pi_{ijk}\pi_{jik}}\right)^{\frac{1}{2\theta}} - 1, \tag{13}$$

where τ_{ijk} is the geometric average between-country trade cost for sector-k, π_{ijk} is the fraction of consumption sourced from abroad, π_{iik} is the fraction of consumption sourced domestically, and θ is the (negative) cost-elasticity of trade. For $i = j$, $\tau_{ijk} = 0$, which means this measure of trade costs is net of internal distribution costs. I present two results in Table 5: (1) trade costs for imports from the US and (2) trade-weighted average trade cost across all exporters. The poorest countries have substantially higher trade costs than the richest in either case. This exercise supports the conclusions of the main paper and demonstrates the results are not driven by the underlying Eaton-Kortum structure.

Table 5: Alternative Trade Cost Estimates, by Importer Income Categories

GDP / Capita	USA as Export Partner (τ_{ik}), %		Across All Exporters ($\bar{\tau}_{ik}$), %	
Percentiles	Agriculture	Nonagriculture	Agriculture	Nonagriculture
<25th	193	90	179	142
25th-50th	131	102	148	92
50th-75th	172	128	133	103
>75th	104	73	77	47

Trade costs using flexible method proposed by Novy (2011). Trade-weighted average across all exporters.

Appendix C: Sample Countries

Table 6: Selected Data and Estimates for 138 Country Sample

	GDP/Worker			Agr Labour	Import Share		Agr Import	Relative Agr
Country	Aggregate	Agr	Nonagr	Share	Agr	Nonagr	Barrier	Input Costs
Angola	6685	234	21251	.72	.15	.09	-11	.02
Albania	7590	741	12065	.48	.04	.32	100	.09
United Arab Emirates	66577	8949	58044	.05	.39	.58	-35	.30
Argentina	28930	13647	27043	.09	.08	.18	-48	.65
Armenia	9728	1898	9182	.13	.01	.06	36	.25
Australia	60073	35843	49964	.05	.31	.46	-66	1.08
Austria	65357	12652	59488	.05	.59	.79	-37	.44
Azerbaijan	8345	1015	9675	.27	.05	.07	42	.15
Burundi	1485	166	12826	.91	0	.04	19	.01
Benin	3374	652	6075	.54	.05	.48	43	.19
Burkina Faso	2550	194	27569	.92	.01	.08	45	.01
Bangladesh	4014	283	7776	.55	.01	.08	27	.06
Bulgaria	15948	8358	14385	.07	.04	.41	10	.98
Bahrain	43884	4407	37136	.01	.62	.38	-30	.21
Bahamas	48276	2346	44219	.04	.56	.79	-39	.08
Bosnia Herzg	11547	3866	9038	.05	.13	.29	57	.71
Belarus	25513	3270	23044	.13	.01	.03	74	.23
Belize	21620	3590	27295	.27	.17	.22	-36	.13
Bolivia	7834	881	11106	.44	.05	.13	15	.11
Brazil	17661	3666	17996	.16	.05	.15	-41	.29
Barbados	40507	3969	36887	.04	.12	.19	9	.14
Cent.Afr.Rep	2078	366	6235	.73	.01	.11	46	.08
Canada	60727	37784	51823	.02	.82	.9	-71	1.2
China	7559	454	19417	.67	.01	.1	-11	.05
Chile	36284	3828	33103	.16	.16	.23	-45	.16
Cote Divoire	7601	1066	9495	.49	.05	.26	-27	.12
Cameroon	6600	506	14253	.6	.02	.1	16	.05
Congo	9619	310	9286	.4	.23	.1	-16	.05
Colombia	13745	1754	14363	.2	.05	.15	-16	.15
Costa Rica	22434	3848	25056	.2	.08	.25	-35	.17
Cuba	16589	2608	16612	.14	.1	.04	-32	.15
Cyprus	43011	7347	40923	.09	.39	.7	-20	.27
Czech Rep	31778	5649	28833	.08	.22	.55	-18	.37
Djibouti	12321	207	44980	.78	.4	.48	-8	.01
Dominican Rp	18871	1782	19656	.16	.06	.17	-3	.12
Algeria	14551	801	14563	.25	.18	.12	53	.14
Ecuador	12178	2032	13557	.24	.19	.16	-46	.15
Egypt	15740	1528	19295	.31	.03	.11	26	.12
Spain	55540	13156	50242	.07	.31	.48	-49	.47
Ethiopia	2002	147	9785	.82	0	.08	27	.02
Fiji	14814	994	21113	.4	.11	.46	-28	.05
France,Monac	61216	28659	54622	.03	.52	.81	-63	1.08
Gabon	19199	675	23129	.38	.15	.3	6	.05
UK	55386	21165	49188	.02	.81	.71	-67	.79
Georgia	8630	1136	9597	.2	.03	.08	40	.17
Germany	60376	20958	53825	.03	.8	.77	-68	.75
Ghana	3110	527	6041	.57	.02	.24	5	.10

Guinea	6818	244	36793	.84	.01	.04	28	.01
Gambia	2867	179	11260	.79	.09	.4	20	.03
GuineaBissau	1723	305	9293	.83	.08	.66	5	.05
Eq.Guinea	22700	180	44889	.7	.06	.1	-19	.01
Greece	48963	6984	49021	.17	.2	.47	-25	.22
Guatemala	19613	1046	32324	.47	.02	.16	-12	.03
Guyana	5755	3191	5129	.17	.07	.21	-6	.70
Honduras	8107	1002	10439	.31	.02	.21	-10	.10
Croatia	21564	4099	19705	.08	.13	.41	12	.31
Haiti	4605	286	11321	.64	.03	.08	24	.03
Hungary	32282	7652	30525	.11	.15	.75	-29	.43
Indonesia	8828	441	15539	.48	.02	.09	-21	.05
Iran	24279	1946	24326	.27	.04	.1	-3	.12
Iraq	21998	2773	21209	.09	.08	.02	-17	.24
Israel	57197	19734	52593	.03	.39	.76	-31	.77
Italy	65439	14886	59187	.05	.37	.56	-51	.51
Jamaica	17164	1243	18673	.21	.1	.35	-9	.10
Jordan	16174	3327	15288	.09	.51	.33	-2	.36
Japan	53166	4029	48953	.04	.43	.39	-48	.22
Kazakhstan	15066	2390	15683	.17	.04	.13	-4	.24
Kenya	4259	258	14958	.75	.01	.13	18	.02
Kyrgyzstan	7831	1822	8910	.26	.01	.07	74	.28
Cambodia	3811	275	10568	.7	.01	.3	107	.05
Korea Rep.	39495	2780	39525	.1	.16	.54	-23	.19
Kuwait	70895	5829	47809	.01	.88	.4	-32	.24
Lao P.Dem.R	3883	354	13477	.77	.01	.23	47	.03
Lebanon	21466	15169	19538	.04	.24	.39	5	1.17
Libya	42502	4569	28082	.06	.22	.11	1	.27
Sri Lanka	10848	403	16696	.45	.02	.17	-20	.03
Lithuania	17925	3966	16695	.12	.18	.48	-1	.38
Latvia	17569	2567	16921	.12	.25	.72	2	.28
Morocco	13006	832	16445	.33	.07	.26	-13	.07
Rep Moldova	5778	2031	6059	.23	.02	.29	48	.49
Madagascar	2116	268	6546	.75	.02	.25	0	.05
Mexico	26380	1933	28791	.22	.18	.64	-30	.13
TFYR Macedna	15400	4075	15240	.13	.1	.35	38	.42
Mali	4272	484	18249	.81	.02	.14	51	.04
Mongolia	4949	2116	4502	.24	.04	.41	22	.72
Mozambique	2644	133	13232	.83	.03	.14	16	.01
Mauritania	5090	438	8876	.53	.09	.23	-27	.06
Mauritius	34345	2064	37244	.12	.16	.21	-22	.07
Malawi	2471	288	11628	.83	.01	.15	33	.04
Malaysia	33879	2979	33614	.19	.88	.9	-68	.17
Niger	2440	309	13411	.86	.01	.14	84	.03
Nigeria	4234	1259	5310	.33	.03	.17	27	.48
Nicaragua	5743	1640	6287	.21	.02	.19	-7	.25
Nepal	4680	274	57178	.93	0	.05	88	.01
Oman	64534	462	66647	.36	.52	.57	-37	.01
Pakistan	9059	1082	14129	.44	.01	.11	19	.13
Panama	16516	1717	16850	.2	.13	.86	-37	.17
Peru	11026	1098	12805	.29	.09	.18	-34	.11
Philippines	9777	607	14645	.4	.05	.38	-11	.07
Papua N.Guin	5148	711	16601	.75	.03	.22	5	.06
Poland	23814	2522	25930	.22	.14	.34	-26	.16
Portugal	38223	3454	37328	.13	.4	.58	-31	.17

Paraguay	10001	2134	12034	.29	.04	.28	33	.24
Qatar	113492	5208	68186	.01	.85	.31	-10	.17
Romania	11893	2454	11404	.15	.05	.27	14	.39
Russian Fed	16792	2799	16571	.11	.09	.1	-23	.34
Rwanda	2255	270	19244	.91	0	.04	48	.02
Saudi Arabia	57898	1585	45930	.1	.23	.2	-4	.08
Sudan	5176	647	9691	.61	.01	.08	45	.09
Senegal	4128	247	13776	.73	.08	.25	-4	.02
Sierra Leone	3027	155	7448	.65	.01	.11	79	.03
El Salvador	13053	812	16109	.28	.04	.16	-1	.05
Somalia	1216	re462	2510	.7	.03	.14	-3	.17
Suriname	22195	1744	22620	.19	.09	.28	-15	.10
Slovakia	24525	3840	23415	.09	.2	.56	2	.31
Slovenia	38960	22798	33874	.02	.35	.73	-6	1.37
Syria	8355	2809	7572	.24	.06	.24	4	.53
Togo	2545	346	5330	.6	.04	.39	4	.09
Thailand	12530	606	25397	.56	.07	.36	-49	.04
Tajikistan	6530	794	8284	.34	.02	.03	4	.12
Turkmenistan	20912	1675	26550	.33	.01	.04	77	.10
Trinidad Tbg	33821	1602	27730	.09	.45	.25	-38	.08
Tunisia	22506	1968	26247	.24	.06	.36	17	.13
Turkey	18381	1942	26020	.41	.03	.34	-13	.12
Tanzania	1376	187	6025	.81	.01	.19	18	.04
Uganda	2520	372	9670	.8	0	.05	32	.04
Ukraine	12088	2858	11380	.14	.01	.12	41	.50
Uruguay	24084	8717	23903	.13	.18	.29	-38	.42
USA	77003	39975	68507	.02	.33	.42	-71	1.07
Uzbekistan	3858	1681	4041	.28	.01	.16	25	.68
Venezuela	25604	4264	19289	.08	.16	.18	-16	.39
Viet Nam	4915	424	12483	.67	.01	.16	-14	.05
Samoa	13191	944	17518	.35	.09	.27	-3	.06
Yemen	5050	360	8309	.48	.2	.16	-1	.07
South Africa	23750	4284	22391	.09	.1	.23	-39	.32
Dem.Rp.Congo	823	180	2165	.62	.01	.16	41	.10
Zambia	2730	202	6554	.69	.01	.34	35	.05
Zimbabwe	10903	458	17662	.63	0	.12	37	.04