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The Missing Food Problem: How Low Agricultural Imports Contribute to International Income and Productivity Differences

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Abstract

This paper finds an important relationship between the international food trade and cross-country income and productivity differences. Poor countries have low labour productivity in agriculture relative to other sectors, yet predominantly consume domestically-produced food. To understand these observations, I describe and exploit a general equilibrium model of international trade to: (1) measure sectoral productivity and trade costs across countries; and (2) quantify the impact of low poor-country food imports on international income and productivity gaps. Specifically, I expand on Yi and Zhang [2010] and modify an Eaton-Kortum trade model to incorporate multiple sectors, non-homothetic preferences, and labour mobility costs. With this model, I estimate PPP-adjusted productivity from observed bilateral trade data, avoiding problematic price and employment data in poor countries that direct output-per-worker estimates require. I find reasonable trade barriers and labour mobility costs account for the low poor-country imports despite their low productivity. Through various counterfactual experiments, I quantify how easing import barriers and labour mobility costs increases imports and *within*-agriculture specialization, shuts down low productivity domestic food producers, and lowers the gap between rich and poor countries. I also find an interaction between domestic labour-market distortions and trade barriers not found in the existing dual-economy literature, which largely abstracts from open-economy considerations. Overall, I account for one-third of the aggregate labour productivity gap between rich and poor countries and for nearly half the gap in agriculture.

JEL Classification: F1, F41, O11

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1 Introduction

The difference in agricultural labour productivity between rich and poor countries is large and accounts for most of the aggregate income and productivity gap.[1] Average labour productivity in agriculture, for example, differ nearly by a factor of 70 between the poorest- and richest-10% of countries, but by only 6 in nonagriculture.[2] Differences within agriculture drive differences in aggregate, since agriculture accounts for most employment and spending in poor countries (see Figures 1a and 1b), and Schultz [1953] calls this the Food Problem. Despite these productivity differences, Figure 2 shows the food import share of GDP rises with income, implying poor countries do not generally substitute imports for low productivity domestic producers.[3] This motivates existing literature to abstract from open-economy considerations and focus on domestic distortions within closed-economy frameworks to understand agricultural productivity gaps. I depart from this approach and show limited food imports itself inhibits structural change and lowers agricultural productivity in poor countries. There is also a quantitatively important interaction between domestic distortions and trade barriers.[4] Overall, I find limited food imports and labour misallocation account for nearly half the agricultural labour productivity gap between rich and poor countries, and a third of aggregate income and productivity differences.

To demonstrate food imports have a first-order contribution to aggregate productivity gaps between rich and poor countries, I present a trade model consistent with stylized facts of development that builds upon Yi and Zhang [2010].[5] Specifically, I embed an augmented Ricardian trade model into a dual-economy (agriculture vs. nonagriculture) model of structural change. The model incorporates horizontally differentiated and tradable agricultural and manufactured goods, individually structured as in Eaton and Kortum [2002], and a nontradable service-sector. Product differentiation within each tradable sector avoids counterfactual special-

[1] See, for example, 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 [2010], Vollrath [2009], Adamopoulos and Restuccia [2010], Duarte and Restuccia [2010], Lagakos and Waugh [2010].

[2] These results are for 2000 and utilize PPP-adjusted agricultural value added data from the UN-FAO. The aggregate difference in this sample of 173 countries is 35. Restuccia et al. [2008] find similar results: for 86 countries in 1985, the poorest 10% have agricultural labour productivity 56 times lower than the richest 10%, but differ in nonagriculture by only 5. Caselli [2005] finds that equalizing agricultural productivity across countries nearly eliminates all international income differences. Specifically, he finds the 90/10 ratio of aggregate income falls from 19 to 1.9 in a sample of 80 countries.

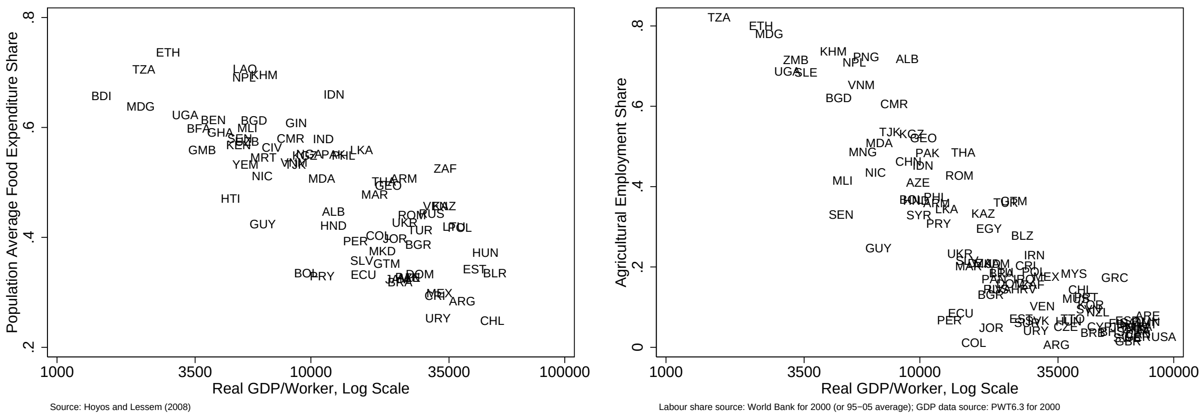
[3] As a fraction of food spending, rich country imports are an order of magnitude larger.

[4] Such interactions have been identified in other literature (see, for example, Kambourov [2009] and Artuc et al. [2010]) but studies accounting for cross-country productivity and income differences typically abstract from such considerations.

[5] Yi and Zhang [2010] develop a multi-sector version of Eaton and Kortum [2002] and clearly link trade and structural transformation. My contribution builds on their stylized treatment by quantitatively applying the framework to cross country. I also incorporate nonhomothetic preferences and labour-market distortions.

Figure 1: The Food Problem in Poor Countries

(a) Food Expenditure Shares, Selected Countries, 2005 (b) Agricultural Employment Shares, by Country



ization patterns found in homogeneous goods frameworks and, importantly, allows for within-sector trade.[6] I exploit the Eaton-Kortum structure to infer sectoral labour productivity from observable trade data, avoiding data limitations that prevent more direct measures.[7] I also perform counterfactual experiments within the fully calibrated model to highlight the importance of agricultural trade - or lack thereof - in accounting for cross country income and productivity differences.

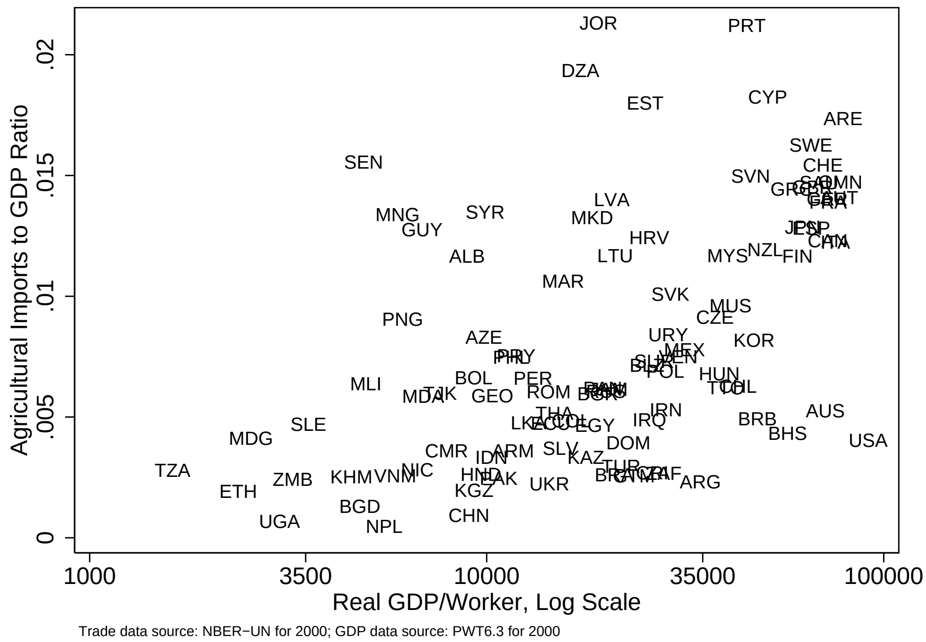
I focus on two distortions that limit food imports: high international trade barriers and costly labour mobility. Trade barriers, such as tariffs, quotas, regulations, or poor infrastructure, increase import prices and lead consumers to opt for lower productivity domestic producers. Costly labour mobility, such as regional migration restrictions or scarce rural education, makes switching to non-agricultural activities difficult for farm labour, thereby increasing farm employment and decreasing farm wages.[8] In fact, wages in agriculture relative to non-agriculture increase strongly with a country's level of development, and differ by a factor of four to five in many poor countries. Low farm wages imply low output prices and consumers - again - opt for lower productivity domestic producers over imports. Without these distortions, increased imports lead low productivity producers to shut down and labour to concentrate in fewer agricultural varieties or switch

[6] Armington models, for instance, imply every country exports to every other country. The Eaton-Kortum structure allows many producers of a product variety but each supplying different parts of the world. Within-sector trade flows are necessary to investigate specialization patterns *within* each sector, which relates sectoral productivity to import flows.

[7] Data limitations lead most studies of cross-country sectoral productivity to focus on developed economies. Rao [1993], Restuccia et al. [2008] are important exceptions, using FAO farm output prices to measure real agricultural productivity across countries.

[8] Vollrath [2009] shows wage gaps do not reflect sectoral differences in physical or human capital endowments. See Caselli and Coleman [2001] for an exploration of the role learning costs play in structural change and, as a follow up, Tombe [2008] for how such costs may interact with transportation costs in a larger set of US states. Cordoba and Ripoll [2006] find schooling or migration costs do not account for the sectoral labour productivity differences, but low *quality* of human capital in rural areas.

Figure 2: Agricultural Import Share of GDP, by Country



to nonagricultural activities.[9] Admittedly, I incorporate both distortions in a simple way and do not address complex political-economy issues to explain *why* these distortions exist, such as balancing pressures between rural and urban residents.

While agnostic about the causes, I can quantify the costs of these distortions independently of implementation and transition issues governments would face. Specifically, I investigate: (1) lowering import barriers everywhere to the average level of the richest countries; (2) eliminating labour mobility costs; and (3) both together. The two distortions have important interaction effects, with trade liberalization and improved labour mobility together driving the largest reductions in cross-country differences. The aggregate productivity gap between the richest- and poorest-10% of countries shrinks by 33% when both distortions are reduced, but only 23% and 7% when import barriers and labour mobility costs are eased individually.[10] These results are particularly important given the literature's focus on domestic distortions alone.

Key to these results are cross-country productivity and trade cost estimates, which I infer from bilateral trade data within the Eaton-Kortum structure of the model. To see how this inference is made, consider the

[9] Existing trade literature consistently finds exporting is associated with a reallocation towards more productive plants is a quantitatively important component of overall productivity growth within the manufacturing sector. See Bernard and Jensen [2001], Pavcnik [2002], Bernard et al. [2006].

[10] Rich and poor countries are the top and bottom deciles of GDP/Capita in 2000.

following features of the global food trade between the 114 countries in my sample.[11] For the bottom quartile of countries, imports account for only 2% of food expenditures while imports are approximately 40% of food spending in the top quartile. Poor countries source half of total food imports from rich countries but very little from other poor countries.[12] Similarly, rich countries source the majority of their total food imports from other rich countries. While I present precise productivity and trade cost estimates from thousands of importer-exporter flows in Section 3.1, the intuition is straightforward. I infer high labour productivity for a country if other countries import a disproportionately high share from that country. I infer high import barriers if overall import shares are below the model's prediction, given a country's productivity.[13]

For concreteness, consider trade between the United Kingdom, Cuba, and Canada. Both the UK and Cuba allocate approximately 1.4% of their food spending to imports from Canada. On the other hand, Canada allocates 1% of its spending to imports from the United Kingdom but only 0.2% to imports from Cuba. The model infers low Cuban productivity from Canada's low share. Given Cuba's low productivity, imports are an attractive alternative to domestic production. In the data, however, Cuba imports a similar share to another - higher productivity - country, the United Kingdom. The model infers high Cuban import costs from Cuba's lower than predicted import share. Overall, I consider over 6,000 trade pairs in agriculture and over 9,000 in manufacturing to estimate that imports costs for the poorest-10% of countries are approximately 43% more in agriculture than the average country, compared to 41% less than average for rich countries.[14] Labour productivity estimates suggest rich countries are over 100 times more productive in agriculture than poor countries, and over 70 times more in manufacturing.[15] Non-tradable services productivity is calibrated so the baseline model aggregate matches data, resulting in a factor of 10 difference between rich and poor.

[11] The precise data used and approach taken to estimate expenditure shares, both domestic and foreign (by source), is similar to Bernard et al. [2003]. I use the NBER-UN Trade Database for the year 2000. I provide details in Section 3.1.

[12] The remaining imports are from the middle-income countries. For more on the low South-South trade levels, see Linder [1961], Markusen [1986], Feenstra [1988], Hunter [1991], Echevarria [2000], Fieler [2010]

[13] The procedure I employ to infer productivity and trade costs from observable trade flows, within the Eaton-Kortum framework, is broadly consistent with a large trade literature that I discuss briefly (see, for example, Eaton and Kortum [2001], Costinot et al. [2010], Levchenko and Zhang [2010], Waugh [2010]. For an alternative mapping of bilateral import share patterns to productivity and trade costs presented by Waugh [2010] will be investigated in Section 6.4

[14] To place the importer-specific fixed effects in context, note that Waugh [2010] finds a -62% fixed-effect for the United States' manufacturing goods trade. My results suggest -76% for manufacturing and -55% in agriculture. Details will follow in Section 3.1. Overall, the trade weighted average import costs across all bilateral trading partners for the 114 countries in my sample is 263% in both agriculture and manufacturing. For rich countries, this number is 104% on average in agriculture and 78% in manufacturing. For comparison, Anderson and van Wincoop [2004] report tariff-equivalent US trade costs of 170%.

[15] Agriculture's relative labour productivity is low in poor countries, consistent cross country productivity comparisons in the macro literature. This does not imply poor countries have comparative advantage in manufacturing, as in a pure Ricardian framework, since labour market distortions lower farm wages. Relative productivity to wages in agriculture is higher in poor countries than rich. This is consistent with a Heckscher-Ohlin interpretation: poor countries are abundant in unskilled labour (or land) used intensively in farming.

Unlike direct estimates, labour productivity inferred from observed trade flows avoids using producer price and labour input data, which are problematic for most developing countries. For certain years, industry-level producer prices among OECD countries are available through the Groningen Growth and Development Centre [Inklaar and Timmer, 2008]. For developing countries, only expenditure prices, not producer prices, are available through the World Bank's International Comparisons Project (ICP). Productivity estimates from expenditure prices will be biased for two reasons: (1) distribution margins are systematically related to a country's level of development [Adamopoulos, 2008]; and (2) expenditure prices capture many manufactured and service components of consumption, such as packaging or preparation. With these limitations in mind, Duarte and Restuccia [2010] study structural change and productivity growth over time in OECD economies with model-implied sectoral productivity estimates; their approach, however, requires accurate employment data. For many developing countries, standard surveys overestimate farm labour since rural residents and farm workers are treated synonymously [Gollin et al., 2004].[16] For these reasons, I estimate productivity revealed through observed bilateral trade patterns.[17]

I contribute to a large international macroeconomics literature on agriculture's role in development.[18] This literature focuses on causes of low agricultural productivity and explanations vary from inefficient farm sizes [Adamopoulos and Restuccia, 2010], poor domestic transportation infrastructure [Adamopoulos, 2010, Gollin and Rogerson, 2010], comparatively low quality farm workers [Lagakos and Waugh, 2010], barriers to labour or intermediate inputs [Restuccia et al., 2008], or just over-counting farm workers in the data [Gollin et al., 2004]. Trade, however, substitutes for the lowest productivity farms to meet subsistence food requirements, increasing average sectoral productivity as they shut-down. My study is not the first to link trade to structural change. Stokey [2001], for example, finds food imports account for the United Kingdom's reduction in agricultural output between 1780 and 1850, and for much of the increased manufacturing. More recently, Teignier [2010] demonstrates a similar pattern for South Korea since the 1960s, although agricultural subsidies and tariff protection limited reallocation and subsequent productivity growth. Rather than investigate time series growth patterns as in these papers, I quantify to what extent the lack of food

[16] Brandt et al. [2008] and Brandt and Zhu [2010], for example, use household-level surveys to infer a 26% agricultural labour share in 2007 rather than the official figure of 41%, when considering hours spent on farm work. Moreover, Gollin and Rogerson [2010] report that even in extremely poor rural areas of Uganda, over 40% of households are active in non-agricultural activities, mainly wholesale and retail trade and manufacturing.

[17] I recognize the trade data is not perfect. For example, shipments valued at less than $100,000, which represent approximately 1% of the transactions, were manually incorporated into the UN trade data by Feenstra et al. [2005]. To the extent this adjustment is not exhaustive, I will not be able to capture small scale trade that is likely more important for trade between developing countries.

[18] Timmer [1988, 2002] provide an effective summary. Matsuyama [1992] and, more recently, Lucas [2009] highlight dynamic gains from labour reallocation, with learning-by-doing in manufacturing. This paper focuses on static gains to structural change.

imports can account for the current cross-sectional level differences.

The model's dual-economy features closely follow recent structural change research, which examines the strong negative correlation between agriculture's share of output and employment and the overall level of economic activity. In particular, I model non-homothetic preferences as in Kongsamut et al. [2001]. Consumers must satisfy a minimum food intake requirement before allocating income across goods according to their preference weights.[19] In addition, to capture large wage differences between agricultural and nonagricultural activities in poor countries observed, I incorporate labour market frictions. This further increases agriculture's share of employment in poor countries. Labour market frictions are used by Caselli and Coleman [2001] in a dynamic model to explain the development experience of the Southern US and by Restuccia et al. [2008] to capture cross-country patterns. Given the static nature of this paper's model, I adopt Restuccia et al. [2008]'s approach. Specifically, farm workers face a cost to switch into nonagricultural activities, proportional to non-farm wages.

The model's trade components follow a large literature based on Eaton and Kortum [2002].[20] This framework is particularly well suited to estimate productivity from trade flows. Of particular relevance to this paper, Costinot et al. [2010] and Levchenko and Zhang [2010] infer productivity and comparative advantage using a similar framework, but only for manufacturing. Waugh [2010] studies trade flows and the impact of trade on cross country income differentials, but - again - only for manufacturing.[21] My model is distinct in two important ways. First, to capture declining food expenditure shares, consumer preferences are non-homothetic. Fieler [2010] also employs non-homothetic preferences within an Eaton-Kortum framework but my approach differs by linking low income elasticity to the good with a high degree of international productivity variation - namely, agriculture. Fieler [2010] considers the opposite case, which may be more relevant between manufactured goods than between agriculture and non-agriculture broadly.[22] The second distinct feature in my model, labour mobility costs, captures large farm-nonfarm wage differences in poor

[19] This contrasts with Ngai and Pissarides [2007]'s approach, where differential productivity growth across sectors, coupled with an elasticity of substitution different from one, generates structural change. Other approaches involve increasing consumer goods variety [Greenwood and Uysal, 2005, Foellmi and Zweilmueller, 2006] or capital deepening with sector-specific factor intensities [Acemoglu and Guerrieri, 2006]. Incorporating non-homothetic preferences is the most natural approach for this paper.

[20] For recent studies utilizing a similar framework, see Bernard et al. [2003], Alvarez and Lucas [2007], Caliendo and Parro [2009], Kerr [2009], Burstein and Vogel [2010], Chor [2010], Costinot et al. [2010], Donaldson [2010], Fieler [2010], Levchenko and Zhang [2010], Waugh [2010], Yi and Zhang [2010].

[21] My findings are robust to alternative specifications of the bilateral trade-cost function. I reproduce my results using an exporter (as opposed to importer) specific trade costs specification. See, for example, Waugh [2010] on the role of export costs within this class of models. I find evidence the type of trade cost asymmetry found by Waugh [2010] for manufactured goods trade is also a feature of the agricultural goods trade.

[22] Additionally, she uses modeling features to generate variable budget shares in a fundamentally different manner from the Stone-Geary preferences I use in this paper.

countries. The model's remaining features are standard: perfectly competitive markets, trade arises through sectoral and international technology differences, and labour as the only productive input.

2 A Model Consistent with Stylized Facts

This section presents the general equilibrium trade model that builds on Yi and Zhang [2010]. Overall, the environment is composed of N countries each with three sectors: agriculture, manufacturing, and services. I incorporate standard dual-economy features found in the macroeconomics literature: (1) non-homothetic preferences and (2) labour market distortions between agriculture and nonagriculture. This preference structure captures Engel's law: food expenditure shares decline dramatically with income. The labour market distortions capture large sectoral wage differences and high labour mobility costs in poor countries. To incorporate open-economy considerations, 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). Between sector trade is also available, where a surplus of exports over imports in agriculture, for example, allows for a net import of manufactured goods. Importantly, this structure does not imply perfect specialization and it links trade patterns to sectoral productivity and trade costs. I conclude this section by defining an equilibrium and by describing a solution procedure for wages and labour allocations.

2.1 Households' Problem

I index countries by $i = 1,...,N$, and each is populated by L_i agents endowed with an inelastically supplied unit of labour, allocated between the three sectors. Within each country, households spread consumption evenly across individual agents. I model non-homothetic preferences as subsistence food requirements within a Stone-Geary type utility function. Households select consumption and labour allocations to maximize

$$\max_{\{C_{ik},L_{ik}\}_{k\in\{a,m,s\}}} U(C_{ia},C_{im},C_{is}) = \varepsilon_a ln(C_{ia}-\bar{a}) + \varepsilon_m ln(C_{im}) + \varepsilon_s ln(C_{is}) \quad (1)$$

$$\text{s.t.} \sum_{k\in\{a,m,s\}} L_i P_{ik} C_{ik} = \sum_{k\in\{a,m,s\}} w_{ik} L_{ik} \quad (2)$$

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 household income after subsistence spending, $\left(\sum_{k\in\{a,m,s\}} w_{ik}L_{ik}\right) - P_{ia}\bar{a}$. As food subsistence requirements increase - through a higher $\bar{a}$ - food's share of total expenditures increases.

2.2 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, denoted $k \in \{a,m\}$, are composed of a continuum of differentiated varieties. Firms produce individual product varieties, denoted z, with linear technology[23]

$$y_{ik}(z) = A_{ik}(z)L_{ik}(z).$$

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; so, any price deviation from marginal costs 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

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

where θ_k governs productivity dispersion and A_{ik} the overall level of productivity, with $A_{ik} \propto E\left[A_{ik}(z)\right]$.[24] 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. For lower θ, the incentive to trade, and the gain from doing so, increases.

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,

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

[23] Incorporating intermediate inputs into this production function is another standard formulation, which increases trade gains as input prices decline. To be conservative, I abstract from this consideration in the baseline results but report the case with intermediates in the appendix.

[24] The constant of proportionality is $\Gamma\left[1-\frac{1}{\theta_k}\right]^{-1}$. This relates to the scale parameter of a Frechet distribution. $\lambda_{ik} = A_{ik}^{\theta_k}$.

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

2.3 International Prices and Trade Patterns

Firms producing the composite manufactured and agricultural good purchase individual varieties from the lowest cost source - at home or abroad. As in Samuelson [1954], trade costs are iceberg: τ_{ijk} sector-k goods are shipped per unit imported by 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}:

$$p_{ik}(z) = \min_{j\in\{1,..,N\}} \left[\frac{\tau_{ijk}w_{jk}}{A_{jk}(z)}\right]. \tag{3}$$

Substitute into a CES index to determine each country's price for tradable good-k, $P_{ik} = \left[\int_0^1 p_{ik}(z)^{1-\rho}dz\right]^{1/(1-\rho)}$. Given the distribution of productivity across varieties, and assuming import costs and wages are not variety-specific, Eaton and Kortum [2002] demonstrate this index reduces simply to

$$P_{ik} = \gamma \left[\sum_{j=1}^{N}\left(\frac{\tau_{ijk}w_{jk}}{A_{jk}}\right)^{-\theta_k}\right]^{-1/\theta_k}, \tag{4}$$

where $\gamma = \Gamma\left(1+\frac{1-\rho}{\theta_k}\right)^{\frac{1}{1-\rho}}$.[25] Notice, Equation 4 is the price paid by consumers in country-i for the aggregate good-k and no knowledge of individual variety sources is necessary.[26]

The share of country-i expenditures sourced from country-j capture 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. As in Eaton and Kortum [2002] the share of country-i spending sourced from country-j for good-k is

$$\pi_{ijk} = \frac{\psi_{ijk}}{\sum_{j=1}^{N}\psi_{ijk}}, \tag{5}$$

with $\psi_{ijk} = \tau_{ijk}^{-\theta_k}\left(A_{jk}/w_{jk}\right)^{\theta_k}$ as the product of trade costs and competitiveness of country-j from the per-

[25] $1+\theta_k > \rho$ must hold, I set ρ such that $\gamma = 1$, which does not violate this restriction.

[26] In order to perform proper PPP-adjustments to labour productivity across countries, individual variety price and quantity information is required. To that end, I will numerically simulate the full model on 50,000 product types. I report details later in the paper and in the appendix. Unadjusted labour productivity from the model's analytic solution is a good approximation to the PPP-adjusted values.

spective 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}.

2.4 Labour Market and Trade Balance Conditions

Trade shares 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:

$$w_{ia}L_{ia} = P_{ia}Y_{ia} = \sum_{j=1}^{N} \left[L_j(P_{ja}\bar{a} + \varepsilon_a \tilde{M}_j)\pi_{jia}\right], \tag{6}$$

$$w_{im}L_{im} = P_{im}Y_{im} = \sum_{j=1}^{N} \left[L_j \varepsilon_m \tilde{M}_j \pi_{jim}\right], \tag{7}$$

$$w_{is}L_{is} = P_{is}Y_{is} = \varepsilon_s \tilde{M}_i L_i. \tag{8}$$

Labour demand by producers of each tradable variety, $L_{ik}(z)$, aggregate to sectoral labour $L_{ik} = \left[\int_0^1 L_{ik}(z)dz\right]$. Also, sectoral labour allocations must total to national employment,

$$\sum_{k\in\{a,m,s\}} L_{ik} = L_i \quad \forall\, i = 1,..,N. \tag{9}$$

I capture labour market distortions with a reduced-form wedge between sectoral wages.[27] Specifically, $w_{ia} = \xi_i w_i$ and $w_{im} = w_{is} = w_i$, where $\xi_i < 1$ captures labour's cost to move off the farm.

The sectoral revenue and labour earnings conditions of the previous section imply international trade balances for each country. Specifically, combine Equations 6 to 8 with labour market clearing Equation 9 and $\tilde{M}_i + P_{ia}\bar{a} = \left(\sum_{k\in\{a,m,s\}} w_{ik}L_{ik}\right)$ to yield

$$L_i(P_{ia}\bar{a} + (\varepsilon_a + \varepsilon_m)\tilde{M}_i) = \sum_{j=1}^{N} L_j[(P_{ja}\bar{a} + \varepsilon_a\tilde{M}_j)\pi_{jia} + \varepsilon_m\tilde{M}_j\pi_{jim}] \quad \forall\, i = 1,..,N. \tag{10}$$

Country-i appears on both the left and right side, so this equation is identical to imports equaling exports.

[27] I abstract from how these differentials are supported in equilibrium. See Lagakos and Waugh [2010] for an excellent treatment of the relationship between sectoral labour frictions and the food problem.

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.

2.5 Equilibrium Definition and Solving the Model

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 1; (2) given wages, price aggregates are consistent with Equation 4; (3) given wages, prices, and labour allocations, international trade balances through Equation 10; and (4) labour markets clear through Equation 9.

Given exogenous parameters (technology, A_{ik}; trade costs, τ_{ijk}; preference weights, ε_k; subsistence requirements, $\bar{a}$; labour mobility costs, ξ_i; total employment, L_i; and trade elasticities, θ_k), one can solve for wages and labour allocations as follows. First, combine prices from Equation 4 and trade shares from Equation 5 with Equations 6 through 8. Wages and labour in agriculture, manufacturing, and services is a set of $4N$ unknowns. Equations 6 through 8, with the labour market clearing Equation 9, is a set of $4N$ equations. Thus, equilibrium wages and labour allocations, given exogenous parameters, solves this system.[28][29] I solve counterfactual experiments in Section 5 using this procedure. Technology and trade costs parameters, however, are not observable and I describe their calibration in Section 3.

3 Calibrating the Model

To guide intuition through the calibration, I first describe the overall approach before moving into details. First, estimate competitiveness $\frac{A_{ik}}{w_{ik}}$ and trade costs τ_{ijk} from bilateral trade flows (details in Section 3.1). These estimates together imply prices from Equation 4 and trade shares from Equation 5. Given prices

[28] Interestingly, wage levels and labour shares are independent of service-sector labour productivity. To see this, note that if $\bar{a} = 0$, $\xi_i = 1$, and there is only one tradable sector, the above system would collapse to $w_i L_i = \frac{\varepsilon}{1-\varepsilon} \sum_{j=1}^{N} \left[L_j w_j \pi_{ji} \right]$, where ε is the tradable goods' budget share. In this framework, the elasticity of substitution across goods is one (from household preferences) and, therefore, budget shares are constant. Thus, this system of equations determines wages across countries, given technology and trade costs. These wage equations are similar to Equation 21 in Eaton and Kortum [2002], which corresponds to their special case of immobile labour. More general preferences, however, would imply $\{\varepsilon_a, \varepsilon_m, \varepsilon_s\}$ are functions of an overall price index and, by extension, productivity in every sector, including services.

[29] Not allowing for trade imbalances will impact model wage estimates, since countries with large current account deficits would have higher wages than in the balanced-trade case. In terms of productivity estimates, imposing trade balance will underestimate productivity dispersion if rich countries typically have current account deficits. For poor countries, the impact will be negligible, given their low import shares. Dekle et al. [2007] incorporated into an Eaton-Kortum framework and find most wage estimates under imbalanced trade are within 10% of the balanced-trade case. They find imposing trade balance results in US wages of about 10% higher than with a current account deficit.

and trade shares, determine international disposable income levels $\tilde{M}_i$ to balance international trade from Equation 10. Given income and prices, consumer demands from the household problem imply wages and labour allocations consistent with international demands and income levels through Equations 6 and 8. The product of competitiveness $\frac{A_{ik}}{w_{ik}}$ and wages now implies sectoral technology parameters A_{ik}. Importantly, I infer sectoral labour productivity from bilateral trade flows with minimal structure. The Eaton-Kortum trade structure within agriculture and manufacturing generates trade patterns independently of household preferences and trade balance conditions. Wage levels depend on trade balance and household preferences but are independent of service-sector labour productivity.

Finally, 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:

$$IP_k = \sum_{i=1}^{N} \frac{P_{ik}}{PPP_i} \gamma_{ik},$$

$$PPP_i = \frac{\sum_{k\in\{a,m,s\}} L_i P_{ik} C_{ik}}{\sum_{k\in\{a,m,s\}} IP_k C_{ik}}.$$

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 $Y_i/L_i = PPP_i^{-1} \sum_{k\in\{a,m,s\}} P_{ik} C_{ik}$.

For the quantitative exercises, I use a set of 114 countries, listed in Table 12. A number of parameters can be set to generally accepted values in the literature; namely, the preference parameters and the Frechet

Table 1: Calibration of 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	$\{0.75, 0.24, 0.01\}$
A_{is}	Aggregate GDP/Worker Data	*Country-Specific*
ξ_i	Relative Wage Data	*Country-Specific*
L_i	Total Employment Data	*Country-Specific*
$\{A_{ia}, A_{im}, \tau_{ija}, \tau_{ijm}\}$	Bilateral Trade Data	*Country-Specific*
$\bar{a}$	US Sectoral Employment Data	0.0160

This table provides a list of model parameters that must be calibrated. All other variables in the model are endogenously determined. The parameters in the bottom two rows are dealt with in detail as Stage 1 and Stage 2, all other parameters either map to observable data or are generally accepted values. Long-run employment shares reflect the values to which US employment data appear to be converging. I report sensitivity of the model to various alternative values of $\{\theta_a, \theta_m\}$ in Section 6.1.

distribution's dispersion parameter. In order: $\varepsilon_a = 0.01$, $\varepsilon_m = 0.24$, and $\varepsilon_s = 0.75$; and, $\theta_a = \theta_m = 7$.[30] Total employment is inferred from PWT6.3 as the ratio of total GDP to GDP/Worker. I list the model parameters, their values, and calibration targets in Table 1. The following sub-sections describe parameterizing productivity, trade costs, subsistence level of food consumption, and, finally, labour market distortions. Given these, all other variables are endogenously determined. I proceed in stages: (1) estimate competitiveness and trade costs to fit bilateral trade, independently of the structure of the household sector supporting such flows in equilibrium; (2) select subsistence parameter to match US data; and (3) set service-sector labour productivity so the model's aggregate labour productivity matches data.

3.1 Productivity and Trade Costs

The empirical strategy relates variation in bilateral import and export flows, relative to each country's domestic purchases, to infer import barriers, export competitiveness, and bilateral trade costs. The share of country-i expenditure imported from country-j, from Equation 5 can be expressed as

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

[30] Regressing $ln\left(\frac{\pi_{ijk}}{\pi_{iik}}\right)$ (see Section 3.1) on a measure of trade costs, τ_{ij}, from the CEPII trade database, along with importer and exporter fixed effects, yields $\theta = 5.5$ in agriculture and $\theta = 6.8$ in manufacturing. For 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 theta in agriculture enhances my results by increasing the scope for comparative advantage within agriculture. To be conservative, I set $\theta_a = \theta_m$. For other estimates, 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 finds anything between 5 and 10 reasonable. Finally, Waugh [2010] finds $\theta = 7.9$ for OECD countries and $\theta = 5.5$ for non-OECD countries, which is identical to my estimate for agricultural trade. All development accounting and trade flow counterfactual exercises are robust to alternative values (see Section 6.1).

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 (productivity per unit-input cost) and trade costs:

$$ln\left(\frac{\pi_{ijk}}{\pi_{iik}}\right) = \underbrace{\theta ln\left(T_{jk}\right) - \theta ln\left(T_{ik}\right)}_{\text{Competitiveness}} - \underbrace{\theta ln\left(\tau_{ijk}\right)}_{\text{Trade Costs}}$$

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.[31][32] Importer-specific trade barriers is a reduced-form approach to capture all import costs such as tariffs, non-tariff barriers, health regulations, low quality local infrastructure, information asymmetries, among many others, in a single number. Importantly, trade costs in this setup are asymmetric between countries: it is more expensive to import goods from Canada into Cuba than from Cuba into Canada. Alternative frameworks, such as in Anderson and van Wincoop [2003], employ symmetric trade costs between pairs.[33] The precise empirical specification I use, separately for each sector, is:

$$\begin{aligned} ln\left(\frac{\pi_{ijk}}{\pi_{iik}}\right) &= \beta_{1k} ln\left(Distance_{ijk}\right) + \beta_{2k} Border_{ijk} + \beta_{3k} Language_{ijk} \\ &\quad + \beta_{4k} Agreement_{ijk} + \eta_{jk} + \delta_{ik} + \nu_{ijk}, \end{aligned} \tag{11}$$

where η_{jk} is the exporter fixed-effect, δ_{ik} the importer fixed-effect, and ν_{ijk} the random component. The model parameter estimates are derived from coefficient estimates as: $\hat{T}_{ik} = e^{\hat{\eta}_{ik}/\theta}$, $\hat{B}_{ik} = e^{-(\hat{\delta}_{ik}+\hat{\eta}_{ik})/\theta}$, and $\hat{P}_{ik} = \gamma\left[\sum_{j=1}^{N}\left(\hat{\tau}_{ijk}^{-1}\hat{T}_{jk}\right)^{\theta}\right]^{-1/\theta}$ from Equation 4.

To fit trade shares π_{ijk} to data, I construct trade share measures similar to Eaton and Kortum [2001], Bernard et al. [2003]. Specifically, I take the ratio of country-i imports from country-j, reported in the

[31] Data on pairwise characteristics and Capital coordinates are from CEPII. http://www.cepii.fr/anglaisgraph/bdd/distances.htm. Distance between importer-i and exporter-e: $6378.7 \arccos\left(\sin(lat_e)\sin(lat_i) + \cos(lat_e)\cos(lat_i)\cos(long_i - long_e)\right)$

[32] I find the trade agreement variable particularly important for European bilateral pairs. Without this control, productivity inferences for these countries, given their high levels of trade, are extremely large. Data is from Fieler [2010].

[33] Asymmetric costs are not excluded from their framework, but it only identifies the *average* of any country-specific costs between members of a pair.

Table 2: Main Estimation Results

	Agriculture	Manufacturing
	(1)	(2)
Ln(Distance)	-1.037	-1.389
	(0.029)***	(0.023)***
Shared Border	0.574	0.472
	(0.105)***	(0.098)***
Shared Language	0.664	0.596
	(0.061)***	(0.052)***
Trade Agreement	0.354	-.323
	(0.124)***	(0.122)***
Exporter FEs	Yes	Yes
Importer FEs	Yes	Yes
Observations	6207	9014
R^2	0.971	0.971

The OLS esimates of Equation 11. 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).

NBER-UN trade database, 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.[34] Bilateral trade data for 2000 is from the NBER-UN Trade Database, which disaggregates by 4-digit SITC code.[35] Agricultural trade flows are all bilateral flows classified with an SITC 1-digit code of 0, such as 0573 (Bananas, Fresh or Dried). Finally, countries do not trade with every other country, leaving zeros in the data for those pairs. For my baseline estimates, I estimate the above specification only on the pairs with positive trade with OLS.[36]

The basic gravity-specification implied by the theory captures the trade data well. The parameter esti-

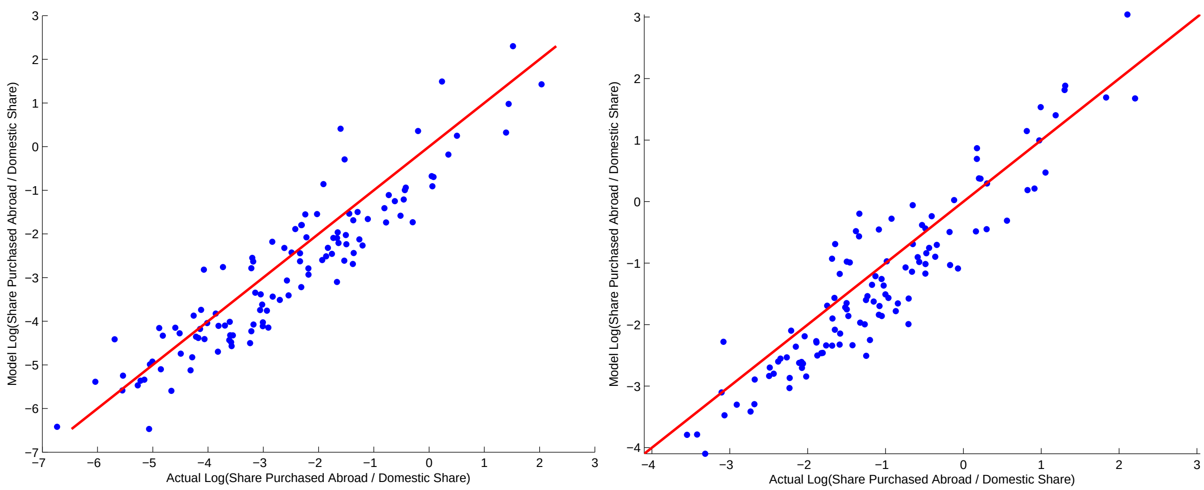
[34]Gross output measures are ideal but I lack internationally comparable measures. The FAO reports gross and net production values (PPP-adjusted, while trade flows are exchange-rate adjusted) and I find a gross-to-net ratio of approximately 5% among developing countries, compared to 15% for the rich. Net output inferred from GDP shares underestimates home-bias in poor countries, so this approach is conservative. Consistent with my treatment in the manufacturing sector, I use the inferred net output measure for agriculture as well.

[35]See Feenstra et al. [2005] for details regarding the construction of this data.

[36]As a robustness check, to handle this left-censoring of the data, I estimate a Tobit model with the minimum observed π_{ij} for each country-i serving as the lower limit, below which statistical agencies do not observe the trade. This procedure is similar, but not identical to, [Eaton and Kortum, 2001]. See Anderson and van Wincoop [2003] for more on estimating gravity models. The censoring threshold for π_{ij} is selected as the maximum likelihood estimate $\bar{\pi}_i = \min_{j \in [1,..,N]} \pi_{ij}$, such that if the true $\pi_{ij} < \bar{\pi}_i$ then I will not observe a trade flow in the data for that i, j pair. The geographic component of trade becomes much more important within the Tobit structure. I explore this alternative specification in the appendix.

Figure 3: Fit of the Stage-1 Calibrated Model

(a) Agricultural Trade (b) Manufacturing Trade



Displays the fit of the Stage-1 calibrated trade flows in the model to the data for each traded goods sector. The normalized trade flow measure is the share of consumer expenditures imported from abroad relative to the share sourced domestically. The vertical axis is the model normalized import rate and the horizontal axis is calculated from the NBER-UN trade database.

mates are listed in Table 2, with 6,207 observed trade pairs in agriculture and 9,014 in manufacturing. To visualize the goodness of fit, I sum $\frac{\pi_{ijk}}{\pi_{iik}}$ within countries for each sector, which represents the relative importance of goods sourced from abroad relative to domestic purchases. The actual and fitted values (summed in similar fashion) are found in Figure 3 and match extremely well.

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 3. On average, rich country competitiveness in manufacturing is 2.4 times poor country competitiveness but only 1.6 times more in agriculture. This does not contradict earlier observations of larger labour productivity differences in agriculture than manufacturing since farm wages are significantly lower than nonfarm wages in poor countries.[37] For all countries, I plot the competitiveness estimates $\hat{T}_{ik}$ in Figures 13 and 14.

When the model is solved, Frechet productivity parameters are $A_{ik} = \hat{T}_{ik} w_{ik}$. Finally, I plot the trade costs captured by the importer-specific fixed effect $\hat{B}_{ik}$ in Figures 11 and 12. Note that these fixed-effects can be

[37]The price of agricultural goods relative to manufacturing, from ICP, is also consistent with this finding. The ratio P_a/P_m is 0.8 in the bottom quintile of countries and nearly 1 for the top. Overall, the relative price of food within the set of tradable goods is U-shaped across countries, with middle income countries having the lowest P_a/P_m ratio.

Table 3: Selected Values from Stage-1 Calibration

Mean for	Competitiveness, $\widehat{\left(A_{jk}/w_{jk}\right)}$		Trade Cost, Importer Fixed-Effect, $\hat{B}_{ik}$	
Countries in:	Agriculture	Manufacturing	Agriculture	Manufacturing
Top-10%	1.44	2.65	-41%	-68%
Bottom-10%	0.89	1.09	43%	-1%

Competitiveness and importer-specific fixed effects implied by the bilateral pattern of sectoral trade. These results suggest rich countries have a comparative advantage in manufactured goods and an absolute advantage in both. Poor countries also face higher costs to import goods. Negative values for $\hat{B}_{ik}$ imply imported goods cost less than in the average country.

below zero, which implies imports cost less than in the average country.[38]

3.2 Subsistence, Service Sector Productivity, and Labour Market Distortions

An important driver of agriculture's high employment and spending share in lower income countries is the need to fulfill minimum food intake requirements. To capture this channel, without selecting subsistence to target potentially suspect employment data in poor countries, I set $\bar{a}$ to match US data. Specifically, Equations 6, 7, and 10 imply labour income in the tradable sectors must equal consumer expenditures on tradables: $P_aC_a + P_mC_m = \xi w\left(\frac{L_a}{L}\right) + w\left(\frac{L_m}{L}\right)$. Normalize $w = 1$ for the US and combine with household demands and labour market clearing conditions to yield

$$\bar{a} \;=\; P_a^{-1}\left[\xi l_a + l_m - \left(\frac{\varepsilon_a + \varepsilon_m}{\varepsilon_s}\right) l_s\right].$$

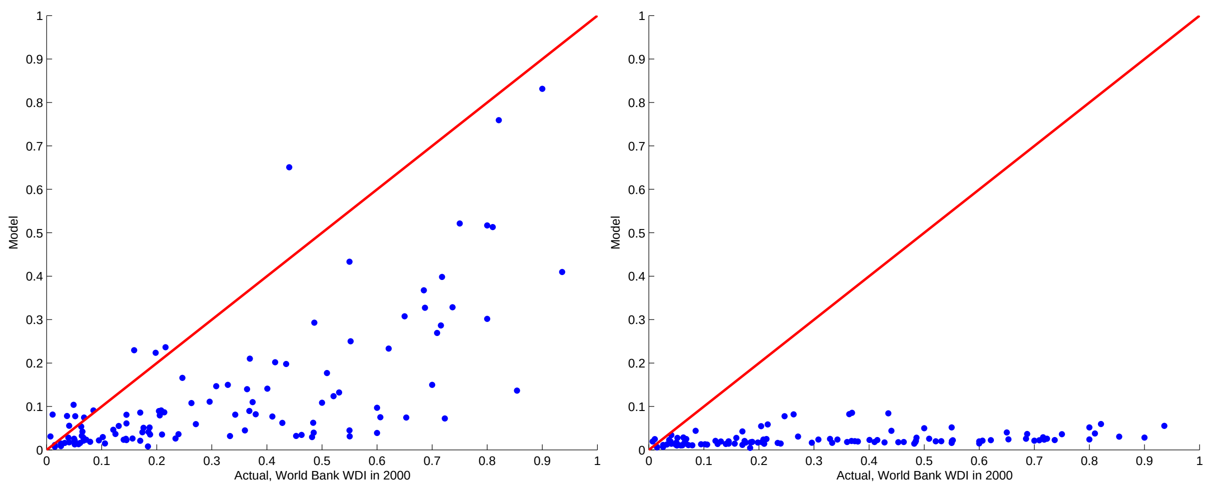
To evaluate this expression, I use: prices from the previous section, which depend only on the trade cost and competitiveness estimates; preference weights$\{\varepsilon_s, \varepsilon_m, \varepsilon_a\}$; labour shares $\{l_s, l_m, l_a\} = \{0.743, 0.232, 0.026\}$, from the World Bank's 2000 WDI; and US labour mobility costs $\hat{\xi}_{US} = 0.8972$, estimated from wage data. I get $\bar{a} = 0.0160$ and subsistence spending, $P_a\bar{a}$, of less than 1% aggregate GDP/Worker for the United States - approximately \$600 per year. For comparison, Restuccia et al. [2008] find a subsistence value of approximately 2.2% of the US aggregate GDP/Worker in 1985.

Two parameters remain. I set service sector labour productivity, A_{is}, so the model implied PPP-adjusted aggregate labour productivity matches data. Finally, each country's labour market distortion, ξ_i, can be matched to sectoral wage data from the International Labour Organization.[39] Wage data is unavailable for

[38] This interpretation was provided by Waugh [2010], who finds a -62% fixed-effect for the United States' manufacturing goods trade. My results suggest -76% for manufacturing and -55% in agriculture.

[39] http://laborsta.ilo.org/

Figure 4: The Role of Subsistence Food Requirements



Displays the model implied share of employment in agriculture along the vertical axis relative to the share reported for 2000 in the World Bank's WDI database. The left panel is the model with subsistence set to match US data. The right panel is the model with subsistence set to zero. Targeting US data allows the model to capture much of the cross country variation. All else equal, the sum of squared deviations between the model and data is 8.18 with subsistence set to match US data and 17.1 with subsistence set to zero.

many countries. I use the observed relationship between relative agricultural wages and GDP/Worker to fit ξ_i for each of the 114 countries. Details on this procedure are in the Data Appendix.

4 Results from the Baseline Calibration

I display the model-implied agricultural employment share in Figure 4a. For the richest and poorest countries, I present each sector's employment share and the relative GDP/Worker in Table 4. The model corresponds well to sectoral data, despite explicitly targeting only aggregate productivity differences. If cross-country employment data are accurate, targeting US data accounts for approximately half of the international variation in agriculture's employment share. For many developing countries, however, standard surveys overestimate farm labour since rural residents and farm workers are treated synonymously. Brandt et al. [2008] and Brandt and Zhu [2010], for example, use household-level surveys to infer a 26% agricultural labour share in 2007 rather than the official figure of 41%, when considering hours spent on farm work. Moreover, Gollin and Rogerson [2010] report that even in extremely poor rural areas of Uganda, over 40% of households are active in non-agricultural activities, mainly wholesale and retail trade and manufacturing. For these reasons, I proceed using the model-implied employment shares.

Table 4: Aggregate Productivity and Employment Shares, Model vs. Data

	Mean of Bottom-10%		Mean of Top-10%	
	Data	Model	Data	Model
GDP/Worker, Relative to Top *	0.04	0.04	1	1
Agricultural Employment Share	0.67	0.45	0.04	0.02
Manufacturing Employment Share	0.08	0.13	0.29	0.23
Services Employment Share	0.25	0.42	0.67	0.75

$*$ denotes target. This table compares the model to data for various statistics.

4.1 Trade Cost Estimates

I decompose trade costs into bilateral components (distance between trading partners and separate indicators for shared border, language, and trade agreement), importer-specific fixed effects, and an idiosyncratic component that is IID across products. These fixed effects capture many possible barriers: tariffs, quotas, health regulations, or poor local road networks. Adjusting this variable downwards to the typical level observed in rich countries will be a key counterfactual experiment I perform to determine the impact of low food imports on international productivity and income differences.

Figures 11 and 12 display the trade cost estimates for both sectors. I separately plot the overall measure (trade weighted across import sources) and the importer-specific fixed effect. In the figures, I represent trade costs by their impact on prices: a trade cost of τ will increase prices by $100(e^{\tau/\theta} - 1)$ percent. The average import costs for the 114 countries in my sample is 263% in both agriculture and manufacturing. For rich countries, this number is 104% on average in agriculture and 78% in manufacturing. The importer-specific fixed component of trade costs average 43% for poor countries and -41% for rich countries in agriculture. This implies that imports are typically 43% more expensive in the poorest 10% of countries relative to the average country.[40]

4.2 Sectoral Labour Productivity

As noted by Costinot et al. [2010], Waugh [2010], Yi and Zhang [2010], A_{jk} is the labour productivity in autarky. With trade, labour productivity in sector-k is given by the conditional mean of operating producer

[40] See Section 6.3 for a discussion on the plausibility of these trade cost estimates.

Table 5: Baseline Model: Cross Country Productivity Differentials

	Top-10% / Bottom-10%		Variance of Logs	
Sector	Data	Model	Data	Model
Aggregate	23.0	23.0	1.00	1.00
Agriculture	79.5	103.9	1.73	2.14
Manufacturing	-	77.4	-	1.99
Services	-	9.9	-	0.75
Nonagriculture	5.8	13.8	0.78	0.47

Presents the baseline estimates of sectoral productivity implied by bilateral trade flows and model wages. Services sector productivity is calibrated so the model aggregate productivity matches the dispersion of GDP/Worker in the PWT6.3. Agricultural labour productivity in the data is PPP-adjusted value-added per worker using net farm output data from FAO, valued at international prices, for 1999-2001. The precise procedure follows Restuccia, Yang, and Zhu (2008) and Caselli (2005).

productivity, $y_{ik} = \frac{w_{ik}}{P_{ik}} = E\left[A_{ik}(z) \mid z \in \{y_{ik}(z) > 0\}\right]$, can be expressed as

$$y_{ik} = \underbrace{\pi_{iik}^{-1/\theta_k}}_{\text{Trade}} \cdot \underbrace{A_{ik}}_{\text{Technology}} . \tag{12}$$

In autarky, all producers operate and labour productivity is A_{ik}. Imports, which lower π_{iik}, leads average productivity to grow as inefficient producers shut-down.[41] Absent a very low π_{iik}, measured labour productivity will closely reflect the underlying technology parameter, A_{ik}. This corresponds to recent literature finding low gains from trade in new-trade models (see, for example, Arkolakis et al. [2009]). The counterfactual gains I find in Section 5 follow from poor-country π_{iik} declining significantly. The import-elasticity of labour productivity within a tradable sector is, from the above expression, $1/\theta_k$. The value for θ_k influences the liberalization experiments I will perform in the next section. I will report sensitivity of my results to various values for θ_k and I find the overall conclusions robust.

I plot relative productivity between agriculture and manufacturing in Figure 9; relative agricultural labour productivity increases with a country's level of development. In the figure, I separately show the pure technology ratio $\frac{A_{ai}}{A_{mi}}$ and the full observed productivity ratio, given trade selection.

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 50,000 products for each sector and country.

[41] See Costinot et al. [2010] for a detailed discussion of the extent to which selection impacts observed productivity.

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 12 match appropriate PPP-adjusted estimates very well. In fact, The agricultural and manufacturing productivity gaps in the simulation are 102.4 and 73.2, respectively.[42] Overall, the correlation between the two measures are 0.997 in agriculture and 0.987 in manufacturing. Going forward, I report sectoral results from Equation 12 and leave further discussion of sectoral-level PPP-adjustments to the appendix.

Table 5 displays the aggregate and sectoral productivity dispersion implied by the baseline model, which match the data well for agriculture. I plot a complete comparison for all countries in Figure 10. Nonagricultural productivity variation, however, is larger than data suggests, reconciled by the model's lower agricultural employment share. Similar comparisons within the manufacturing and service sectors across a broad range of countries are difficult for lack of producer price data. Broadly speaking, however, lower service-sector productivity variation than in tradable goods sectors is consistent with Herrendorf and Valentinyi [2010].[43]

While direct international comparison is problematic, I examine a subset of countries for which real labour productivity (per hour) exists in the GGDC Productivity Level Database [Inklaar and Timmer, 2008]. I find the variance of log manufacturing productivity is 1.42 in the model for these countries and 0.19 in services, while GGDC figures are 0.53 and 0.16.[44] Moreover, the ratio of the 75th to 25th percentile is 7 in the model and 3 in the GGDC data. An alternative trade cost specification in Section 6.4 provides less variation in productivity estimates. The counterfactual results in the following section are robust - indeed, strengthened - by this alternative specification, so I continue with the baseline model.

5 Counterfactual Experiments: Trade, Productivity, and Income

To account for the sources of productivity gaps between rich and poor countries, I perform a set of counterfactual experiments within the model. Specifically, I investigate: (1) lowering importer fixed-effects, B_{ik}, to the average level of the richest-10% of countries for both sectors; (2) allowing full labour mobility by setting $\xi_i = 1$ for all i; and (3), to capture interactions between the domestic and foreign distortions, both (1)

[42] Standard errors from 20 iterations are 0.8 and 7.

[43] For an interesting illustration of the difficulty of making direct cross-country productivity comparisons, especially within the service-sector, see Baily and Solow [2001]

[44] I use the GGDC figures corresponding to manufacturing less electrical equipment and services less postal and telecommunications. Electrical equipment, postal, and telecommunications are aggregated into a single, separate category.

Table 6: Trade Between 1st and 4th Quartiles

(a) Baseline Model

	Import Share from: Poor	Import Share from: Rich	Domestic Share
Poor	9%	47%	98%
Rich	2%	74%	62%

(b) Counterfactual: Lower Importer Fixed-Effects

	Import Share from: Poor	Import Share from: Rich	Domestic Share
Poor	25%	23%	33%
Rich	10%	47%	42%

Displays the fraction of total imports by source-country income levels. Poor are the bottom quantile of countries in terms of GDP/Capita and rich are the top. Large shares imported from Rich countries does not imply that rich countries export more food to poor countries than vice-versa (in fact, the reverse is true). Prior to liberalization, poor countries bought very little from each other. Following liberalization of import and labour markets, food trade between poor countries rises dramatically. The fraction of varieties domestically produced also falls to one-third its original value. This Ricardian-selection is the source of the increased sectoral productivity. I show the shares across all income percentiles for both poor and rich importers in Figures 15 and 16.

and (2) together. Following each of these experiments, poor countries increases their level of food imports dramatically (see Figures 5, 6, and 7). Imports allow the lowest productivity domestic producers to shut down and tradable-sector productivity increases, especially in poor countries. I interpret the portion of the rich-poor gap that these counterfactual experiments eliminates as the contribution of the two distortions. I present details in the following sections.

5.1 International Food Trade Flows

I present the bilateral trade patterns for the trade liberalization experiment in Table 6. I show the shares across all income percentiles for both poor and rich importers in Figures 15 and 16. Until subsistence food requirements are met, poor country consumers allocate significant resources to agriculture since trade barriers inhibit their ability, and internal labour markets reduce their incentive, to import food. Following liberalization, the fraction of varieties produced domestically falls below that of rich countries. The fraction of food imports sourced from other poor countries more than triples and the fraction from rich countries falls in half. Middle-income countries (see Figures 15 and 16) also become an important source for poor-country food imports. I find some developing countries *increase* their resource commitment to agriculture while others move labour into non-agricultural activities. In essence, poor countries more efficiently allocate their food production among themselves. The counterfactual volume of South-South trade grows by an order of magnitude to account for nearly one-fifth of global agricultural trade, and together with North-South trade accounts for slightly more than half (see Figures 17 and 18). These counterfactual trade patterns drive important changes in productivity and income differences between rich and poor countries.

Table 7: Results of Main Counterfactual Experiments

		Liberalization Experiments		
	Baseline	Liberalized Trade	Mobile Labour	Both
Labour Productivity Top-10%/Bottom-10%				
Aggregate	23.0	17.7	21.5	15.3
Agriculture	103.2	88.5	98.3	57.5
Manufacturing	77.4	47.0	78.4	52.8
Agriculture in the Poorest-10%				
Employment Share	0.45	0.37	0.33	0.03
Change in Labour Productivity	-	17%	6%	60%
Import Share of Expenditures	0.03	0.67	0.24	0.96

Displays the rich-poor productivity gaps and various statistics for the poorest-10% of countries. Specifically, the share of employment in agriculture, the share of consumer spending on food, and the share of spending allocated to imports. The biggest reduction in cross country productivity differences results from liberalizing trade in the presence of costless labour mobility. Liberalized-trade involves lowering both agricultural and manufacturing import barriers. Import barriers are lowered to the average for the richest ten-percent of countries, by sector. Mobile labour involves eliminating between-sector wage differences.

Importantly, despite low relative labour productivity, the counterfactual trade flows following reduction of import barriers confirm an earlier finding: poor countries have a comparative advantage in agricultural goods. The fraction of total exports accounted for by agricultural goods rises in poor countries by more than in rich. I report each country's percentage point change in agriculture's share of total exports in Figure 19.

5.2 Cross-Country Productivity Gaps

Table 7 displays model-implied gaps in sectoral and aggregate productivity across countries, under various measures and experiments. Reducing import barriers and allowing costless labour mobility results in dramatic reductions in productivity gaps. The richest 10% of countries initially had aggregate productivity 23 times the poorest but those same countries were only 15 times as productive after both distortions were relaxed. The agricultural productivity gap for these countries is nearly cut in half, from over 103 to 58. The reduction in log aggregate productivity variation is also significant. While not displayed, nearly all the aggregate gains found in the broader liberalization experiments remain when *only* agricultural import barriers are reduced. This is intuitive, given the importance of the agricultural sector for poor country consumers resulting from subsistence food requirements.

Together, these results suggest that nearly one-third of the gap between rich and poor countries can be accounted for by the lack of food imports. There are also interaction effects between domestic and foreign (trade) distortions. Initially, the difference between the richest and poorest 10% of countries is 23. Lowering import barriers lowers the gap to 17.7, labour mobility barrier reductions lower the gap to 21.5, combined the gap falls to 15.3. This implies 23% of the observed gap is from high import barriers alone, 7% from costly labour mobility alone, but 33% from both distortions together. The reduction in cross-country income variation reveals a similar pattern. The variance in log GDP/Worker across all countries in the sample falls by 7% following trade liberalization, 5% following labour mobility improvements, and 17% following an improvement in both distortions. The contribution of both distortions is greater than the sum of their individual contributions. This result is particularly important given the literature's focus on domestic distortions within closed-economy frameworks.

5.3 Decomposition: Cross Country Aggregate Productivity and Income Variation

Given technology levels, I decompose aggregate productivity changes into two broad channels: (1) Ricardian trade selection and (2) structural change. Selection occurs because of low productivity domestic producers shutting down with increased import levels. Recall Equation 12, $y_{ik} = \pi_{iik}^{-1/\theta_k} A_{ik}$, defines sectoral labour productivity, which changes inversely with the domestic expenditure share. To determine the contribution of trade selection in the reduction of aggregate productivity differences, I re-estimate the trade liberalization counterfactual holding sectoral labour allocations fixed at their initial levels.[45] I display the results in Table 8. The aggregate productivity gap falls to 20.9 - instead of 17.7 - when labour allocations are fixed. This indicates Ricardian trade selection accounts for nearly half (40%) the contribution of import barriers to international productivity differences.

That productivity differences *within sectors* shrinks following liberalized trade and labour markets is an important point to emphasize. Trade models with horizontally differentiated goods and heterogeneous productivity across firms can account for Ricardian selection while homogeneous goods frameworks cannot. It also suggests that many of the inefficient production technologies employed in low-income countries - such as small farm sizes - may be abandoned if access to imports improves. To reiterate, however, I am not advancing a specific policy recommending. Accounting for within-sector changes is important to quantify the contribution of low imports and labour misallocation to observed income and productivity differences

[45] The labour mobility improvements are not relevant in this case, since $\xi_i = 1$ implies labour allocations are not relevant for aggregate productivity.

Table 8: Counterfactual Aggregate Productivity Gaps, with Fixed Labour Allocations

	Labour Productivity Top-10%/Bottom-10%		
	Baseline	Liberalize Trade	Liberalize Trade with Fixed Labour
Aggregate	23.0	17.7	20.9

This shows aggregate productivity for the richest-10% of countries relative to the poorest-10%. I restimate the trade liberalization counterfactual holding sectoral labour allocations fixed at their initial levels. This shows that approximately half (40%) the contribution of import barriers on aggregate productivity differences operate through Ricardian trade selection.

Table 9: Contribution to Productivity Gaps, Various θ

	$\theta = 7$	$\theta = 5$	$\theta = 10$	$\theta_a = 5.5$ $\theta_m = 6.8$
Aggregate	33%	60%	27%	46%
Agriculture	44%	44%	46%	47%
Manufacturing	32%	42%	24%	32%

Displays the contribution to productivity gaps between rich and poor countries of both import and labour mobility distortions for various values of the productivity dispersion parameter θ. I report the baseline value of 7 in the first column, followed by 5 and 10 to reflect the range suggested by Anderson and van Wincoop (2004). The final column reports for the values of θ implied by using CEPII trade costs to proxy τ_{ij} (see footnote 30). Excluding Niger results in lower contributions to aggregate productivity gaps, since Niger's labour allocation is highly sensisitive to trade costs. The alternative values are 23%, 27%, 21%, and 27%, respectively.

across countries.

6 Discussion and Robustness of Results

6.1 Alternative Values for θ

The import-elasticity of labour productivity within a tradable goods sector is $1/\theta$. My baseline result is that the two distortions contributes to one-third of the observed differences in aggregate labour productivity between rich and poor countries. They further contribute to nearly half the difference within agriculture and one-third in manufacturing. I repeat the experiments for various values of θ to ensure my results are robust. I report the alternative contributions in Table 9. Overall, the headline result varies between 27% and 60% depending on the value of θ, with the baseline value yielding conservative results.

6.2 Alternative Counterfactual Experiments

I investigate a more limited experiment involving reducing import-barriers in *only* the poorest-10% of countries by fifty percentage points and improve poor-country labour markets only until $\xi_i = 0.8$. The wage wedge implied by this value of ξ corresponds to an urban/nonagricultural unemployment rate of 20% and no rural/agricultural unemployment in the Harris and Todaro [1970] framework.[46] I display the results of this experiment in Table 10. The reduction in the gap between rich and poor is, as expected, much less than previous experiments. The magnitudes, though, are still impressive given the limited liberalization among only the poorest-10%. The gap between the richest and poorest falls by more than 18% (from 23 to 18.8) in aggregate and by nearly 20% within agriculture (from 103 to 84).

I perform three more counterfactual experiments to illustrate the behavior of the model. To isolate food trade in particular, I liberalized trade within the agricultural and manufacturing sectors separately. In these scenarios, the aggregate labour productivity gap falls to 15.8 when agricultural trade is liberalized, in conjunction with fully mobile labour, but only to 21 in the case of manufacturing trade liberalization. I report the results of these two experiments in Table 10. Finally, I examine the productivity and income response to a *full* liberalization of labour markets and international trade. Specifically, I set $\xi_i = 1$ for all countries and $\tau_{ij} = 1$ for all trading pairs (i, j) for both sectors. I report the results of this experiment in Table 11. The average growth in aggregate real GDP/Worker amongst the poorest countries of my sample is 120% under frictionless trade, and 160% when labour mobility costs are also zero. For rich countries, the aggregate gains are approximately 30% under both scenarios. The resulting gap in labour productivity between rich and poor countries falls nearly in half in aggregate and by two-thirds in agriculture. Of course, this exercise merely illustrates the model's behavior, since removing *all* trade costs is not feasible.

6.3 Plausibility of Trade Cost Estimates

The country-specific import costs suggest nearly a one hundred percentage point difference between rich and poor countries. These results are plausible, given the voluminous contributions to trade costs beyond tariffs and transport costs that often cannot be directly measured (see Anderson and van Wincoop [2004]). Traditional measure of trade costs can account for much of the estimate. First, observed WTO average tariff rates are larger in poorer countries, on the order of 20% for agricultural imports under MFN. Tariff

[46] To see this, the agricultural wage w_a will equal the *expected* nonagricultural wage w_n. The unemployment rate reflects the probability of not securing employment at a given wage. So, $w_a = u_n 0 + (1 - u_n) w_n \Rightarrow \frac{w_a}{w_n} = 1 - u_n$, which equals 0.8 if $u_n = 0.2$.

Table 10: Counterfactual Productivity Gaps, Various Experiments

(a) Limited and Unilateral Liberalization in Poorest-10% of Countries

	Liberalization Experiments			
	Baseline	Liberalized Trade	Mobile Labour	Both
Labour Productivity Top-10%/Bottom-10%				
Aggregate	23.0	22.7	21.3	18.8
Agriculture	103.2	101.0	98.2	83.8
Manufacturing	77.4	55.8	78.3	60.1

(b) Reduce Agricultural Import Barriers Only

	Liberalization Experiments			
	Baseline	Liberalized Trade	Mobile Labour	Both
Labour Productivity Top-10%/Bottom-10%				
Aggregate	23.0	17.5	21.5	15.8
Agriculture	103.2	85.0	98.3	57.2
Manufacturing	77.4	78.1	78.4	78.8

(c) Reduce Manufacturing Import Barriers Only

	Liberalization Experiments			
	Baseline	Liberalized Trade	Mobile Labour	Both
Labour Productivity Top-10%/Bottom-10%				
Aggregate	23.0	23.6	21.5	21.0
Agriculture	103.2	105.4	98.3	99.0
Manufacturing	77.4	45.8	78.4	50.2

This shows productivity for the richest-10% of countries relative to the poorest-10% for various alternative counterfactual experiments.

The top panel: Liberalized-trade involves lowering both agricultural and manufacturing import barriers in the poorest-10% by fifty percentage points. Mobile labour involves setting $\xi = 0.8$ in poor countries. Even this limited and unilateral liberalization results in an 18% reduction in the aggregate labour productivity gap between rich and poor countries.

The middle and bottom panels: trade liberalization is for only agriculture (middle panel) and for manufacturing (bottom panel) separately. Mobile labour in both cases involves zero mobility costs ($\xi_i = 1$). The largest reductions come from liberalizing agricultural goods trade.

Table 11: Counterfactual Productivity Gaps, *Full* Liberalizations

	Baseline	*Frictionless International Trade*	
		Costly Labour Mobility	Costless Labour Mobility
Labour Productivity Top-10%/Bottom-10%			
Aggregate	23.0	14.3	12.6
Agriculture	103.2	60.0	32.0
Manufacturing	77.4	28.7	32.0

This shows productivity for the richest-10% of countries relative to the poorest-10%. I restimate the model under perfectly free trade ($\tau_{ij} = 1$ for all (i, j) pairs) and, in addition, under zero labour mobility costs ($\xi_i = 1$).

costs go beyond average values, since variation across substitutable products matters nearly as much. Kee et al. [2008], accounting for tariff variation across products and the different product elasticities imply trade restrictiveness[47] is 64% larger than average tariff rates imply. Large distortions from product-line tariff variation is also found for the United States by Irwin [2010], with a uniform tariff-equivalent estimate of 75%. Next, many studies find non-tariff barriers of roughly equal importance (and often more important) for a country's level of restrictiveness Kee et al. [2009]. A host of other trading difficulties exist for poor countries that increase trade costs. Contracting costs and insecurity, poor local distribution infrastructure, information gathering costs, currency controls, local content regulations, or health regulations in the case of food. Distribution costs are no doubt a significant driver of trade costs for poor countries, with such costs already on the order of 50% for rich countries.

6.4 Implications for Price Differentials

Agricultural and manufacturing prices in the model decline with income. ICP data for 2005, however, suggest price levels in these traded goods sectors are increasing with income. Moreover, the *relative* price of agriculture to non-agricultural goods in the model is rising with income but strong declining with income in the ICP data. Since model-prices capture the full price involved in purchasing goods, including transport to the point of consumption, some of the differences may be illusory. Given low infrastructure quality in poor countries, these concerns may be significant. However, one should not even take ICP prices at face value. FAO farm-gate prices, on the other hand, which I display in Figure 20, suggests far higher agricultural prices in poor countries than ICP suggests. Putting this point aside, and taking ICP price estimates as given, an

[47] Trade restrictiveness is the uniform tariff rate that generate identical dead-weight loss as a particular tariff/NTB structure

alternative specification of trade costs allows the model to more closely match ICP-implied price levels.

6.4.1 Exporter-Specific Trade Costs

I redo the analysis under the alternative form of trade cost asymmetry suggested by Waugh [2010]; specifically, country-specific export costs rather than import costs.[48] The World Bank's *Doing Business Index* surveys the cost of exporting an identical shipment of goods from a variety of countries and displays a clear decline in such costs with income. Poor country export costs are perhaps twice that of rich. If exporter-costs are included only with the manufacturing sector, the baseline dispersion of productivity across countries shrinks to 24 (from 77). Counterfactual experiments in this environment yield even greater reductions in aggregate productivity since poor country manufacturing sectors - to which farm labour will reallocate - have higher productivity. If exporter-costs are imposed on both sectors, the productivity gap is 50 in agriculture and 30 in manufacturing. In this case, import barriers and labour misallocation still account for nearly 20% of the aggregate gap between rich and poor. I conclude that my results are largely robust to my choice of trade cost asymmetry and provide more detailed results, with specific Tables and Figures, in the appendix.

6.5 OECD Agricultural Producer Support

Support programs for the agricultural sector in higher-income countries are large. The OECD estimates producer support estimates as high as 60% of production in Korea and Japan, 31% in the European Union, 22% in Canada, and 11% in the United States.[49] My main productivity estimates, A_{ia}, capture producer supports. Previous counter-factual exercises apply if PSE levels remain unchanged. Removal of support results in lower poor-country imports and higher rich-country imports. I present details of this experiment in the appendix and I find all main results robust.

6.6 Actual Development Experiences

Finally, this paper's counterfactual experiments suggest food imports facilitate structural change and development. Two notable historical experiences are broadly consistent with this claim. First, between 1780 and 1850, the United Kingdom experienced massive reallocation of labour off the farm at the same time as

[48] I use the agricultural trade data and 2005 ICP prices to show asymmetric trade costs identified by Waugh [2010] for manufactured goods is also a feature of the agricultural goods trade. For example, it is generally most costly for the United States to import food from developed economies than for developing countries to import food from the US. Perhaps export subsidy programs may play a role here.

[49] Source: Agricultural Policies in OECD Countries 2009: Monitoring and Evaluation.

food imports rose. Technological change in the manufacturing sector and the declining cost of important inputs, such as power and transportation, increased manufacturing productivity. Were higher trade volumes the result of higher manufacturing productivity or vice-versa? Stokey [2001] argues increased food imports, independent of technical change, accounts fully for the reduction in domestic food production and approximately half of real wage growth.

South Korea since the mid-1960s provides a second historical episode where increased food imports may have facilitated structural change and increased aggregate productivity and income. The FAO Food Balance sheets for South Korea show products accounting for over 75% of calorie consumption - cereals and starchy-roots (potatoes, etc.) - were nearly all domestically produced in the early 1960s. By 2000, imports were twenty-seven times their 1961 quantity (nearly 9% growth per year) and more than double domestic production. Tariffs for some of the most important imported goods, such as Wheat, are as low as 3% (applied, and 9% bound). Consequently, South Korea's employment share in agriculture fell from over 50% to less than 10%. The remaining domestic production has become increasingly concentrated in fewer varieties, with rice alone accounting for more than 50% of cultivated land.[50] Teignier [2010] concludes food imports facilitated reallocation and productivity increases, though to a smaller extent than possible given large support programs - among the highest in the world - for domestic farmers.

7 Conclusion

This paper examines the relationship between the international food trade and differences in labour productivity between rich and poor countries. A large literature finds labour productivity differences *within* the agricultural sector accounts for nearly the entire aggregate productivity gap. To understand these within-sector differences, existing studies focus on domestic distortions within closed-economy frameworks. Instead, I describe and exploit a general equilibrium model of international trade to: (1) measure sectoral productivity and trade costs across countries from observed import and export flows; and (2) quantify the impact of low poor-country food imports on international income and productivity gaps. Specifically, I expand on Yi and Zhang [2010] and modify an Eaton-Kortum trade model to incorporate multiple sectors and standard features from the macroeconomics literature - namely, non-homothetic preferences and labour mobility costs. With this model, I estimate PPP-adjusted productivity without producer price or employment data. This

[50]Source: South Korea Agricultural Policy Review, Vol. 5 No. 1. Agriculture and Agri-Food Canada.

is particularly important for developing countries, where agricultural employment estimates are overstated [Brandt and Zhu, 2010, Brandt et al., 2008, Gollin et al., 2004] and systematic non-agricultural producer price estimates are unavailable. I find agricultural labour productivity differs by a factor of 100 between rich and poor countries, more than in manufacturing and much more than in services.

Despite low agricultural productivity, poor countries import very little of their food. I focus on two distortions to account for the low food imports: high international trade barriers and costly labour mobility. Trade barriers increase import prices and labour mobility frictions increase farm employment and decrease farm wages. Both distortions lead consumers to opt for lower productivity domestic producers. Counterfactual experiments within the calibrated model determine how much of the productivity and income differences between rich and poor countries are due to limited food imports and labour misallocation. Liberalization of domestic labour markets and lowering import barriers shut-down low productivity domestic producers and facilitates labour reallocation out of unproductive agricultural varieties. More specifically, both specialization *within* agriculture and trade between developing countries increase dramatically. Fewer farm workers are also required and the resulting labour reallocation further increases aggregate productivity in poor countries. In addition, I find an interaction between domestic labour-market distortions and import barriers, with both distortions together accounting for more cross-country productivity differences than each separately. Overall, low food imports and labour misallocation accounts for half the agricultural productivity differences between rich and poor countries and a third of the aggregate differences.

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A Tables and Figures

Table 12: Relative Productivity and Trade Estimates

Country	Real GDP/Worker (PWT 6.3)	Relative Ag. Productivity	Home Bias in Ag	Home Bias in Nonag	Ag Import Barrier	Nonag Import Barrier
ALB	7590.271	.39115682	.96141678	.69874883	116.23558	35.421284
ARE	66576.617	.44485646	.61258745	.42578775	-18.620369	-53.892677
ARG	28930.211	.58822697	.92331129	.81713331	-31.249567	-54.02153
ARM	9728.3887	.48998314	.98607594	.93895686	52.866177	38.422016
AUS	60072.863	.57381749	.68545008	.54253531	-50.1661	-65.197693
AUT	65356.531	.43096933	.4135825	.21421564	-20.688431	-58.447227
AZE	8344.5225	.3909446	.95296329	.93601954	58.564125	11.980983
BDI	1484.5964	.3851738	.9966318	.9570998	35.336205	47.586834
BGD	4014.1082	.30144984	.99489081	.91947263	43.869297	-24.635656
BGR	15948.272	.40791327	.95872879	.60820246	26.421473	-31.066128
BHR	43883.574	.45361263	.37662947	.62962717	-14.125608	-41.283718
BHS	48276.43	.57115817	.44156331	.27013373	-23.095102	-33.775581
BIH	11547.183	.37477651	.87371927	.73112261	73.309517	15.562359
BLR	25513.055	.44623926	.98642498	.9683097	91.117615	25.764761
BLZ	21620.295	.73690593	.83211309	.79179543	-19.825785	-3.4059961
BOL	7833.9316	.42441931	.95463169	.86706454	31.046803	-13.168035
BRA	17660.801	.47839239	.94823343	.85341001	-24.6385	-58.092987
BRB	40506.512	.62988985	.88369179	.81707412	25.189732	2.0579891
CAN	60726.898	.52735758	.17978513	.10846359	-54.533997	-69.607185
CHL	36284.004	.568097	.83947229	.77406633	-28.651699	-52.482285
CHN	7559.1113	.27769059	.99373788	.90127778	5.4443336	-63.081043
CMR	6600.2842	.40258005	.98312026	.90316433	32.569183	-7.6996498
COL	13745.382	.52220678	.94951999	.85174996	.21882121	-36.463806
CRI	22434.385	.65378511	.91839951	.74750924	-18.682486	-34.551842
CUB	16589.055	.73064089	.90199858	.95611066	-15.214612	7.4105468
CYP	43011.164	.54910803	.60781217	.30474305	-3.2015181	-28.692625
CZE	31778.24	.40388408	.78479379	.45648283	-1.8401186	-46.059528
DOM	18871.377	.57409	.94462961	.83033311	13.785944	-6.762392
DZA	14551.485	.24858868	.8226999	.88474596	70.361885	-27.203905
ECU	12178.112	.63464582	.80907476	.83972847	-28.973389	-25.910892
EGY	15739.912	.42501581	.97270417	.89575201	42.46011	-22.299734
ESP	55540.348	.47999349	.69178373	.52950901	-32.949368	-63.288963
ETH	2001.5085	.34709328	.99612582	.9237144	43.246174	4.3161197
FRA	61215.82	.42952317	.47984272	.2127251	-46.736046	-74.542259
GAB	19198.613	.40116626	.85290688	.7041955	22.552519	-27.402355
GBR	55386.16	.47294986	.19167638	.30696738	-51.370808	-70.356552
GEO	8629.6055	.4205569	.97356004	.92317873	56.330154	11.483145
GER	60376.449	.45014486	.1989603	.23394805	-52.131054	-74.166313
GHA	3109.5029	.36462086	.98229206	.75973243	21.250496	-16.157288

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... table 12 continued

Country	Real GDP/Worker (PWT 6.3)	Relative Ag. Productivity	Home Bias in Ag	Home Bias in Nonag	Ag Import Barrier	Nonag Import Barrier
GMB	2867.2598	.26624116	.90920943	.61966658	36.30434	-16.088514
GRC	48963.172	.53542763	.79882061	.54401541	-8.650218	-47.199192
GTM	19613.189	.8248201	.98411417	.84365767	4.647737	-9.9256105
GUY	5755.3135	.470209	.9320249	.79902595	10.763121	-14.257613
HND	8106.8535	.57012063	.97656822	.79237938	6.1110044	-17.688372
HRV	21563.98	.47247696	.86566246	.589167	27.8923	-9.1185513
HUN	32281.992	.45421082	.84972095	.25820506	-12.490937	-45.643238
IDN	8827.8955	.31406319	.97858161	.91279435	-4.1200795	-56.2113
IRN	24279.256	.47311798	.96224785	.90294707	13.080079	-31.706249
ITA	65438.621	.43283814	.62625158	.45005322	-34.368046	-70.017349
JAM	17163.977	.46379858	.90370435	.65703332	7.1718373	-29.846788
JOR	16173.863	.4016206	.48802936	.6774441	14.357027	-19.893681
JPN	53166.207	.31194833	.57334828	.61662436	-31.655426	-72.500595
KAZ	15065.728	.41171774	.959952	.8687017	11.999783	-34.486782
KGZ	7831.019	.41997975	.9946304	.93580574	90.92321	18.829765
KHM	3811.2412	.24670576	.99335039	.7234664	124.21813	-15.165354
KOR	39495.418	.28960797	.84103942	.45653099	-6.4119534	-71.588135
LAO	3883.1799	.37166846	.99248093	.78021073	63.206375	6.1703076
LBY	42501.613	.49303922	.77914327	.88688254	17.761953	-9.0768642
LKA	10848.017	.49249989	.97575247	.83043873	-3.3311014	-28.865454
LTU	17925.152	.42437679	.81858528	.51731342	15.331088	-16.681107
LVA	17569.195	.36693966	.75201631	.28633946	18.558769	-29.939064
MAR	13006.281	.45928419	.927104	.74079555	3.4475424	-32.662697
MDA	5778.0376	.36736712	.97938186	.74590325	64.000237	9.0598278
MDG	2116.3748	.30560085	.98440021	.7474438	16.96875	-22.301098
MEX	26379.596	.393978	.81716233	.36352396	-14.011316	-59.917614
MKD	15400.013	.43038976	.89876306	.66855162	54.501045	7.944171
MLI	4272.3198	.30154476	.98487151	.85884619	67.92749	-7.9862909
MNG	4949.4604	.32729781	.96017265	.60031152	37.980572	-11.134032
MOZ	2643.6362	.36331731	.97207379	.86094666	32.287895	3.2383001
MRT	5089.9858	.44948477	.91180551	.77724105	-10.426609	-17.935457
MUS	34345.426	.62497592	.83736217	.79004896	-5.9959579	-19.806093
MYS	33878.715	.39930263	.1155616	.09930795	-52.302139	-73.056992
NER	2440.2144	.26194119	.98998141	.86838865	100.86871	18.319036
NGA	4234.168	.23728889	.9738096	.82959747	43.586437	-41.20121
NIC	5743.2651	.54447824	.9832809	.81121922	9.5045967	-6.6013904
NPL	4679.5435	.37024894	.99880934	.9483645	104.91924	18.450016
OMN	64533.863	.56666619	.48471743	.45963252	-20.699299	-41.747982
PAK	9059.4248	.35754877	.99065626	.88874733	35.617798	-36.012218
PAN	16515.746	.39707556	.87120342	.13788819	-20.300501	-55.828621
PER	11026.101	.48054996	.91168296	.81760824	-17.149261	-42.004776
PHL	9777.0186	.34894532	.95292133	.61925316	5.1450987	-49.129383
PNG	5147.5142	.38255289	.97337526	.77683401	22.000086	-16.372852
POL	23813.854	.45402408	.8617813	.65672165	-10.345575	-39.855751

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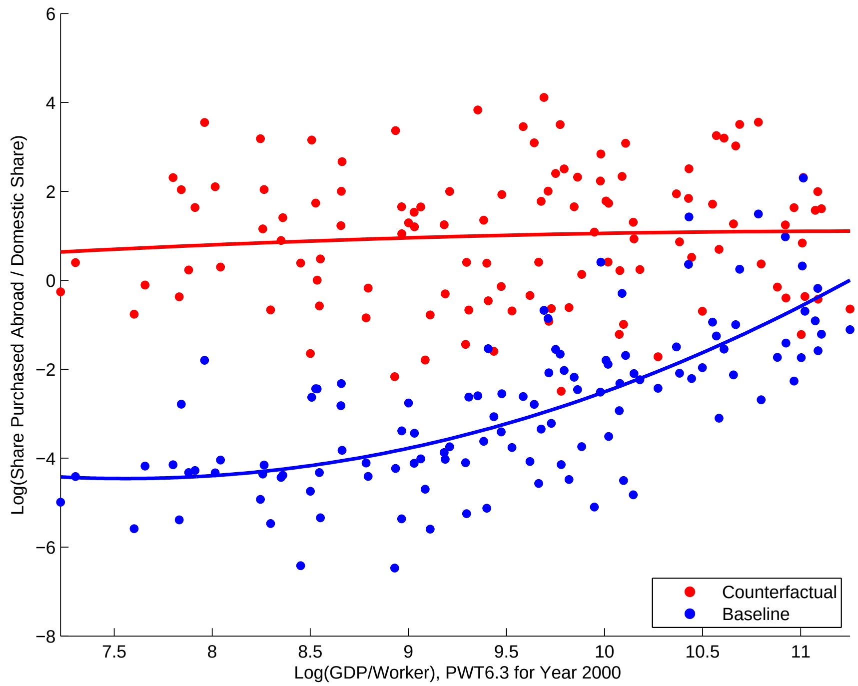
... table 12 continued

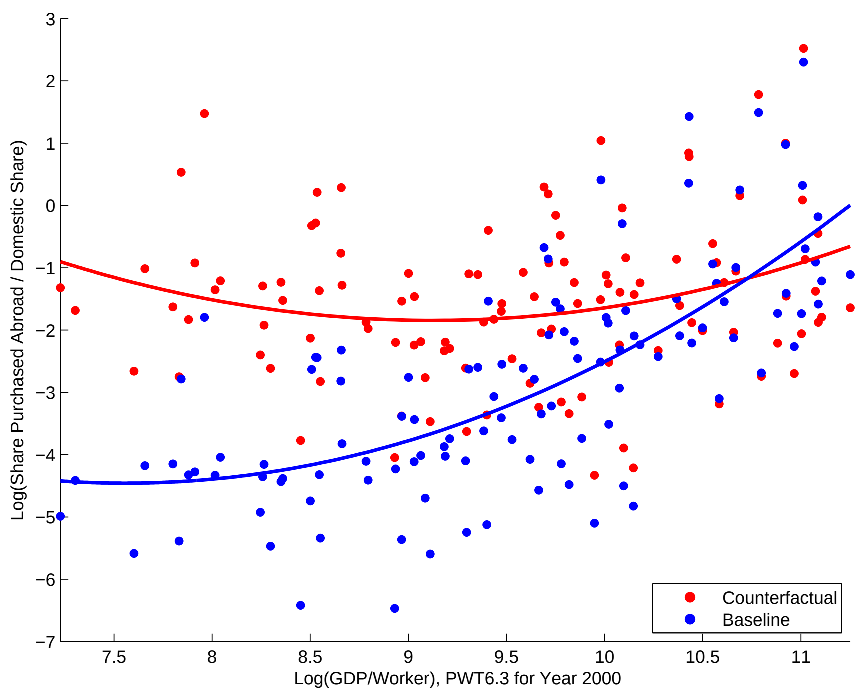
Country	Real GDP/Worker (PWT 6.3)	Relative Ag. Productivity	Home Bias in Ag	Home Bias in Nonag	Ag Import Barrier	Nonag Import Barrier
PRT	38223.16	.4306064	.60384381	.42459369	-14.400739	-53.67141
PRY	10000.54	.45730346	.9551084	.74019635	49.548306	-16.345976
ROM	11892.55	.3478418	.95351768	.73561662	30.557854	-34.01915
RUS	16792.43	.33892775	.90989524	.90612638	-6.7339177	-49.172535
SAU	57897.566	.35190997	.76930201	.80598259	11.971082	-46.539055
SDN	5175.5542	.36969495	.9942534	.91511351	61.522282	-8.2719154
SLE	3026.7737	.2853317	.99199003	.89181894	95.976143	15.57388
SLV	13053.375	.60670823	.96081477	.83843374	15.87324	-13.850939
SUR	22195.484	.55933756	.90996349	.72771931	1.5714281	-22.388821
SVK	24524.709	.39087147	.79760838	.44502318	17.925068	-33.120319
SVN	38960.258	.3969709	.64999944	.27385515	11.000682	-41.536098
SYR	8355.4863	.39964205	.94422925	.76356459	20.058931	-24.974756
TGO	2544.9956	.27694082	.96148098	.61944824	20.037184	-23.952509
THA	12530.275	.38763082	.92903525	.64243913	-32.958405	-63.073338
TJK	6530.2212	.44627711	.97833043	.97203553	20.12665	12.346147
TKM	20911.957	.43660912	.99226308	.96496046	93.682884	20.936636
TTO	33820.656	.57613021	.54945815	.75556767	-21.91465	-23.144445
TUN	22505.564	.41643357	.9370814	.63800621	33.481415	-29.153522
TUR	18381.109	.41552803	.97293139	.65911072	3.6455681	-51.358505
TZA	1376.3237	.25590083	.99364263	.81406415	34.848835	-19.801512
UGA	2519.8564	.42649615	.99762428	.95553136	48.702965	33.835415
UKR	12087.757	.31721985	.98681301	.88269752	57.582664	-28.444921
URY	24083.666	.64031476	.82175672	.71544683	-21.733906	-37.96516
USA	77003.289	.49307323	.67464781	.58444643	-54.888073	-76.028572
UZB	3857.9875	.28255773	.98547316	.84358966	40.940517	-23.165609
VEN	25604.17	.42014474	.84088588	.82016724	.2384045	-41.836048
VNM	4914.9805	.35769731	.98893237	.83897406	2.478817	-38.810883
YEM	5050.4082	.32764158	.79635417	.84302258	15.492043	-19.490442
ZAF	23749.947	.4343161	.89864075	.76840812	-23.157085	-54.141731
ZMB	2729.6191	.26534802	.9891625	.66928852	51.460373	-19.407759
ZWE	10903.287	.45615458	.99608648	.88828504	53.36005	-11.625922

Figure 5: Normalized Import Shares: No Import Barriers



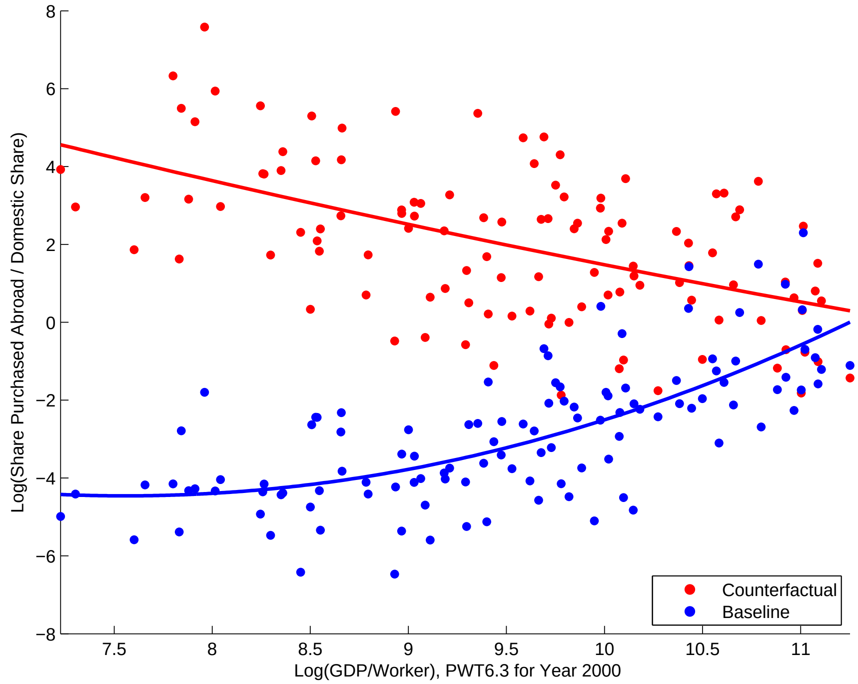
Display result of setting import barriers to the average level in rich-countries. Poor country normalized import shares increase slightly more than rich. The resulting normalized import share is unrelated to income. Dots represent countries with a quadradic best-fit line also illustrated.

Figure 6: Normalized Import Shares: No Labour Mobility Costs



Display result of removing labour mobility costs, $\xi_i = 1$, in all countries. Poor country normalized import shares increase as a result. Dots represent countries with a quadradic best-fit line also illustrated.

Figure 7: Normalized Import Shares: No Import Barriers or Labour Mobility Costs



Display result of removing both labour mobility costs, $\xi_i = 1$, and setting import barriers to the average of rich-country levels. Normalized import shares increase more in poor countries than rich. Dots represent countries with a quadradic best-fit line also illustrated.

Figure 8

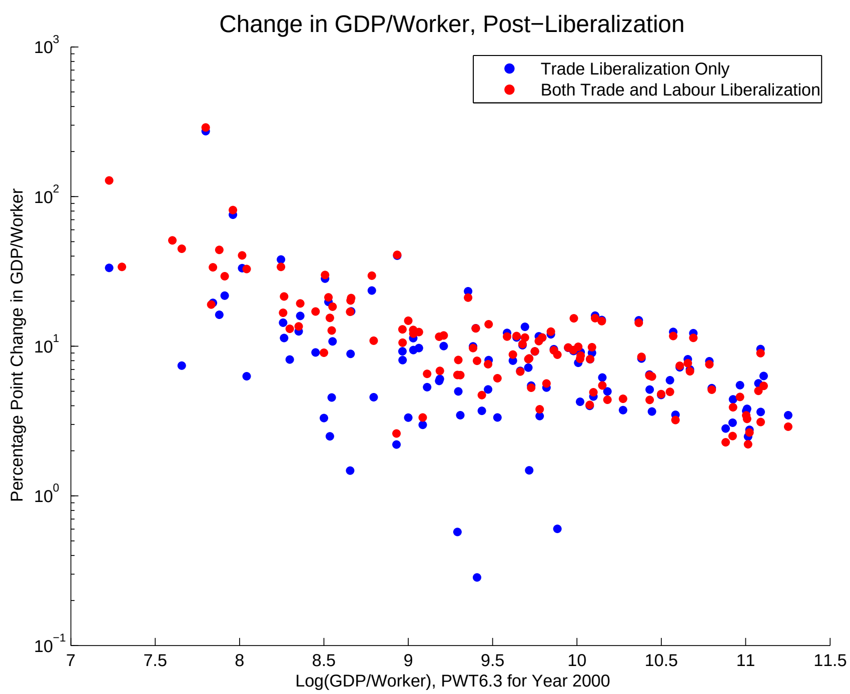


Figure 9: Real Output-per-Worker in Agriculture Relative to Manufacturing

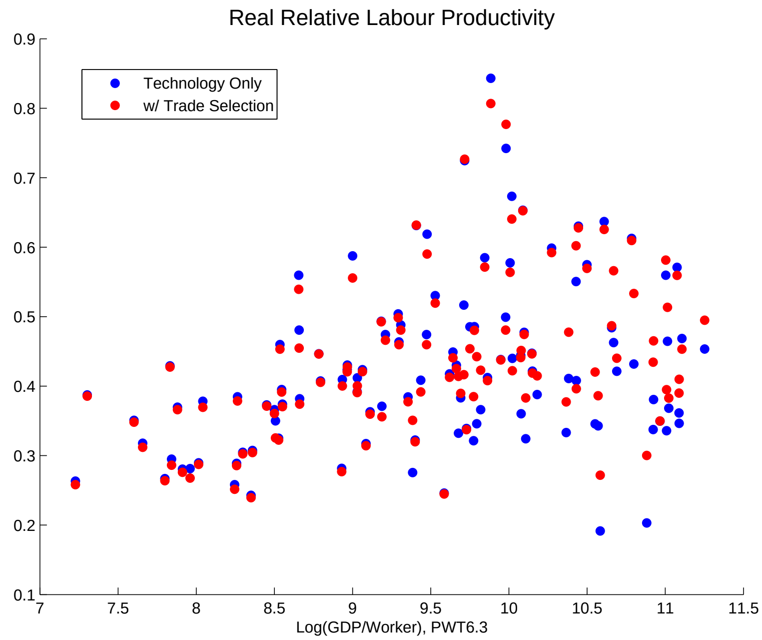


Figure 10: Agricultural Labour Productivity, Model Estimates vs. Data

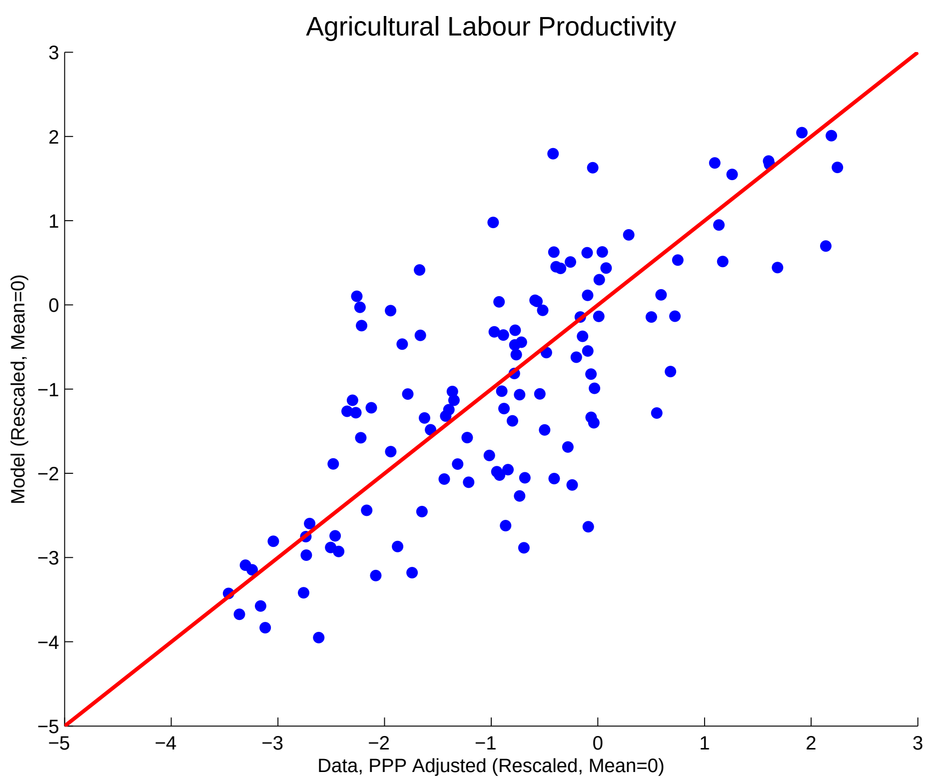
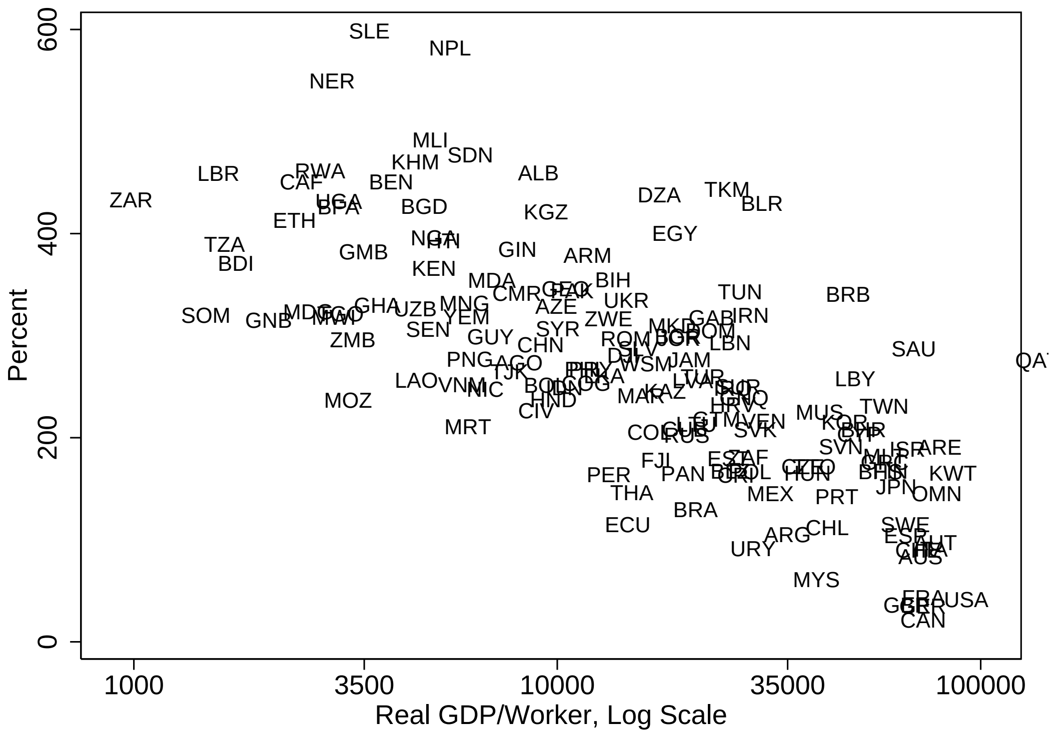


Figure 11: Trade Cost Estimates for Agricultural Goods

(a) Overall (Trade Weighted) Trade Barriers



(b) Importer-Specific Fixed Effects

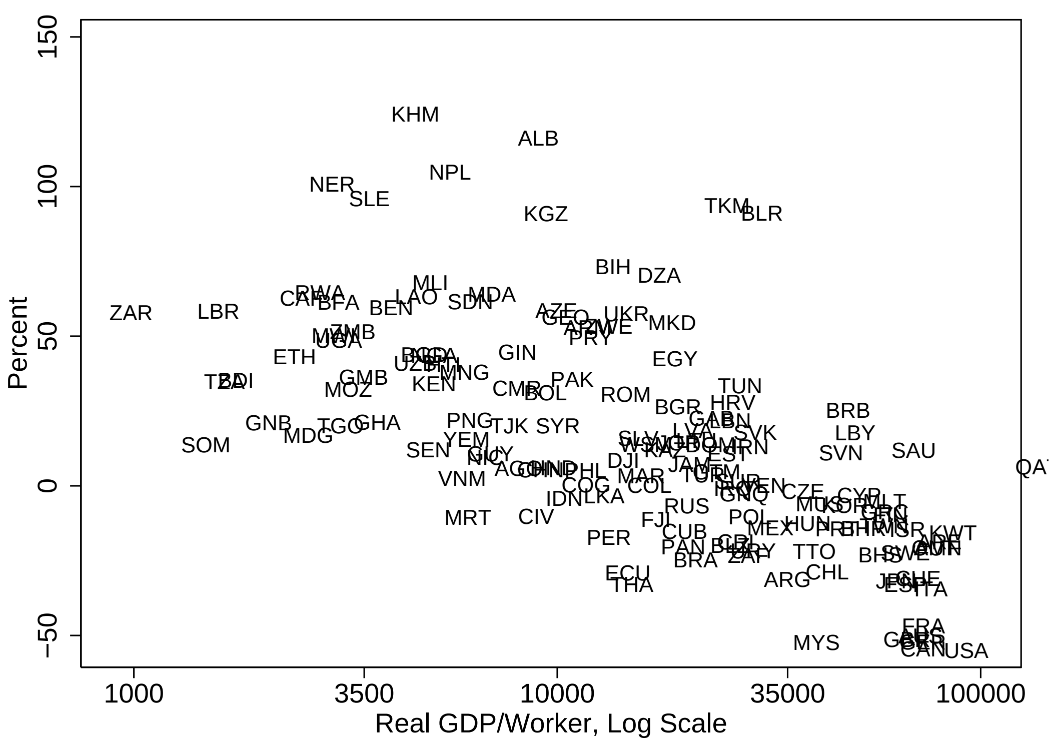
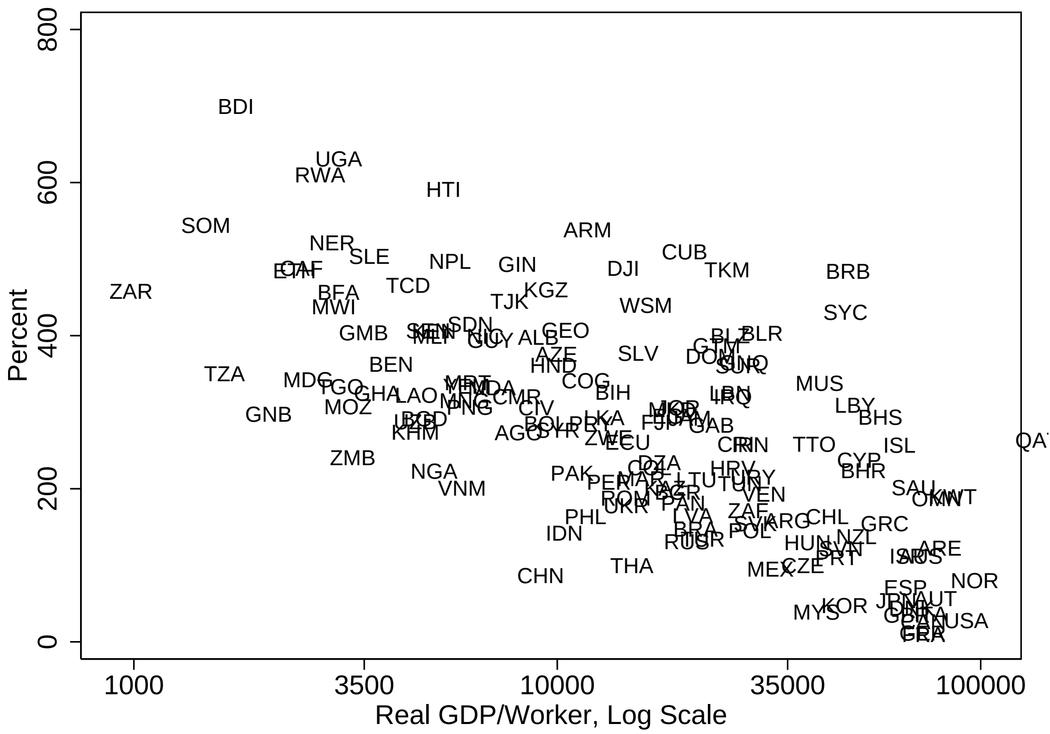


Figure 12: Trade Cost Estimates for Manufactured Goods

(a) Overall (Trade Weighted) Trade Barriers



(b) Importer-Specific Fixed Effects

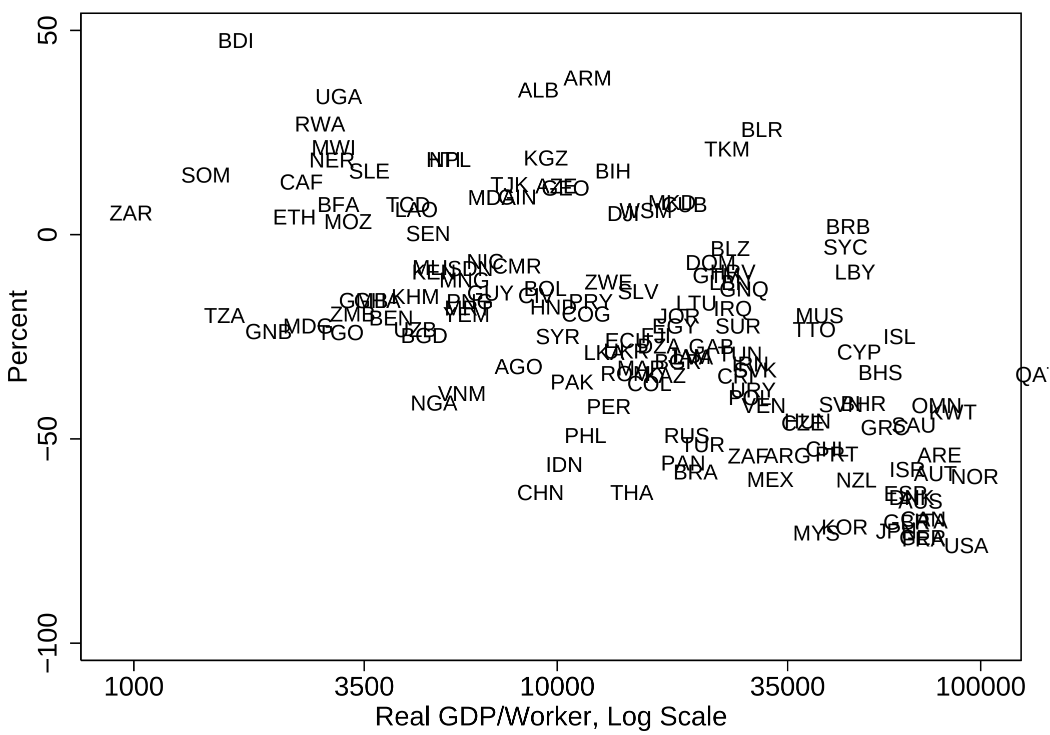


Figure 13: Competitiveness Measure for Agriculture

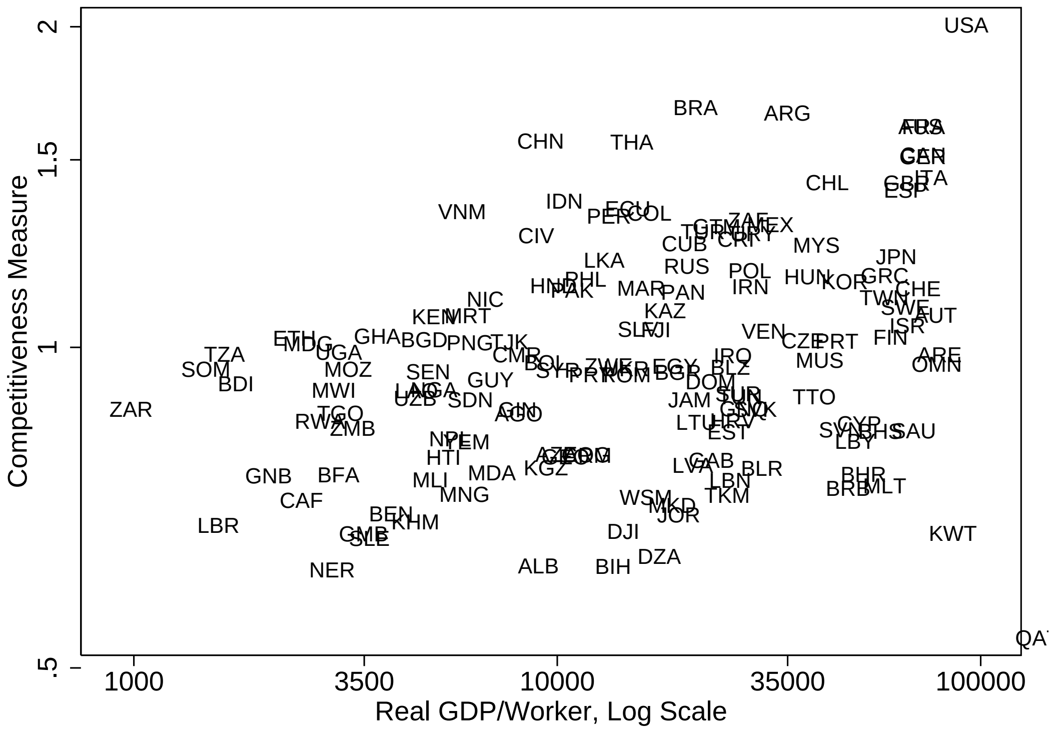


Figure 14: Competitiveness Measure for Manufacturing

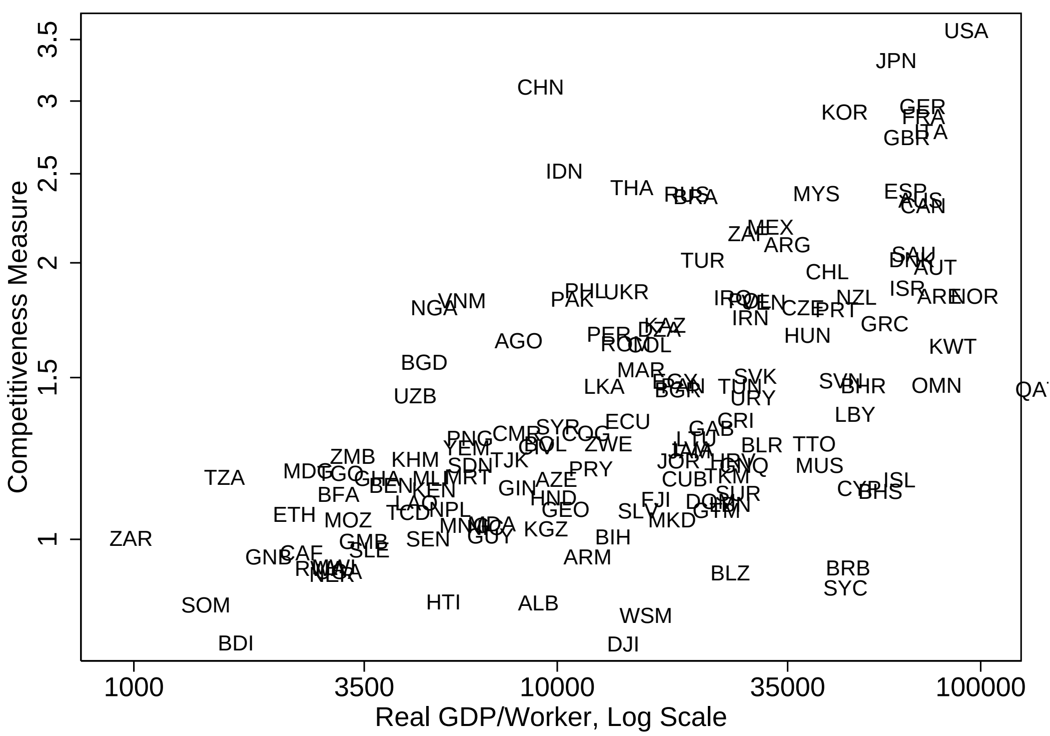


Figure 15: Import Shares of Poorest Countries, by Source Country Percentile

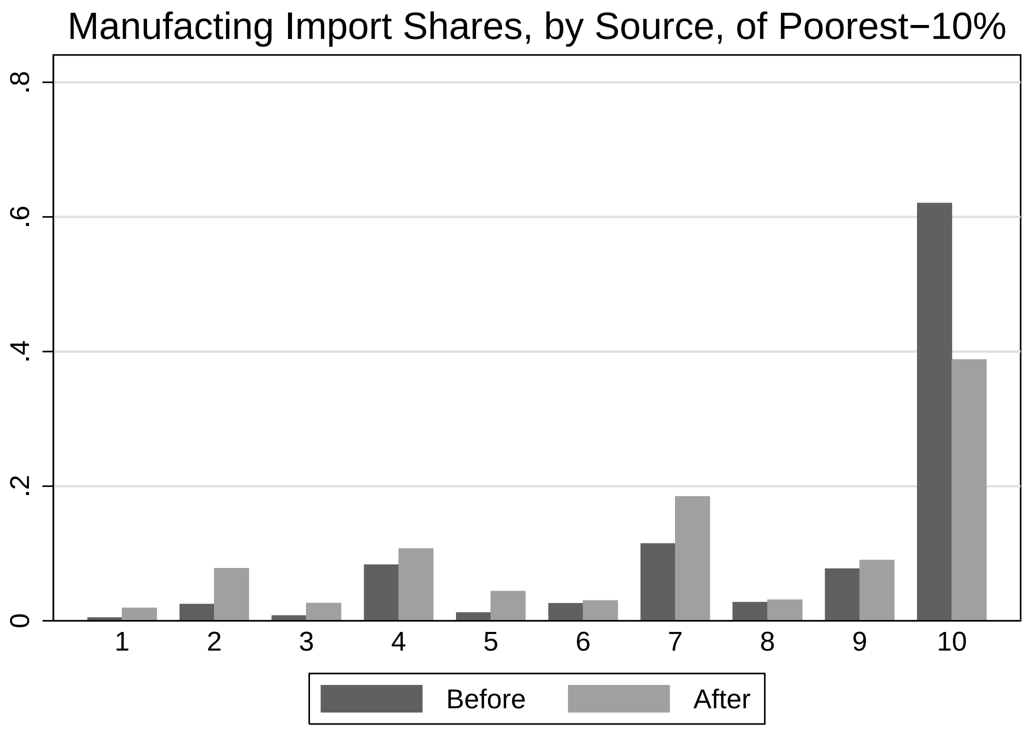


Figure 16: Import Shares of Richest Countries, by Source Country Percentile

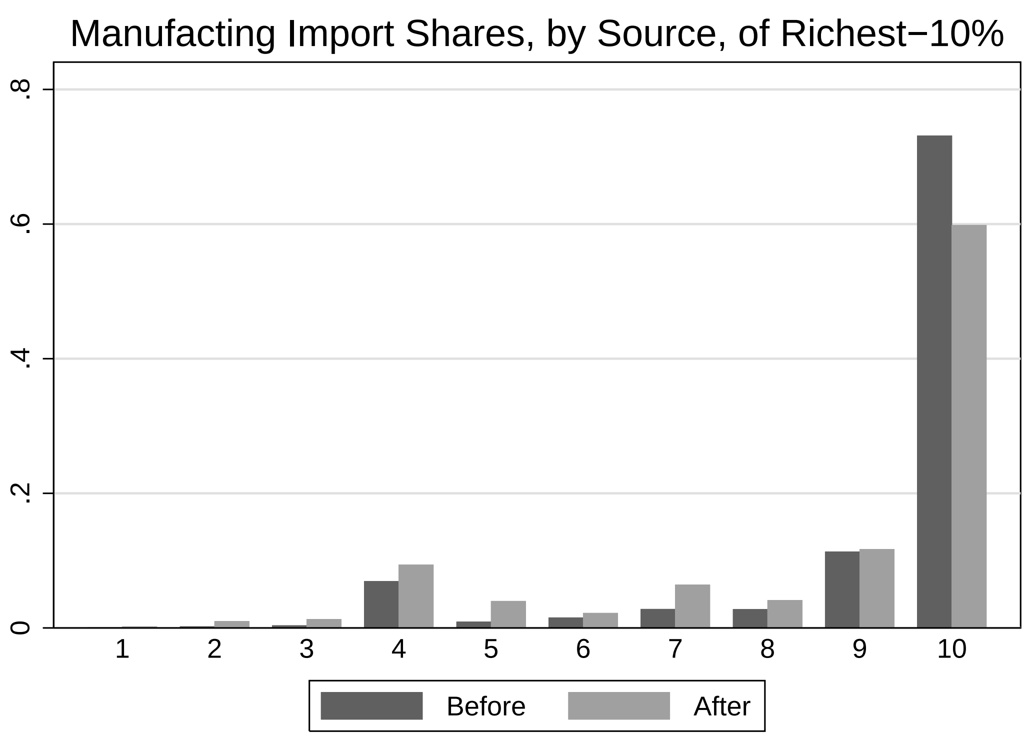


Figure 17: Increasing S-S Trade, Following Full Removal of Import Barriers

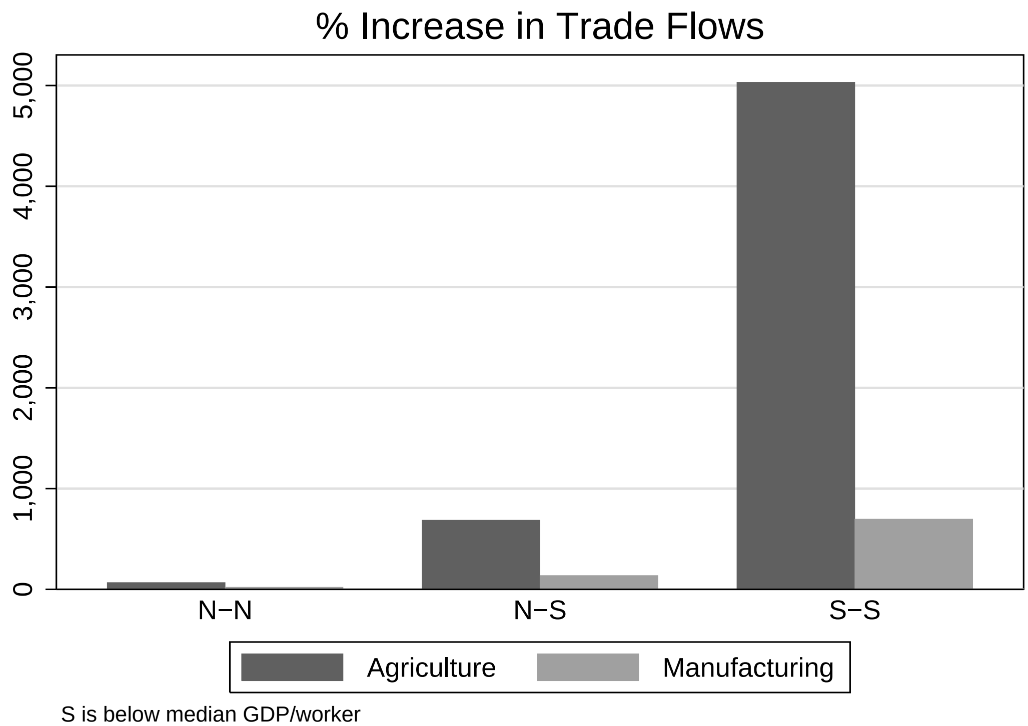


Figure 18: Increasing S-S Trade, Following Full Removal of Import Barriers

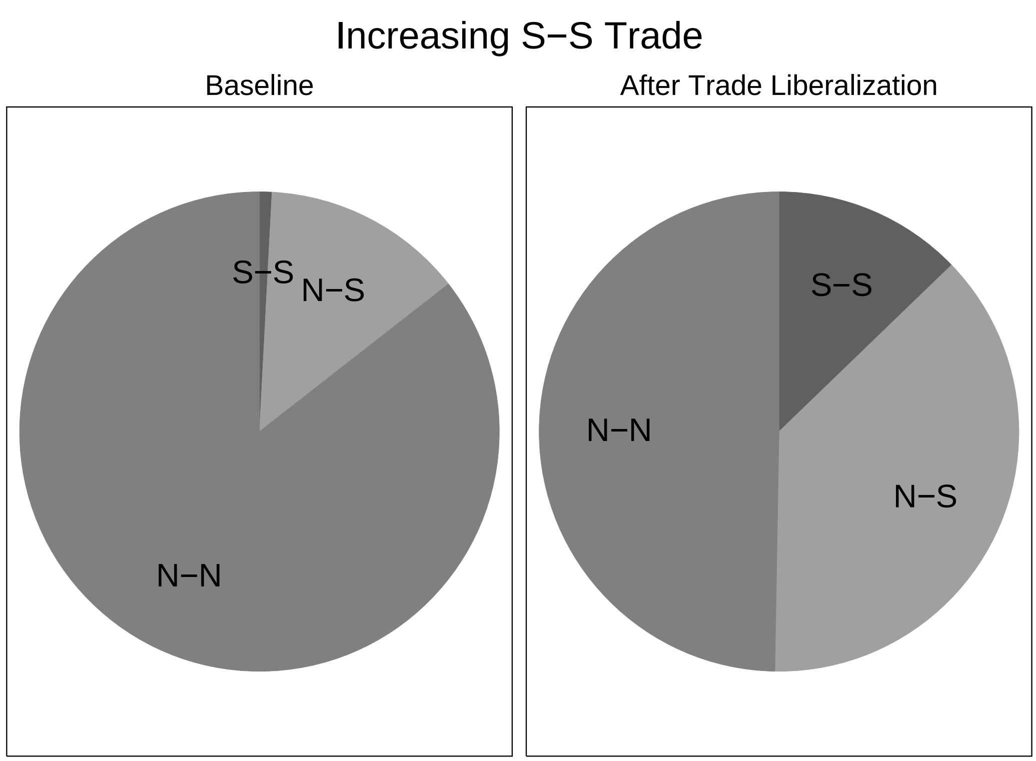


Figure 19: Increased Share of Agriculture in Total Exports Following Trade Liberalization

Figure 20: FAO Food Prices are Higher than ICP Prices, Especially for Poor Countries