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Capital Goods Trade, Relative Prices, and Economic Development*

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Abstract

International trade in capital goods has quantitatively important effects on economic development through two channels: capital formation and aggregate TFP. We embed a multi country, multi sector Ricardian model of trade into a neoclassical growth framework. Our model matches several trade and development facts within a unified framework: the world distribution of capital goods production and trade, cross-country differences in investment rate and price of final goods, and cross-country equalization of price of capital goods. Reducing barriers to trade capital goods allows poor countries to access more efficient means of capital goods production abroad, leading to relatively higher capital-output ratios. Meanwhile, poor countries can specialize more in their comparative advantage—non-capital goods production—and increase their TFP. The income gap between rich and poor countries declines by 40 percent by eliminating barriers to trade capital goods.

JEL codes: O11, O4, F11, E22

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1 Introduction

Cross-country differences in income per worker are large: The income per worker in the top decile is more than 50 times the income per worker in the bottom decile (Penn World Tables version 8.1; see Feenstra, Inklaar, and Timmer, 2015). Development accounting exercises such as those by Caselli (2005), Hall and Jones (1999), and Klenow and Rodríguez-Clare (1997) show that roughly 50 percent of the differences in income per worker are accounted for by differences in factors of production (capital and labor) and the rest is attributed to differences in aggregate total factor productivity (TFP).

In this paper, we provide a quantitative theory of economic development in which international trade in capital goods is an important component. Two facts motivate our emphasis on capital goods trade: (i) capital goods production is concentrated in a few countries (noted in Eaton and Kortum (2001)) and (ii) the dependence on capital goods imports is negatively related to economic development. Ten countries account for almost 80 percent of world capital goods production. Capital goods production is more concentrated than gross domestic product (GDP) and other manufactured goods.[1] The second fact is that the imports-to-production ratio for capital goods is negatively correlated with income per worker. Malawi imports 14 times as much capital goods as it produces, Greece imports twice as much as it produces, while the US imports just over half as much as it produces.

In our theory, international trade in capital goods affects economic development through two channels: capital and TFP. First, reductions in barriers to trade capital goods allows poor countries access more efficient technologies for capital goods production in rich countries. This reduces their relative price of investment relative to rich countries and, as a result, poor countries increase their investment rate and steady-state capital-output ratio relative to those in rich countries. Second, by importing more capital goods from rich countries, the poor countries allocate their resources more efficiently by specializing more in their comparative advantage—non-capital goods production—which increases their TFP relative to rich countries. Both channels reduce the cross-country income differences. Quantitatively, we demonstrate that the reduction in income differences due to the second channel is as large as that due to the first channel.

[1] Sixteen countries account for 80 percent of the world's GDP while seventeen countries account for 80 percent of the global output of intermediate goods.

We embed a multi country Ricardian model into a neoclassical growth model. Our Ricardian framework builds on Alvarez and Lucas (2007), Dornbusch, Fischer, and Samuelson (1977), Eaton and Kortum (2002), and Waugh (2010). Each country is endowed with labor that is not mobile internationally. In contrast to the above trade papers, capital is an endogenous factor of production in our model. Each country has technologies for producing a final consumption good, structures, a continuum of capital goods, a continuum of intermediate goods (i.e., non-capital goods), and a composite intermediate good. All of the capital goods and intermediate goods can be traded. Neither the final consumption good nor structures can be traded. Countries differ in their distributions of productivities in both capital goods and intermediate goods. Trade barriers are assumed to be bilateral iceberg costs. We model other domestic distortions via final goods productivity in each country.

Differences in income per worker in our model are a function of (i) differences in standard development accounting elements, such as final goods productivity and capital-output ratio, and (ii) differences in international trade elements, such as barriers to trading capital goods and intermediate goods, and comparative productivities in capital goods and intermediate goods sectors.[2]

We calibrate the model to be consistent with the observed bilateral trade in capital goods and intermediate goods, the observed relative prices of capital goods and intermediate goods, and income per worker. Our model fits these targets well. For instance, the correlation in home trade shares between the model and the data is 0.90 for capital goods and is 0.93 for intermediate goods; the correlation between model and data income per worker is 1.

Our model reconciles several trade and development facts in a unified framework. First, we account for the fact that a few countries produce most of the capital goods in the world: In our model and in the data, 10 countries account for 80 percent of the world capital goods production. The pattern of comparative advantage in our model is such that poor countries are net importers of capital goods and net exporters of intermediate goods.

Second, the contribution of factor differences in accounting for cross-country income differences in our model is similar to the contribution in the data.

[2]In the *closed economy* models of Buera, Kaboski, and Shin (2011) and Greenwood, Sanchez, and Wang (2013), cross-country differences in financial frictions generate cross-country differences in capital. Our motivating facts suggest that closed economy models can provide only part of the reason for cross-country differences in capital.

Third, we deliver the facts that the investment rate measured in domestic prices is uncorrelated with income per worker and the investment rate measured in international prices is positively correlated with income per worker, facts noted previously by Restuccia and Urrutia (2001) and Hsieh and Klenow (2007).

Fourth, our model is consistent with observed prices. As Hsieh and Klenow (2007) point out, the price of capital goods is roughly the same across countries and the relative price of capital is higher in poor countries because the price of the nontradable consumption good is lower in poor countries. In our model, the elasticity of the price of capital goods with respect to income per worker is 0.01, compared to -0.01 in the data. The elasticity of the price of consumption goods is 0.37 in the model and 0.31 in the data. Our model is also consistent with the fact that the price of structures is positively correlated with economic development.

We then compare our benchmark model to a world with no frictions in capital goods trade but with the calibrated barriers in the trade of other goods. In this counterfactual experiment, the gap in capital-output ratio (or the gap in investment rate) between rich and poor countries decreases from 1.6 to 1.2 and the gap in income per worker decreases from roughly 28 to almost 17. (Aggregate capital in our model is a Cobb-Douglas aggregate of producer durables and structures.)

In this counterfactual, the relative price of capital plays a key role. As trade barriers are reduced, the relative price of capital decreases in poor countries. That is, the amount of consumption good that a household has to give up in order acquire a unit of investment decreases. This, in turn, increases the investment rate in poor countries relative to rich countries. In the benchmark, the investment rate in rich countries is 60 percent higher than that in poor countries while in the counterfactual it is only 20 percent higher. Consequently, the capital-output ratio increases in poor countries and so does income.

Restuccia and Urrutia (2001) use a neoclassical growth model with *exogenous* relative price of capital and document the reduction in capital-output ratio differences and, hence, income differences due to the reduction in differences in the relative price of capital. In our model, reduction in trade barriers endogenously reduces the differences in relative price of capital. In addition, the reduction in trade barriers also reduce the cross-country differences in TFP and, hence, income differences. This additional effect is absent in Restuccia and Urrutia (2001) since measured TFP is orthogonal to capital-output ratio in the neoclassical growth model. This additional effect is quantitatively important. Without the additional effect via TFP, the income gap in our model would have decreased from roughly 28 to almost 23, a reduction of 18 percent, but the with the additional effect the reduction is almost 40 percent.

Hsieh (2001) provides evidence on the channel in our model via a contrast between Argentina and India. During the 1990s, India reduced barriers to capital goods imports that resulted in a 20 percent fall in the relative price of capital between 1990 and 2005. This led to a surge in capital goods imports, and the investment rate increased 1.5-fold during the same time period. After the Great Depression, Argentina restricted imports of capital goods. From the late 1930s to the late 1940s, the relative price of capital doubled and the investment rate declined.

The experience of Korea also presents some evidence in favor of the channel in our model. Korea's trade reforms starting in 1960s reduced the restrictions on imports of capital goods (see Westphal, 1990; Yoo, 1993). During 1970-80, Korea's imports of capital goods increased 11-fold. Over a period of 40 years, the relative price of capital in Korea decreased by a factor of almost 2 and the investment rate increased by a factor of more than 4 (Nam, 1995). (See also Rodriguez and Rodrik, 2001, for a discussion of trade policies affecting relative prices.)

In related work, Eaton and Kortum (2001) also quantify the role of capital goods trade barriers in accounting for cross-country income differences. They construct a "trade-based" price of capital goods using a gravity regression. As noted by Hsieh and Klenow (2007), the trade-based price of capital goods is negatively correlated with economic development whereas in the data the price is practically uncorrelated with economic development. And, the negative correlation between the *relative* price of capital goods and economic development is mainly due to the fact that price of final goods is positively correlated with economic development. Changes in capital goods trade barriers affect the relative price of capital in Eaton and Kortum (2001) only through the changes in the absolute price of capital since they hold fixed the price of final goods. In our model, removing capital goods trade barriers changes mainly the cross-country distribution of the final good price. The resulting change in the relative price of capital affects the investment rates in our model and the cross-country distribution of income.

In Hsieh and Klenow (2007), eliminating capital goods trade barriers has no effect on the investment rate in poor countries relative to rich countries for two reasons. First, in their model, the inferred capital goods trade barriers are no different in poor countries than in rich countries, so a removal of these barriers has essentially no effect on the *difference* in the absolute price of capital between rich and poor countries. Second, the trade barriers in their model do not affect the price of the final consumption good. As a result, removing barriers to trade in capital goods does not alter the cross-country differences in relative price of capital and, hence, does not affect the cross-country differences in investment rates. In our model, removal of capital goods trade barriers leads to an increase in the price of final goods in poor countries relative to rich countries. The resulting decline in the relative price of capital in poor countries leads to an increase in their investment rates.

In Armenter and Lahiri (2012), policies that affect relative prices and investment rates also affect measured TFP, generating an amplification effect on cross-country income differences, as in our model. However, we do not assume free trade in capital goods in order deliver prices of capital goods that are similar to those in the data. Instead, we infer the barriers that are consistent with both the prices and the trade volumes. In turn, our model is able to simultaneously deliver the world distribution of capital goods production, investment, and and trade flows.

The rest of the paper is organized as follows. Section 2 develops the multi country Ricardian trade model and describes the equilibrium. Section 3 describes the calibration. The quantitative results are presented in Section 4. Section 5 concludes.

2 Model

Our model extends the framework of Alvarez and Lucas (2007), Eaton and Kortum (2002), and Waugh (2010) to two tradable sectors and embeds it into a neoclassical growth framework (see also Mutreja, 2016). There are I countries indexed by $i = 1, \ldots, I$. Time is discrete and runs from $t = 0, 1, \ldots, \infty$. There are two tradable sectors, capital goods and intermediates (or non-capital goods), and two nontradable sectors, structures and final goods. (We use "producer durables" and "capital goods" interchangeably.) The capital goods and intermediate goods sectors are denoted by e and m, respectively, while the structures and final goods sectors are denoted by s and f. Within each tradable sector there is a continuum of varieties. Individual capital goods varieties are aggregated into a composite producer durable, which augments the stock of producer durables. Individual intermediate goods varieties are aggregated into a composite intermediate good. The composite intermediate good is an input in all sectors. Final goods are consumed locally.

Each country i has a representative household with a measure L_i of workers.[3] Labor is immobile across countries but perfectly mobile across sectors within a country. The household owns its country's stock of producer durables and stock of structures. The respective capital stocks in period t are denoted by K^e_{it} and K^s_{it}. They are rented to domestic firms. Earnings from capital and labor are spent on consumption and investments in producer durables and structures. The two investments augment the respective capital stocks. Henceforth, all quantities reported using lower case letters denote per worker values, i.e., $k^e_{it} = K^e_{it}/L_{it}$ and, where it is understood, country and time subscripts are omitted and we focus only on the solution to the steady state of the model.

2.1 Endowments

The representative household in country i supplies its labor L_{it} at time t inelastically to all domestic firms.

2.2 Technology

There is a unit interval of varieties in the two tradable sectors: capital goods and intermediate goods. Each variety within each sector is tradable and is indexed along the unit interval by $v_b \in [0, 1]$ for $b \in \{e, m\}$.

Composite goods Within each tradable sector, all of the varieties are combined with constant elasticity in order to construct a sectoral composite good according to

$$q_{ei} = \left[\int_0^1 q_{ei}(v_e)^{1-1/\eta} dv_e\right]^{\eta/(\eta-1)} \text{ and } q_{mi} = \left[\int_0^1 q_{mi}(v_m)^{1-1/\eta} dv_m\right]^{\eta/(\eta-1)}$$

where η is the elasticity of substitution between any two varieties.[4] The term $q_{bi}(v_b)$ is the quantity of variety v_b used by country i to produce the sector b composite intermediate good. The composite intermediate good, q_{mi}, is used by domestic firms in

[3] We have also solved the model using efficiency units of labor constructed via years of schooling and Mincer returns. We also allowed for growth over time in the number of workers, as well as growth in the efficiency units of labor. None of these extensions affect our quantitative results.

[4] The value of η plays no quantitative role other than satisfying technical conditions which ensure convergence of the integrals.

country i as an intermediate input in production in all sectors. The composite capital good, q_{ei}, augments the domestic stock of producer durables.

Varieties Each variety can be produced by any country using the stock of structures, the stock of producer durables, labor, and the composite intermediate good. The technologies for producing varieties in sectors e and m are

$$\begin{aligned} y_{ei}(v_e) &= z_{ei}(v_e)\left[(k^e_{ei}(v_e)^{\mu}k^s_{ei}(v_e)^{1-\mu})^{\alpha}\ell_{ei}(v_e)^{1-\alpha}\right]^{\nu_e} m_{ei}(v_e)^{1-\nu_e}, \\ y_{mi}(v_m) &= z_{mi}(v_m)\left[(k^e_{mi}(v_m)^{\mu}k^s_{mi}(v_m)^{1-\mu})^{\alpha}\ell_{mi}(v_m)^{1-\alpha}\right]^{\nu_m} m_{mi}(v_m)^{1-\nu_m}. \end{aligned}$$

The term $m_{bi}(v_b)$, for $b \in \{e, m\}$, denotes the quantity of the composite intermediate good used by country i as an input to produce variety v_b, $\ell_{bi}(v_b)$ denotes the quantity of labor employed, and $k^e_{bi}(v_b)$ and $k^s_{bi}(v_b)$ denote the stocks of producer durables and structures capital.

The parameter $\nu_b \in [0, 1]$, for $b \in \{e, m\}$, denotes the share of value added in total output in sector b. The share of capital in the value added is determined by α, while $\mu \in [0, 1]$ denotes the share producer durables in the capital stock composite. All of these parameters are constant across countries, and α and μ are constant across sectors as well.

Following Eaton and Kortum (2002), the term $z_{bi}(v_b)$ determines the productivity for variety v_b in country i. The productivity is drawn from independent country- and sector-specific Fréchet distributions. The shape parameter θ is the same across sectors and countries; the scale parameter, T_{bi}, for $b \in \{e, m\}$, and $i = 1, 2, \ldots, I$ is sector- and country-specific. The c.d.f. for productivity draws in sector b in country i is $F_{bi}(z) = \exp(-T_{bi}z^{-\theta})$. From now on we will denote each variety in sector b by just its productivity z_b, as in Alvarez and Lucas (2007).

Within each sector, the expected value of productivity in country i across the continuum of varieties is $\gamma^{-1}T_{bi}^{\frac{1}{\theta}}$, where $\gamma = \Gamma(1 + \frac{1}{\theta}(1-\eta))^{\frac{1}{1-\eta}}$ and $\Gamma(\cdot)$ is the gamma function. We refer to $T_{bi}^{\frac{1}{\theta}}$ as the fundamental productivity in sector b in country i.[5] If $T_{ei} > T_{ej}$, then on average, country i is more efficient than country j at producing capital goods. Average productivity at the sectoral level determines specialization

[5] As discussed in Waugh (2010) and Finicelli, Pagano, and Sbracia (2012), fundamental productivity differs from measured productivity because of selection. In a closed economy, country i produces all varieties in the continuum so its measured productivity is equal to its fundamental productivity. In an open economy, country i produces only the varieties for which it has a comparative advantage, and imports the rest. So its measured productivity is higher than its fundamental productivity.

across sectors. A country with a relatively large ratio T_e/T_m will tend to be a net exporter of capital goods and a net importer of intermediate goods. The parameter $\theta > 0$, governs the coefficient of variation of the productivity draws. A smaller value of θ implies more variation in productivity draws across varieties and, hence, more room for specialization within each sector.

Nontradable goods Final goods and structures are nontradable. The final good is produced domestically using capital, labor, and intermediates according to

$$y_{fi} = A_{fi} \left[((k_{fi}^e)^{\mu} (k_{fi}^s)^{1-\mu})^{\alpha} \ell_{fi}^{1-\alpha} \right]^{\nu_f} m_{fi}(v_f)^{1-\nu_f}.$$

Country-specific TFP in final goods is given by A_{fi}.

Structures are produced similarly:

$$y_{si} = A_{si} \left[((k_{si}^e)^{\mu} (k_{si}^s)^{1-\mu})^{\alpha} \ell_{si}^{1-\alpha} \right]^{\nu_s} m_{si}(v_s)^{1-\nu_s}.$$

Capital accumulation As in the standard neoclassical growth model, the representative household enters each period with predetermined stocks of producer durables and structures. The stocks accumulate according to

$$k_{t+1}^e = (1 - \delta_e) k_t^e + x_t^e,$$
$$k_{t+1}^s = (1 - \delta_s) k_t^s + x_t^s.$$

The rate of depreciation of the stock of producer durables is given by δ_e, and that for structures is given by δ_s. The terms x_t^e and x_t^s denote the investment flow in period t.

We define the aggregate capital stock per worker as

$$k = (k^e)^{\mu} (k^s)^{1-\mu}.$$

International trade Trade is Ricardian: country i purchases each variety z_b from its least cost supplier. International trade is subject to barriers that take the iceberg form and vary across sectors. Country i must purchase $\tau_{bij} \geq 1$ units of sector b goods from country j in order for one unit to arrive; $\tau_{bij} - 1$ units *melt* away in transit. We assume that $\tau_{bii} = 1$ for all (b, i).

2.3 Preferences

The representative household values the stream of consumption according to

$$\sum_{t=0}^{\infty} \beta^t \ln(c_t),$$

where $\beta < 1$ is the period discount factor.

2.4 Equilibrium

A competitive equilibrium satisfies the following conditions: 1) the representative household maximizes utility taking prices as given, 2) firms maximize profits taking prices as given, 3) each country purchases each good from its least cost supplier and 4) markets clear.

We take world GDP as the numéraire. Recall that we focus on steady states.

2.4.1 Household optimization

In each period, the stocks of producer durables and structures are rented to domestic firms at the competitive rental rates r_{ei} and r_{si}. The household splits its income between consumption, c_i, which has price P_{fi}, and investments in producer durables and in structures, x_i^e and x_i^s, which have prices P_{ei} and P_{si}, respectively.

The household is faced with a standard consumption-savings problem, the solution to which is characterized by two Euler equations, a budget constraint, and two capital accumulation equations. In steady state these conditions are as follows:

$$r_{ei} = \left[\frac{1}{\beta} - (1 - \delta_e)\right] P_{ei},$$
$$r_{si} = \left[\frac{1}{\beta} - (1 - \delta_s)\right] P_{si},$$

$$P_{fi}c_i + P_{ei}x_i^e + P_{si}x_i^s = w_i + r_{ei}k_i^e + r_{si}k_i^s,$$

$$x_i^e = \delta_e k_i^e, \text{ and}$$
$$x_i^s = \delta_s k_i^s.$$

2.4.2 Firm optimization

Since markets are perfectly competitive, prices equal marginal costs. Denote the price of variety z_b, produced by country j and purchased by country i, by $p_{bij}(z_b)$. Then $p_{bij} = p_{bjj}(z_b)\tau_{bij}$, where $p_{bjj}(z_b)$ is the marginal cost of producing variety z_b in country j. Since country i purchases variety z_b from the country that can deliver it at the lowest price, the price in country i must be $p_{bi}(z_b) = \min_{j=1,\ldots,I}[p_{bjj}(z_b)\tau_{bij}]$. The price of the sector b composite good in country i is then

$$P_{bi} = \gamma_b \left[\sum_k (u_{bk}\tau_{bik})^{-\theta} T_{bk} \right]^{-\frac{1}{\theta}} \tag{1}$$

where $u_{bi} = \left(\frac{r_i^e}{\mu\alpha\nu_b}\right)^{\mu\alpha\nu_b} \left(\frac{r_i^s}{(1-\mu)\alpha\nu_b}\right)^{(1-\mu)\alpha\nu_b} \left(\frac{w_i}{(1-\alpha)\nu_b}\right)^{(1-\alpha)\nu_b} \left(\frac{P_{mi}}{1-\nu_b}\right)^{1-\nu_b}$ is the unit cost for a bundle of inputs for producers in sector b in country i.

Next we define sectoral aggregates for inputs and output.

$$k_{bi}^e = \int k_{bi}^e(z_b)\varphi_b(z_b)dz_b,$$

$$k_{bi}^s = \int k_{bi}^s(z_b)\varphi_b(z_b)dz_b,$$

$$\ell_{bi} = \int \ell_{bi}(z_b)\varphi_b(z_b)dz_b,$$

$$m_{bi} = \int m_{bi}(z_b)\varphi_b(z_b)dz_b,$$

$$y_{bi} = \int y_{bi}(z_b)\varphi_b(z_b)dz_b,$$

where $\varphi_b = \prod_i \varphi_{bi}$ is the joint density for productivity draws across countries in sector b (φ_{bi} is country i's density function). For instance, $\ell_{bi}(z_b)$ denotes the quantity of country i's labor employed in the production of variety z_b. If country i imports variety z_b, then $\ell_{bi}(z_b) = 0$. Hence, ℓ_{bi} is country i's of labor employed in sector b. Similarly, m_{bi}, k_{bi}^e, and k_{bi}^s denote the quantity of the intermediate composite good and the quantities of the stocks of producer durables and structures that country i uses as an input in sector b. Lastly, y_{bi} is the quantity of sector b output produced by country i.

Cost minimization by firms implies that factor usage at the sectoral levels exhausts the value of output.

$$
\begin{aligned}
r_i^e k_{bi}^e &= \mu(1-\alpha)\nu_{bi} P_{bi} y_{bi}, \\
r_i^s k_{bi}^s &= (1-\mu)(1-\alpha)\nu_{bi} P_{bi} y_{bi}, \\
w_i \ell_{bi} &= (1-\alpha)\nu_{bi} P_{bi} y_{bi}, \\
P_{mi} m_{bi} &= (1-\nu_{bi}) P_{bi} y_{bi}.
\end{aligned}
$$

2.4.3 Trade flows

In sector b, the fraction of country i's expenditures allocated to varieties produced by country j is given by

$$
\pi_{bij} = \frac{(u_{bj}\tau_{bij})^{-\theta} T_{bj}}{\sum_k (u_{bk}\tau_{bik})^{-\theta} T_{bk}} \tag{2}
$$

2.4.4 Market clearing conditions

We begin by describing the domestic market clearing conditions for each country.

$$
\begin{aligned}
\ell_{ei} + \ell_{si} + \ell_{mi} + \ell_{fi} &= 1, \\
k_{ei}^e + k_{si}^e + k_{mi}^e + k_{fi}^e &= k_i^e, \\
k_{ei}^s + k_{si}^s + k_{mi}^s + k_{fi}^s &= k_i^s, \\
m_{ei} + m_{si} + m_{mi} + m_{fi} &= q_{mi}.
\end{aligned}
$$

The first condition imposes that the labor market clears in country i. The second and third conditions require that the stocks of producer durables and structures be equal to the sum of the stocks used in production in all sectors. The last condition requires that the use of composite intermediate good equals its supply: Its use consists of intermediate inputs in each sector, its supply consists of both domestically- and foreign-produced varieties.

The next three conditions require that the quantities of consumption and investment goods purchased by the household must equal the amounts available in country i:

$$
c_i = y_{fi},\ x_i^e = q_{ei},\ \text{and}\ x_i^s = y_{si}.
$$

The next market clearing condition requires that the value of output produced by country i equals the value that all countries (including i) purchase from country i.

$$L_i P_{bi} y_{bi} = \sum_j L_j P_{bj} q_{bj} \pi_{bji},\ b \in \{e, m\}.$$

The left hand side is the value of gross output in sector b produced by country i. The right hand side is the world expenditures on sector b goods: $L_j P_{bj} q_{bj}$ is country j's total expenditure on sector b goods, and π_{bji} is the fraction of those expenditures sourced from country i. Thus, $L_j P_{bj} q_{bj} \pi_{bji}$ is the value of trade flows in sector b from country i to country j.

To close the model we impose balanced trade country by country:

$$L_i P_{ei} q_{ei} \sum_{j \neq i} \pi_{eij} + L_i P_{mi} q_{mi} \sum_{j \neq i} \pi_{mij} = \sum_{j \neq i} L_j P_{ej} q_{ej} \pi_{eji} + \sum_{j \neq i} L_j P_{mj} q_{mj} \pi_{mji}.$$

The left-hand side denotes country i's imports of capital goods and intermediate goods, while the right-hand side denotes country i's exports. This condition allows for trade imbalances at the sectoral level within each country; however, a surplus in capital goods must be offset by an equal deficit in intermediates and vice versa.

2.5 Discussion of the model

Our model provides a tractable framework for studying how trade affects capital formation, measured TFP, and income per worker. The real income per worker in our model is $y = (w + rk)/P_f$. In country i,

$$y_i \propto A_{fi} \left(\frac{T_{mi}}{\pi_{mii}} \right)^{\frac{1-\nu_f}{\theta \nu_m}} k_i^{\alpha}. \tag{3}$$

In equation (3), T_m and A_f are exogenous. The remaining components on the right-hand side of (3), namely, π_{mii} and k_i, are equilibrium objects.

The neoclassical growth model also allows for endogenous capital formation as we do, but in that model the capital-output ratio is independent of TFP; in our model it is not. To see this, the income per worker in the neoclassical growth model can be written more conveniently as $y = Z^{\frac{1}{1-\alpha}} \left(\frac{k}{y} \right)^{\frac{\alpha}{1-\alpha}}$. In steady state, the gross marginal product capital, which is a function of just $\frac{k}{y}$, is pinned down by the discount factor, so changes in Z have no effect on $\frac{k}{y}$.

The corresponding expression for income per worker in our model is

$$y_i \propto \left(A_{fi} \left(\frac{T_{mi}}{\pi_{mii}} \right)^{\frac{1-\nu_f}{\theta \nu_m}} \right)^{\frac{1}{1-\alpha}} \left(\frac{k_i}{y_i} \right)^{\frac{\alpha}{1-\alpha}}. \tag{4}$$

In steady state the capital-output ratio, for both equipment and structures, is proportional to the investment rates in each type of investment good: $\frac{k_i^b}{y_i} \propto \frac{x_i^b}{y_i}$ for $b \in \{e, s\}$. Moreover, the investment rate is proportional to the inverse of the relative price: $\frac{x_i^b}{y_i} \propto \frac{P_{fi}}{P_{bi}}$. Therefore, the capital-output ratio is given by

$$\begin{aligned} \frac{k_i}{y_i} &= \left(\frac{k_i^e}{y_i} \right)^{\mu} \left(\frac{k_i^s}{y_i} \right)^{1-\mu} \\ &\propto \left(\frac{x_i^e}{y_i} \right)^{\mu} \left(\frac{x_i^s}{y_i} \right)^{1-\mu} \\ &\propto \left(\frac{P_{fi}}{P_{ei}} \right)^{-\mu} \left(\frac{P_{fi}}{P_{si}} \right)^{\mu-1} \end{aligned} \tag{5}$$

(see the Appendix). All else equal, any policy that affects the relative price of capital will affect economic development via the investment rate and hence through the capital-output ratio. In particular, consider an extreme scenario in which there was no cross-country difference in the relative price of capital, i.e., P_{ei}/P_{fi} is constant across countries, holding all else equal. Then the cross-country income gap would reduce by $\frac{\alpha\mu}{1-\alpha}$. In our model, the cross-country gap in TFP would also shrink, so the net effect on the income gap is larger than one would infer from a model in which TFP is orthogonal to the capital-output ratio.

The role of capital goods trade Equations (4) and (5) help us sort out the effect of trade barriers on economic development. A reduction in barriers to trade capital goods reduces the relative price of capital goods via a fall in the home trade share, π_{eii}. To see how, note that in equilibrium, the price of capital goods relative to final goods is given by

$$\frac{P_{ei}}{P_{fi}} \propto \left(\frac{A_{fi}}{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}} \right) \left(\frac{T_{ei}}{\pi_{mii}} \right)^{\frac{\nu_e - \nu_f}{\theta \nu_m}} \tag{6}$$

Note specifically the first term in equation (6): the ratio of productivity in final goods, A_{fi}, to the measured productivity in capital goods, $(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}$. The main intuition involves the Balassa-Samuelson effect. Lower barriers improve specialization and lead to higher measured productivity in capital goods production, and hence, a lower relative price of capital goods.[6] Generally, the reduction in the relative price will be greater for poor countries than for rich countries because (i) the responsiveness of the home trade share to otherwise identical reductions in trade barriers are larger for poor countries, and (ii) poor countries tend to face larger trade barriers to begin with.

Our calibration implies that just over a quarter of the income gap can be accounted for by cross-country differences in the relative price of capital goods. To see how, recall equations (4) and (5). All else equal, equalizing the relative price of capital goods across countries would reduce the income gap by $\frac{\alpha\mu}{1-\alpha} \approx 0.28$. In our model, when the relative price gap is reduced by opening up to trade, the TFP gap also shrinks. As such, the effects of trade policy on the cross-country income gap are manifested in capital-output ratios as wells as in measured TFP.

To summarize, trade affects economic development via measured TFP and capital formation. Comparative advantage parameters and barriers to international trade affect the extent of specialization in each country, which affects measured TFP and the relative price of investment goods. In response to changes in relative prices the representative household alters its investment rate, resulting in changes in the steady-state capital-output ratio. In our quantitative exercise we discipline the model using relative prices, bilateral trade flows, and income per worker to explore the importance of capital goods trade.

3 Calibration

We calibrate our model using data for a set of 102 countries for the year 2011. This set includes both developed and developing countries and accounts for about 90 percent of world GDP in version 8.1 of the Penn World Tables (see Feenstra, Inklaar, and Timmer, 2015). Our calibration strategy uses cross-country data on income per worker, bilateral trade, output for capital goods and intermediate goods sectors, and prices of capital goods, intermediate goods, structures, and final goods. Next we describe how we map

[6] Sposi (2015) discusses the effect of trade barriers on measured productivity, and how the cross-country difference in the relative price is affected primarily by the price of the nontraded good.

our model to the data; details on specific countries, data sources, and data construction are described in the Appendix.

We begin by mapping disaggregate data to sectors in the model. Capital goods and structures in the model correspond to the categories "Machinery and equipment" and "Construction", respectively, in the World Bank's International Comparisons Program (ICP).

For production and trade data on capital goods, we use two-digit International Standard Industrial Classification (ISIC) categories that coincide with the definition of "Machinery and equipment" used by the ICP; specifically, we use categories 29-35 in revision 3 of the ISIC. Production data are from INDSTAT2, a UNIDO database. The corresponding trade data are available at the four-digit level from Standard International Trade Classification (SITC) revision 2. We follow the correspondence created by Affendy, Sim Yee, and Satoru (2010) to link SITC with ISIC categories.

Intermediate goods correspond to the manufacturing categories other than capital goods, i.e., categories 15-28 and 36-37 in revision 3 of the ISIC. We repeat the above procedure to assemble the production and trade data for intermediate goods.

Prices of capital goods and structures come directly from the 2011 benchmark study of the Penn World Tables (PWT). We construct the price of intermediate goods by aggregating across all nondurable goods categories (excluding services) in the 2005 benchmark study. The price of final goods corresponds to "Price level of consumption" in version 8.1 of PWT.

Our measure of income per worker is also from version 8.1 of PWT, and is constructed the same way as in the model: GDP at current U.S. dollars, deflated by the price level of consumption using PPP exchange rates, divided by the number of workers.

3.1 Common parameters

We begin by describing the parameter values that are common to all countries (Table 1). The discount factor β is set to 0.96, in line with values in the literature. Following Alvarez and Lucas (2007), we set $\eta = 2$ (this parameter is not quantitatively important for the questions addressed in this paper).

As noted earlier, the capital stock in our model is $k = (k^e)^\mu (k^s)^{1-\mu}$. The share of capital in GDP, α, is set to 1/3, as in Gollin (2002). Using capital stock data from the Bureau of Economic Analysis (BEA), Greenwood, Hercowitz, and Krusell (1997) measure the rates of depreciation for both producer durables and structures. We set our values in accordance with their estimates: $\delta_e = 0.12$ and $\delta_s = 0.06$. We also set the share of producer durables in composite capital, μ, at 0.56 in accordance with Greenwood, Hercowitz, and Krusell (1997).

Table 1: Parameters common across countries

Parameter	Description	Value
α	k's Share	0.33
ν_m	k and ℓ's Share in intermediate goods	0.67
ν_e	k and ℓ's Share in capital goods	0.80
ν_s	k and ℓ's Share in structures	0.58
ν_f	k and ℓ's Share in final goods	0.58
δ_e	Depreciation rate of producer durables	0.12
δ_s	Depreciation rate of structures	0.06
θ	Variation in (sectoral) factor productivity	4
μ	Share of producer durables in composite capital	0.56
β	Discount factor	0.96
η	Elasticity of substitution in aggregator	2

The parameters ν_m, ν_e, ν_s, and ν_f control the shares of value added in the production of intermediate goods, capital goods, structures, and final goods, respectively. To calibrate ν_m and ν_e, we use the data from the World Input-Output Database. Specifically, we compute the share of manufactured intermediates inputs in gross output of intermediates, which corresponds to $1 - \nu_m$, and the share of manufactured intermediates in gross output of capital goods, which corresponds to $1 - \nu_e$. We compute these shares for 40 countries and apply the cross-country average to every country in our model.

We impose that $\nu_s = \nu_f$ in the model, which implies that the price of structures relative to final goods is fixed and is equal to A_{fi}/A_{si}. Computing ν_f is slightly more involved since there is not a clear industry classification for final goods. Instead, we infer this share by interpreting national accounts data through the lens of our model. To determine ν_f, we exploit an identifying restriction implied by our model which says that the value added generated in final goods and structures production must satisfy the national accounts identity and balanced trade. We begin by noting that each country's expenditures on intermediate goods must equal the value of intermediate inputs used across sectors in that country:

$$P_{mi}m_i = (1-\nu_f)P_{fi}c_{fi} + (1-\nu_s)P_{si}x_i^s + (1-\nu_e)P_{ei}x_i^e + (1-\nu_m)P_{mi}y_{mi}$$

Rearranging the above expression yields

$$(GO_{mi} - EXP_{mi} + IMP_{mi}) = (1-\nu_f)(CON_i + INV_{si}) + (1-\nu_e)GO_{ei} - (1-\nu_m)GO_{mi}$$

where CON_i is consumption expenditures in country i, INV_{si} is gross capital formation for structures, GO_{bi} is gross output of sector $b \in \{e, m\}$ and EXP_{mi} and IMP_{mi} are gross exports and imports of intermediates. Using a standard method of moments estimator, our estimate of ν_f is 0.58.

Estimating θ The parameter θ in our model controls the dispersion in factor productivity. We follow the procedure of Simonovska and Waugh (2014) to estimate θ (see the Appendix for a description of their methodology).

We estimate θ for (i) all manufactured goods (producer durables + intermediate goods), (ii) only intermediate goods, and (iii) only producer durables. Our estimate for all manufactured goods is 3.7 (Simonovska and Waugh, 2014, obtain an estimate of 4). Our estimate for the capital goods sector is 4.3; for the intermediate goods sector it is 4. In light of these similar estimates, we set $\theta = 4$ for both sectors.[7]

3.2 Country-specific parameters

Country-specific parameters in our model are labor force, L; productivity parameters in the capital goods and intermediate goods sectors, T_e and T_m, respectively; productivity parameters in the final goods and structures sectors, A_f and A_s, respectively; and the bilateral trade barriers, τ_e and τ_m. We take the labor force in each country from version 8.1 of PWT. The other country-specific parameters are calibrated to match a set of targets.

Bilateral trade barriers Using data on prices and bilateral trade shares, in both capital goods and intermediate goods, we calibrate the bilateral trade barriers in each

[7] Our estimate of θ and the parameters in Table 1 satisfy the restriction imposed by the model: $\beta < 1$ and $1 + (1-\eta)/\theta > 0$.

sector using a structural relationship implied by our model:

$$\frac{\pi_{bij}}{\pi_{bjj}} = \left(\frac{P_{bj}}{P_{bi}}\right)^{-\theta} \tau_{bij}^{-\theta}, b \in \{e, m\}. \tag{7}$$

We set $\tau_{bij} = 100$ for bilateral country pairs where $\pi_{bij} = 0$.

Countries in the bottom decile of the income distribution have larger barriers to export capital goods than countries in the top decile. One way to summarize this feature is to compute a trade-weighted export barrier for country i as $\frac{1}{X_{bi}} \sum_{j \neq i} \tau_{bij} X_{bji}$, where X_{bji} is country i's exports to country j in sector $b \in \{e, m\}$ and X_{bi} is country i's total exports in that sector. The trade-weighted export barrier in the capital goods sector for countries in the bottom income decile is 3.99 while for countries in the top decile it is 2.04. The calibrated trade barriers in intermediate goods display a similar pattern: The trade-weighted export barrier for poor countries is 6.33 while for rich countries it is 1.81.

Productivities Using data on relative prices, home trade shares, and income per worker, we use the model's structural relationships to calibrate T_{ei}, T_{mi}, A_{fi}, and A_{si}. The structural relationships are given by

$$\frac{P_{mi}/P_{fi}}{P_{eU}/P_{fU}} = \left(\frac{A_{fi}}{A_{fU}}\right) \left(\frac{T_{mi}/\pi_{mii}}{T_{mU}/\pi_{mUU}}\right)^{-\frac{1}{\theta}} \left(\frac{T_{mi}/\pi_{mii}}{T_{mU}/\pi_{mUU}}\right)^{\frac{\nu_m - \nu_f}{\theta \nu_m}}, \tag{8}$$

$$\frac{P_{ei}/P_{fi}}{P_{eU}/P_{fU}} = \left(\frac{A_{fi}}{A_{fU}}\right) \left(\frac{T_{ei}/\pi_{eii}}{T_{eU}/\pi_{eUU}}\right)^{-\frac{1}{\theta}} \left(\frac{T_{mi}/\pi_{mii}}{T_{mU}/\pi_{mUU}}\right)^{\frac{\nu_e - \nu_f}{\theta \nu_m}}, \tag{9}$$

$$\frac{P_{si}/P_{fi}}{P_{sU}/P_{fU}} = \left(\frac{A_{fi}}{A_{fU}}\right) \left(\frac{A_{sU}}{A_{si}}\right) \left(\frac{T_{mi}/\pi_{mii}}{T_{mU}/\pi_{mUU}}\right)^{\frac{\nu_s - \nu_f}{\theta \nu_m}}, \tag{10}$$

$$\frac{y_i}{y_U} = \left(\frac{A_{fi}}{A_{fU}}\right) \left(\frac{T_{ei}/\pi_{eii}}{T_{eU}/\pi_{eUU}}\right)^{\frac{\mu\alpha}{\theta(1-\alpha)}} \left(\frac{A_{si}}{A_{sU}}\right)^{\frac{(1-\mu)\alpha}{1-\alpha}} \times \left(\frac{T_{mi}/\pi_{mii}}{T_{mU}/\pi_{mUU}}\right)^{\frac{1-\nu_f + \frac{\alpha}{1-\alpha}(1+\mu\nu_e+(1-\mu)\nu_s)}{\theta\nu_m}}. \tag{11}$$

We normalize T_{eU}, T_{mU}, A_{sU}, and A_{fU} to 1 and solve for T_{ei}, T_{mi}, A_{si}, and A_{fi} for each country i (see the Appendix for derivations of the equations). None of our results depend on this normalization.

These structural relationships reveal the intuition for how we identify productivity.

The expression for income per worker tells us something about "aggregate" productivity, i.e., a combination of A_{fi}, T_{ei}, A_{si}, and T_{mi}. The three expressions for relative prices reveal how the aggregate productivity is split across the sectors.

Table D.1 in the Appendix presents the calibrated productivity parameters. The average gap in fundamental productivity in the capital goods sector between countries in the top and bottom deciles is 14.1. In the intermediate goods sector, the average productivity gap is 5.3.[8] That is, rich countries have a comparative advantage in capital goods production, while poor countries have a comparative advantage in intermediate goods production. Thus, the model is consistent with the observation that poor countries are net importers of capital goods.

4 Results

This section provides results on how well the model fits the data, and examines counterfactuals to quantify the extent to which trade in capital goods affects economic development across countries.

4.1 Model fit

The first step of the calibration uses $2I(I-1) = 20,604$ observations on trade shares and $2(I-1) = 202$ observations on prices of intermediate goods and capital goods (relative to the U.S.) in order to pin down $2I(I-1) = 20,604$ barriers—equation (7). The second step involves using $I-1 = 101$ observations on income per worker (relative to the U.S.) and $3(I-1) = 303$ observations on relative prices (relative to the U.S.) in order to compute $4(I-1) = 404$ productivity parameters—equations (8)-(11), respectively. As such, the model utilizes $2(I-1) = 202$ more data points than there are parameters and will not match all of the data exactly.

Prices The correlations between the model and the data for the absolute price of capital goods, the relative price of capital goods, the absolute price of intermediate goods, and the relative price of intermediate goods are 0.87, 0.86, 0.99, and 0.84, respectively.

[8]The productivity gap in each sector is in terms of gross-output productivity. This can be a misleading comparison in terms of labor productivity when value added shares differ across sectors. To adjust for this, we compute the value-added productivity gap across countries in each sector. The gap in value-added productivity, $T_e^{\nu_e/\theta}$ is 8.3, and that for intermediate goods is 3.1.

To see why the model prices do not match the data exactly, note that the absolute prices of intermediate goods and capital goods in the model must satisfy:

$$P_{bi} = \gamma B_b \left(\sum_j (u_{bj} \tau_{bij})^{-\theta} T_{bj} \right)^{-\frac{1}{\theta}}. \tag{12}$$

(See the Appendix for the derivation.) Since equation (12) is independent from the set of equations used to calibrate the trade barriers and productivity parameters, the absolute prices implied by (12) need not be the same as the observed prices.

This also implies that our model does not perfectly reproduce the observed home trade shares and income per worker. However, we make an adjustment by recalibrating the A_{fi} so that the model does exactly match the income per capita. In our model, A_{fi} does not affect the equilibrium outcome for home trade shares, capital stock, prices of intermediates, prices capital goods, or prices of structures, it only scales the price of final goods, and hence, income per worker. This adjustment ensures that the model perfectly reproduces the observed income per worker, but the model still does not reproduce the observed home trade shares or relative prices.

Income per worker Figure 1 plots the income per worker in the model against that in the data. The fit for income per worker is perfect by construction. Log variance in the final goods sector productivity (A_f) accounts for 8.9 percent of the log variance in income per worker. (Recall that changes in A_f do not affect home trade shares or capital per worker.) This does *not* imply that factors account for the remaining variation in income per worker, since measured TFP is not just A_f but includes exogenous components, T_{mi}, and endogenous components, π_{mii}.

Trade shares Figure 2 plots the home trade shares in capital goods, π_{eii}, in the model against the data. The observations line up close to the 45-degree line; the correlation between the model and the data is 0.90. The home trade shares for intermediate goods also line up closely with the data; the correlation is 0.93. The correlation between bilateral trade shares (excluding the home trade shares) in the model and that in the data is 0.93 in the capital goods sector and 0.91 in the intermediate goods sector.

Figure 1: Income per worker, US=1

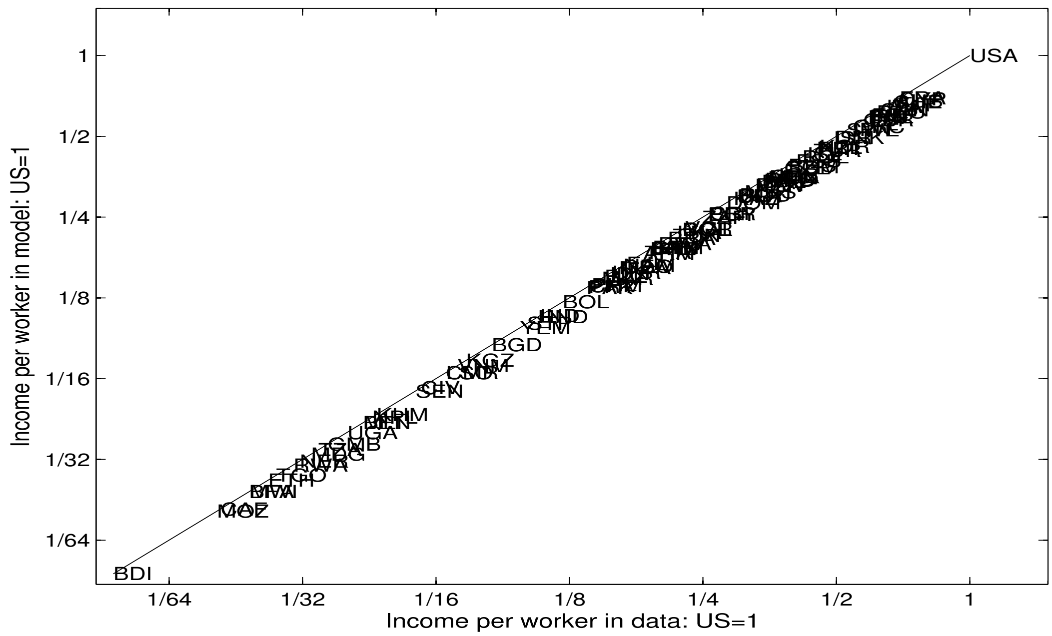
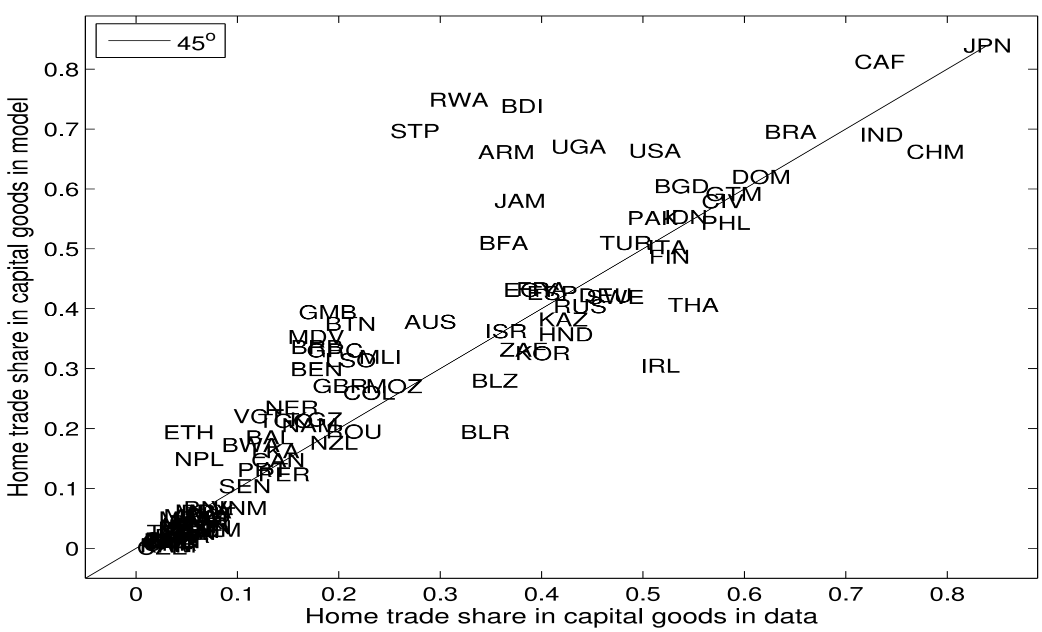


Figure 2: Home trade share in capital goods



4.2 Implications

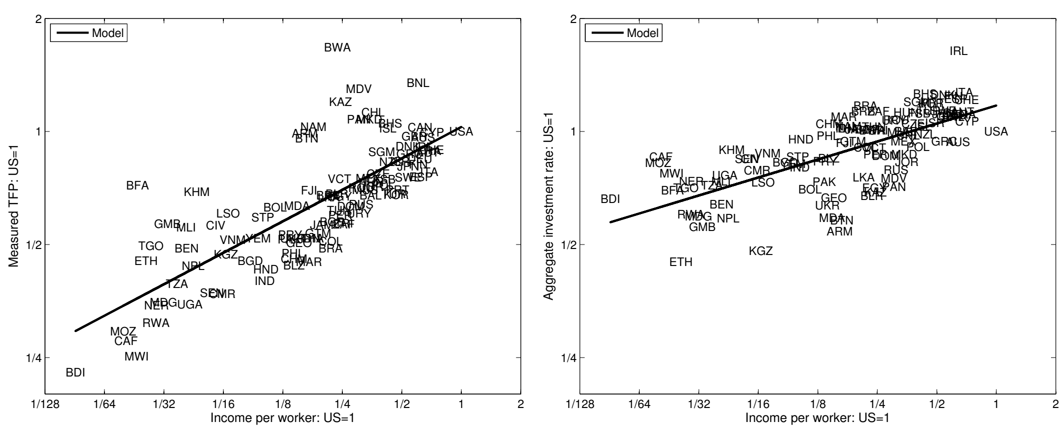
This subsection examines the cross-sectional predictions of the model for data that were not directly targeted in the calibration.

Development accounting While the calibration directly targets income per worker, it does not target either capital or measured TFP. We show next that the model accurately distributes the burden of income differences to differences in capital and differences in TFP in similar proportions as in the data.

Suppose we conduct a development accounting exercise using the model's output and examine the cross-country variation in measured TFP and in the capital output ratio. That is, $y_i = Z_i^{\frac{1}{1-\alpha}} \left(\frac{k_i}{y_i}\right)^{\frac{\alpha}{1-\alpha}}$. Log variance in $(k/y)^{\frac{\alpha}{1-\alpha}}$ is 2.1% in the model, compared to 3.2% in the data. Log variance in $Z^{\frac{1}{1-\alpha}}$ is 89.7% in the model compared to 91.8% in the data. Finally, the covariance between the log of the two objects is 7.9% in the model compared to 6.3% in the data. Clearly the model places a larger burden on TFP than on capital-output ratios to account for the cross-country income differences. This feature consistent with the evidence in King and Levine (1994) who argue that capital is not a primary determinant of economic development.

Note that there is a strong empirical correlation between TFP and the capital-output ratio—both correlate positively with income per worker as shown in figure 3. Our model is consistent with this feature, and furthermore, our model provides a direct channel through which the two objects are correlated in equilibrium.

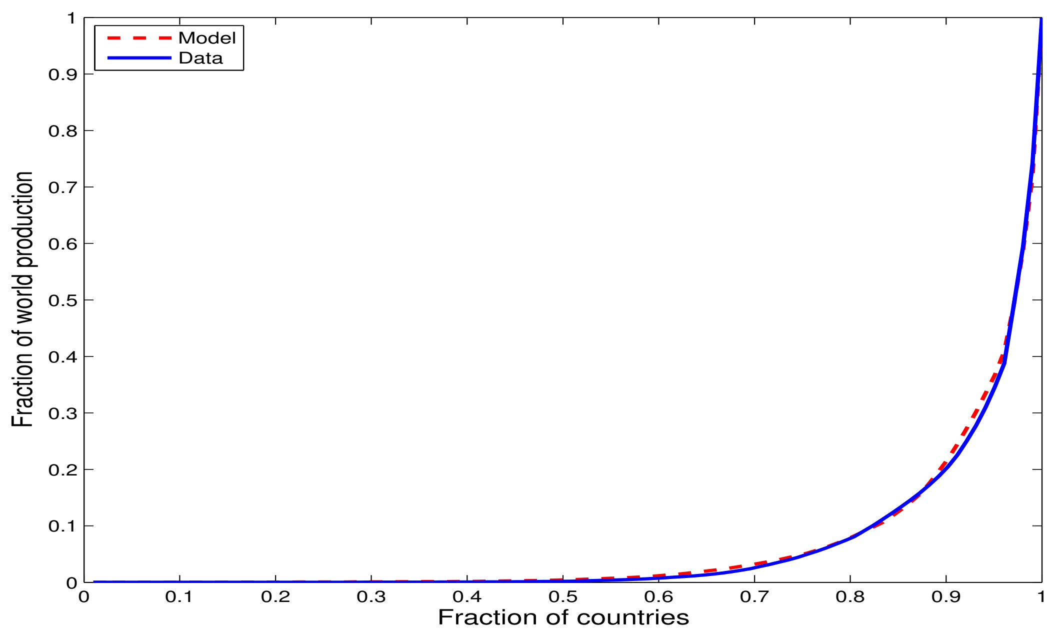
Figure 3: Measured TFP (left) and capital-output ratio (right) against income per worker



Note: In the model the capital-output ratio is proportional to the investment rate.

Capital goods production and trade flows Our model also replicates well the extent to which production of capital goods is distributed across countries. Figure 4 illustrates the cdf for capital goods production. In the model and in the data, 10 countries account for close to 80 percent of the world's capital goods production. The correlation between model and data for capital goods production is 0.84, so the countries do in fact line up correctly in Figure 4. Furthermore, poor countries are net importers of capital goods in the model and in the data and, as noted earlier, our model is consistent with the observed bilateral trade flows.

Figure 4: Distribution of capital goods production



Relative prices and investment rates In the data, while the *relative* price of capital goods is higher in poor countries, the absolute price of capital goods does not exhibit such a systematic variation with level of economic development. As noted in Section 4.1, our model is consistent with data on the absolute price of capital goods and the price relative to consumption goods. The elasticity of the absolute price with respect to income per worker is 0.01 in the model and is -0.01 in the data; the elasticity of the relative price is -0.36 in the model and -0.30 in the data.

As pointed out by Hsieh and Klenow (2007), the negative correlation between the relative price of capital goods and economic development is mainly due to the price of consumption, which is lower in poor countries. Our model is consistent with this fact:

The elasticity of the price of consumption goods is 0.37 in our model and 0.31 in the data.

Finally, the price of structures is positively correlated with income per worker; the elasticity of the price of structures is 0.41 in the model and 0.36 in the data.

In our model, the capital goods and structures investment rates, measured in domestic prices, are constant across countries. Our model implies that in steady state $P_{ei}x_i^e = \phi_e r_{ei} k_i^e$ and $P_{si}x_i^s = \phi_s r_{si} k_i^s$, where $\phi_b = \frac{\delta_b}{1/\beta-(1-\delta_b)}$ for $b \in \{e, s\}$. Recall $k_i = (k_i^e)^{\mu}(k_i^s)^{1-\mu}$, so $r_{ei}k_i^e = \mu r_i k_i$ and $r_{si}k_i^s = (1-\mu)r_i k_i$. Since capital income $r_i k_i = w_i\alpha/(1-\alpha)$, it follows that $P_{ei}x_i^e = \phi_e \mu w_i \alpha/(1-\alpha)$ and $P_{si}x_i^s = \phi_s(1-\mu)w_i\alpha/(1-\alpha)$. Therefore, aggregate investment per worker is $P_{ei}x_i^e + P_{si}x_i^s = [\mu\phi_e + (1-\mu)\phi_s]w_i\alpha/(1-\alpha)$. Income is $w_i + r_i k_i = w_i/(1-\alpha)$, so the investment rate in domestic prices is

$$\frac{P_{ei}x_i^e + P_{si}x_i^s}{w_i + r_i k_i} = \alpha[\mu\phi_e + (1-\mu)\phi_s],$$

which is a constant.

Our model also captures the systematic variation in investment rates measured in purchasing power parity (PPP) prices. Rich countries have higher investment rates than poor countries; the elasticity of capital goods investment rate with respect to income per worker is 0.36 in the model and is 0.40 in the data.

4.3 Quantitative role of capital goods trade

To understand the quantitative role of capital goods trade, we conduct two counterfactual experiments: (i) we eliminate all barriers to capital goods trade by setting $\tau_{eij} = 1$ for all country pairs and (ii) we equalize barriers to capital goods trade so that all countries face the same barrier to export as does the U.S. In both experiments, we leave all other parameters at their calibrated values; specifically, the intermediate goods trade barriers remain at the benchmark levels.

Frictionless trade in capital goods We examine a counterfactual in which there are no barriers to trade capital goods, i.e., $\tau_{eij} = 1$, and leave all other parameters at their calibrated values. Table 2 reports how the income gap, and the components therein, change in the counterfactual relative to the benchmark. We compute the gap for each variable as the average of the 10 richest relative to the average of the 10 poorest countries. In this experiment, the gap in the capital-output ratio between rich and poor countries falls from 1.62 to 1.22.

Table 2: Gap in income per worker and its components

	Benchmark model	Frictionless trade in capital goods	U.S. barriers in capital goods
y	27.94	16.80	17.87
$Z^{\frac{1}{1-\alpha}}$	20.72	14.79	15.27
$(k/y)^{\frac{\alpha}{1-\alpha}}$	1.27	1.10	1.13
Z	7.62	6.08	6.21
k/y	1.62	1.22	1.28
$(k^e/y)^{\mu}$	1.90	1.35	1.42
k^e/y	3.14	1.70	1.86

Note: Gaps are defined as the ratio of the average for 10 richest countries relative to the average for the 10 poorest countries, measured in terms of income per capita. $y = Z^{\frac{1}{1-\alpha}} \left(\frac{k}{y}\right)^{\frac{\alpha}{1-\alpha}}$ denotes income per capita, where Z is measured TFP and $\frac{k}{y}$ is the capital-output ratio. The capital-output ratio is a Cobb-Douglas aggregate of the producer-durables-capital-output ratio and the structures-capital-output ratio: $\frac{k}{y} = \left(\frac{k^e}{y}\right)^{\mu} \left(\frac{k^s}{y}\right)^{1-\mu}$. The structures-capital-output ratio in the model does not change across counterfactuals.

In the presence of trade barriers, poor countries with a comparative disadvantage in capital goods production transform consumption into investment at an inferior rate relative to the world frontier. In the frictionless world, poor countries can transform consumption into investment at a higher rate since they have access to a superior international production possibilities frontier. That is, they can import more units of capital for each unit of intermediate goods that they export. This is reflected by lower relative price of investment and higher steady-state investment rate, resulting in a smaller gap in capital-output ratio relative to rich countries. If TFP were held fixed, this alone would reduce the income gap from 27.94 to 24.26.

However, in the model measured TFP positively co-moves with the capital-output ratio. That is, poor countries with a comparative disadvantage in capital goods production can specialize more in intermediate goods, thus increasing their TFP. Specifically, the gap in TFP falls from 7.62 to 6.08. As such, the net effect on the income gap is reduction from 27.94 to 16.80.

As noted above, the relative price of capital in poor countries falls relative to that in rich countries. In particular, the elasticity of the relative price with respect to income per worker increases from -0.36 to -0.20. The change in the elasticity is accounted for almost entirely by changes in the absolute price of final goods, and very little by the absolute price of capital goods. That is, with frictionless trade in capital goods, PPP holds so the elasticity of the absolute price of capital goods is zero. However, the elasticity of the absolute price is close to zero in the benchmark as well, see Table 3. The elasticity of the relative price of final goods decreases from 0.37 to 0.20 in the counterfactual, reflecting the fact that final goods prices in poor countries increase relative to rich countries.

Table 3: Price elasticities with respect to income per worker

	Benchmark model	Frictionless trade in capital goods	U.S. barriers in capital goods
P_e	0.01	0.00	0.00
P_f	0.37	0.20	0.21
P_e/P_f	-0.36	-0.21	-0.21

Technology vs. Policy Trade barriers involve policy-induced impediments, as well as technological impediments. In this counterfactual we attempt to remove only the policy component. Suppose that every country had the same trade barrier as the U.S. That is, we imagine an admittedly extreme scenario that the U.S. trade barrier is entirely technological. To operationalize this thought experiment, we compute the average trade-weighted export barrier for the U.S. in each sector: $\bar{\tau} = \frac{1}{X_{US}} \sum_{i \neq US} \tau_{iUS} X_{iUS}$, where X_{iUS} are exports from the U.S. to country i and X_{US} is U.S. exports. This computation yields a capital goods trade barrier to every bilateral pair, $\tau_{eij} = \bar{\tau}_e = 1.81$. With these trade barriers, the income gap falls from 27.94 to 17.87. The relative contributions from TFP and the capital-output ratio are almost identical to those in the frictionless trade counterfactual. Recall that in the counterfactual with frictionless trade the gap declined from 27.94 to 16.80, so reducing the barriers to the U.S. levels achieves almost the same results as completely eliminating all trade costs.

This does not imply that income per worker would not increase by much if we were to reduce the barriers below the U.S. levels. This simply means that the increase in income from further reductions is roughly proportionate in all countries, which implies that most of the income gap can be eliminated by moving trade barriers to U.S. levels.

Empirical evidence The experience of Korea presents some evidence in favor of the channel in our model. Korea's trade reforms starting in 1960s reduced the restrictions on imports of capital goods (see Westphal, 1990; Yoo, 1993). During 1970-80, Korea's imports of capital goods increased 11-fold. Over a period of 40 years, the relative price of capital in Korea decreased by a factor of almost 2 and the investment rate increased by a factor of more than 4 (Nam, 1995). (See also Rodriguez and Rodrik, 2001, for a discussion of trade policies affecting relative prices.)

Hsieh (2001) provides evidence on the channel in our model via a contrast between Argentina and India. During the 1990s, India reduced barriers to capital goods imports that resulted in a 20 percent fall in the relative price of capital between 1990 and 2005. This led to a surge in capital goods imports and consequently the investment rate increased by 1.5 times during the same time period. After the Great Depression, Argentina restricted imports of capital goods. From the late 1930s to the late 1940s, the relative price of capital doubled and the investment rate declined.

5 Conclusion

In this paper we show that international trade in capital goods has quantitatively important effects on economic development through two channels: (i) capital formation and (ii) aggregate TFP. We embed a multi country, multi sector Ricardian model of trade into a neoclassical growth framework. Our model matches several trade and development facts within a unified framework. It is consistent with the world distribution of capital goods production, cross-country differences in income, investment rate, and price of final goods, and cross-country equalization of price of capital goods.

Reductions in barriers to trade capital goods allows poor countries access to more efficient technologies for capital goods production in rich countries. This reduces their relative price of investment relative to rich countries and, as a result, poor countries increase their investment rate and steady-state capital-output ratio relative to those in rich countries. Furthermore, by importing more capital goods from rich countries, the poor countries allocate their resources more efficiently by specializing more in their comparative advantage—non-capital goods production—which increases their TFP relative to rich countries. Both channels reduce the cross-country income differences.

By fully eliminating barriers to trade capital goods, the gap in capital-output ratio (or the gap in investment rate) between rich and poor countries decreases from 1.6 to 1.2 and the gap in income per worker decreases from roughly 28 to almost 17. If one ignored endogenous changes in TFP and only considered the effect through changes in relative prices, the income gap would fall from 28 to about 23. Setting capital goods barriers to U.S. levels has almost the same effect on the income gap as moving to frictionless trade in capital goods.

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A Derivations

A.1 Price indices and trade shares

We derive the price index and bilateral trade shares for intermediate goods. Expressions for prices and trade shares in the capital goods sector are analogous.

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

$$P_{mi} = \gamma B_m \left[\sum_j (d_{mj} \tau_{mij})^{-\theta} T_{mj} \right]^{-\frac{1}{\theta}}. \tag{13}$$

Let π_{mij} be the fraction of country i's total spending on intermediate goods that was obtained from country j. The fraction of country i's expenditures that are sourced from country j, is also the probability that country j is the least cost provider to country i. This probability is given by

$$\pi_{mij} = \Pr\left\{ p_{mij}(z_m) \le \min_l \left[p_{mil}(u) \right] \right\} = \frac{(d_{mj}\tau_{mij})^{-\theta} T_{mj}}{\sum_l (d_{ml}\tau_{mil})^{-\theta} T_{ml}}, \tag{14}$$

A.2 Relative prices

Here we derive equations for three relative prices: $P_{ei}/P_{fi}, P_{mi}/P_{fi}$, and P_{si}/P_{fi}. Equations (13) and (14) imply that

$$\begin{aligned} \pi_{mii} &= \frac{\tau_{mi}^{-\theta} T_{mi}}{(\gamma B_m)^\theta P_{mi}^{-\theta}} \\ \Rightarrow P_{mi} &\propto \frac{\left(\frac{r_i}{w_i}\right)^{\alpha\nu_m} \left(\frac{w_i}{P_{mi}}\right)^{\nu_m} P_{mi}}{\left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta}}}, \end{aligned}$$

which implies that $\frac{w_i}{P_{mi}} \propto \left(\frac{w_i}{r_i}\right)^{\alpha} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}}$. Similarly,

$$P_{ei} \propto \frac{\left(\frac{r_i}{w_i}\right)^{\alpha\nu_e} \left(\frac{w_i}{P_{mi}}\right)^{\nu_e} P_{mi}}{\left(\frac{T_{ei}}{\pi_{eii}}\right)^{\frac{1}{\theta}}}, \quad P_{si} \propto \frac{\left(\frac{r_i}{w_i}\right)^{\alpha\nu_s} \left(\frac{w_i}{P_{mi}}\right)^{\nu_s} P_{mi}}{A_{si}}, \quad P_{fi} \propto \frac{\left(\frac{r_i}{w_i}\right)^{\alpha\nu_f} \left(\frac{w_i}{P_{mi}}\right)^{\nu_f} P_{mi}}{A_{fi}}.$$

We show how to solve for P_{ei}/P_{fi}, and the other relative prices are solved for analogously. Taking ratios of the expressions above and substituting for w_i/P_{mi} we get

$$\begin{aligned}
\frac{P_{ei}}{P_{fi}} &\propto \left(\frac{r_i}{w_i}\right)^{\alpha(\nu_e-\nu_f)} \left(\frac{w_i}{P_{mi}}\right)^{\nu_e-\nu_f} \frac{A_{fi}}{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}} \\
&= \frac{A_{fi}}{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}} \left(\frac{r_i}{w_i}\right)^{\alpha(\nu_e-\nu_f)} \left[\left(\frac{w_i}{r_i}\right)^{\alpha} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}}\right]^{\nu_e-\nu_f} \\
&= \frac{A_{fi}}{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_e-\nu_f}{\theta\nu_m}} .
\end{aligned}$$

Similarly,

$$\frac{P_{mi}}{P_{fi}} \propto \frac{A_{fi}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_f}{\theta\nu_m}} \text{ and } \frac{P_{si}}{P_{fi}} \propto \frac{A_{fi}}{A_{si}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_s-\nu_f}{\theta\nu_m}} .$$

A.3 Capital stock

Since $r_i k_i = \frac{\alpha}{1-\alpha} w_i$, aggregate stock of capital per worker $k_i \propto \frac{w_i}{r_i} = \frac{w_i}{r_{ei}^{\mu} r_{si}^{1-\mu}} \propto \left(\frac{w_i}{P_{ei}}\right)^{\mu} \left(\frac{w_i}{P_{si}}\right)^{1-\mu}$ ($r_{ei} \propto P_{ei}$ and $r_{si} \propto P_{si}$ come from the Euler equations). We derive w_i/P_{ei} by making use of the relative prices above:

$$\frac{w_i}{P_{ei}} = \frac{w_i}{P_{mi}} \frac{P_{mi}}{P_{ei}} \propto \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}} \left(\frac{w_i}{r_i}\right)^{\alpha} \frac{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_e}{\theta\nu_m}} .$$

Analogously,

$$\frac{w_i}{P_{si}} \propto \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}} \left(\frac{w_i}{r_i}\right)^{\alpha} \frac{A_{si}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_s}{\theta\nu_m}} .$$

Again, use the fact that $k_i \propto \frac{w_i}{r_i}$ and then

$$
\begin{aligned}
k_i &\propto \left(\left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}} k_i^{\alpha} \frac{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_e}{\theta\nu_m}} \right)^{\mu} \\
&\times \left(\left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}} k_i^{\alpha} \frac{A_{si}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_s}{\theta\nu_m}} \right)^{1-\mu} \\
\Rightarrow k_i &\propto \left(\left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}} \frac{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_e}{\theta\nu_m}} \right)^{\frac{\mu}{1-\alpha}} \\
&\times \left(\left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{1}{\theta\nu_m}} \frac{A_{si}}{(T_{mi}/\pi_{mii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_m-\nu_s}{\theta\nu_m}} \right)^{\frac{1-\mu}{1-\alpha}}.
\end{aligned}
$$

To derive an expression for the capital-output ratio, note that investment rates at domestic prices are identical across countries in our model: $\frac{P_{ei}x_i^e}{P_{fi}y_i}$ is a constant; similarly, $\frac{P_{si}x_i^s}{P_{fi}y_i}$ is also a constant. Therefore, $x_i^e/y_i \propto P_{fi}/P_{ei}$ and $x_i^s/y_i \propto P_{fi}/P_{si}$. To solve for the capital-output ratio write $k_i = (k_i^e)^{\mu}(k_i^s)^{1-\mu}$ in terms of relative price as follows: $k_i^e \propto x_i^e, k_i^s \propto x_i^s$, $x_i^e/y_i \propto P_{fi}/P_{ei}$, and $x_i^s/y_i \propto P_{fi}/P_{si}$. Finally, use the expressions for relative prices in terms of $A_{fi}, T_{ei}, T_{si}, \pi_{eii}$, and π_{mii} given above.

$$
\frac{k_i}{y_i} \propto \left(\frac{A_{fi}}{(T_{ei}/\pi_{eii})^{\frac{1}{\theta}}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_e-\nu_f}{\theta\nu_m}} \right)^{-\mu} \left(\frac{A_{fi}}{A_{si}} \left(\frac{T_{mi}}{\pi_{mii}}\right)^{\frac{\nu_s-\nu_f}{\theta\nu_m}} \right)^{\mu-1}.
$$

B Data

This section of the Appendix describes the sources of data as well as any adjustments we make to the data to map it to the model.

B.1 Production and trade data

Mapping the trade dimension of our model to the data requires data on both production and international trade flows. Our focus is on manufactured intermediate goods. We interpret manufacturing broadly as defined by revision 3 of the International Standard Industrial Classification (ISIC): two-digit codes 15-37. Within manufacturing, capital goods corresponds to ISIC 29-35. Intermediates corresponds to all of manufacturing not classified as capital goods. Structures in our model corresponds to ISIC category

45. Final goods in our model correspond to the remaining ISIC categories excluding capital goods, intermediate goods, and structures.

We obtain production data from multiple sources. First, we utilize value added and gross output data from the INDSTAT2, a database maintained by UNIDO (2013), which is reported at the two-digit Ievel using ISIC. This data extends no further than 2010, and even less for many countries. We turn to data on value added output in United Nations National Accounts Main Aggregates Database which reports value added output for 2011. For countries that report both value added and gross output in INDSTAT, we use the ratio from the year that is closet to 2011, and apply that ratio to the value added from UNIDO to recover gross output. For countries that are have no data on gross output in INDSTAT for any years, we apply the average ratio of value-added-to-gross output across all countries, and apply that ratio to the value added figure in UNIDO for 2011. In our data set, the ratio of value-added-to-gross output does not vary significantly over time, and is also not correlated with level of development or country size.

Our source of trade data is the UN Comtrade Database http://comtrade.un.org. Trade is reported for goods using revision 2 of the Standard International Trade Classification (SITC) at the four-digit level. We make use of the correspondence tables created by Affendy, Sim Yee, and Satoru (2010) to map SITC2 to ISIC. We also omit any petroleum-related products from the trade data.

Using the trade and production data, we construct bilateral trade shares for each country pair by following Bernard, Eaton, Jensen, and Kortum (2003) as follows:

$$\pi_{ij} = \frac{X_{ij}}{ABS_{bi}},$$

where i denotes the importer and j denotes the exporter. X_{ij} denotes manufacturing trade flows from j to i, and ABS_i is country i's absorption defined as gross output less net exports of manufactures.

B.2 National accounts and price data

PPP GDP and population For our baseline calibration, we collect data on output-side real GDP at current PPPs (2005 U.S. dollars) from version 8.1 of the Penn World Tables (see Feenstra, Inklaar, and Timmer, 2015, (PWT from now on)) using the variable `cgdpo`.

We use the variable emp from PWT to measure the number of workers in each country. The ratio $\frac{\texttt{cgdpo*pl\_gdpo}}{(1-\alpha)\texttt{pl\_c*emp}}$ corresponds to GDP per worker, $y = w/P_f$, in our model (labor compensation in U.S. dollars deflated by the PPP price of consumption).

We construct the price of intermediate goods, capital goods, and structures by combining disaggregate price data from the World Bank's 2011 International Comparison Program (ICP): http://siteresources.worldbank.org/ICPEXT/Resources/ICP_2011.html. The data has several categories that fall under what we classify as manufactures: "Food and nonalcoholic beverages", "Alcoholic beverages, tobacco, and narcotics", "Clothing and foot wear", and "Machinery and equipment"; as capital goods: "Machinery and equipment"; and as structures: "Construction". The ICP reports expenditure data for these categories in both nominal U.S. dollars and real U.S. dollars. The conversion from nominal to real uses the PPP price, that is: the PPP price equals the ratio of nominal expenditures to real expenditures. As such, we compute the PPP for intermediates as a whole of manufactures for each country as the sum of nominal expenditures across categories divided by the sum of real expenditures across categories.

C Estimation of θ

Simonovska and Waugh (2014) build on the procedure in Eaton and Kortum (2002). We refer to these papers as SW and EK henceforth. We briefly describe EK's method before explaining SW's method. For now we ignore sector subscripts, as θ for each sector is estimated independently.

In our model (equation (7)),

$$\log\left(\frac{\pi_{ij}}{\pi_{jj}}\right) = -\theta(\log\tau_{ij} - \log P_i + \log P_j) \tag{15}$$

where P_i and P_j denote the aggregate prices in countries i and j for the sector under consideration. If we knew τ_{ij}, it would be straightforward to estimate θ, but we do not. A key element is to exploit cross-country data on disaggregate prices of goods within the sector.

Let x denote a particular variety in the continuum. Each country i faces a price, $p_i(x)$, for that good. Ignoring the source of the producer of good x, a simple no-arbitrage argument implies that, for any two counties i and j, $\frac{p_i(x)}{p_j(x)} \leq \tau_{ij}$. Thus, the gap in prices between any two countries provides a lower bound for the trade barrier between them. In our model, we assume that the same bilateral barrier applies to all goods in the continuum, so $\max_{x \in X}\{\frac{p_i(x)}{p_j(x)}\} \leq \tau_{ij}$, where X denotes the set of goods for which disaggregate prices are available. One could thus obtain the bilateral trade barrier as $\log \hat{\tau}_{ij}(X) = \max_{x\in X}\{\log p_i(x) - \log p_j(x)\}$.

EK derive a method of moments estimator, $\hat{\rho}_{EK}$, as:

$$\hat{\rho}_{EK} = -\frac{\sum_i \sum_j \log\left(\frac{\pi_{ij}}{\pi_{jj}}\right)}{\sum_i \sum_j [\log \hat{\tau}_{ij}(X) - \log \hat{P}_i(X) + \log \hat{P}_j(X)]}, \tag{16}$$

where $\log \hat{P}_i(X) = \frac{1}{|X|} \sum_{x \in X} \log p_i(x)$ is the average price of goods in X in country i and $|X|$ is the number of goods in X.

SW show that the EK estimator is biased. This is because the sample of disaggregate prices is only a subset of all prices. Since the estimated trade barrier is only a lower bound to the true trade barrier, a smaller sample of prices leads to a lower estimate of $\hat{\tau}_{ij}$ and, hence, a higher estimate of $\hat{\rho}_{EK}$. SW propose a simulated method of moments estimator to correct for the bias.

The SW methodology is as follows. Start with an arbitrary value of θ. Simulate marginal costs for all countries for a large number of goods as a function of θ. Compute the bilateral trade shares π_{ij} and prices $p_i(x)$. Use a subset of the simulated prices and apply the EK methodology to obtain a biased estimate of θ, call it $\rho(\theta)$. Iterate on θ until $\hat{\rho}_{EK} = \rho(\theta)$ to uncover the true θ.

The first step is to parameterize the distribution from which marginal costs are drawn. This step requires exploiting the structure of the model. The model implies that

$$\log \frac{\pi_{ij}}{\pi_{ii}} = F_j - F_i - \theta \log(\tau_{ij}), \tag{17}$$

where $F_i \equiv \log d_i^{-\theta} T_i$. The F_i governs the distribution of marginal costs in country i. In order to estimate these, SW use a parsimonious gravity specification for trade barriers:

$$\log \tau_{ij} = dist_k + brdr_{ij} + exj + \varepsilon_{ij}. \tag{18}$$

The coefficient $dist_k$ is the effect of distance between countries i and j lying in the kth distance interval.[9] The coefficient $brdr_{ij}$ is the effect of countries i and j having a

[9] The distance intervals are measured in miles using the great circle method: [0,375); [375,750); [750,1500); [1500,3000); [3000,6000); and [6000,max).

shared border. The term ex_j is a country-specific exporter fixed effect. Finally, ε_{ij} is a residual that captures impediments to trade that are orthogonal to the other terms. Combining the gravity specification with equation 17, SW use ordinary least squares to estimate F_i for each country and bilateral trade barriers for all countries.

The second step is to simulate prices for every good in the "continuum" in every country. Recall that $p_{ij}(x) = \tau_{ij}\frac{d_j}{z_j(x)}$, where z_j is country j's productivity. Instead of simulating these productivities, SW show how to simulate the inverse marginal costs, $imc_j = z_j(x)/d_j$. In particular, they show that the inverse marginal cost has the following distribution: $F(imc_i) = \exp(-\tilde{F}_i imc_i^{-\theta})$, where $\tilde{F}_i = \exp(F_i)$. They discretize the grid to 150,000 goods and simulate the inverse marginal costs for each good in each country. Combining the simulated inverse marginal costs with the estimated trade barriers, they find the least-cost supplier for every country and every good and then construct country-specific prices as well as bilateral trade shares.

The third step is to obtain a biased estimate of θ using the simulated prices. Choose X to be a subset of the 150,000 prices such that X contains the same number of disaggregate prices as in the data. Call that estimate $\rho_s(\theta)$. Then perform $s = 100$ simulations. Finally, choose a value for θ such that the average "biased" estimate of θ from simulated prices is sufficiently close to the biased estimate obtained from the observed prices – that is, $\frac{1}{100}\sum_s \rho_s(\theta) = \hat{\rho}_{EK}$.

One caveat is that the number of disaggregate price categories that fall under producer durables is small. Therefore, we also include consumer durables to expand the sample size.

D Calibrated productivity parameters

Table D.1: Productivity parameters

Country	**Isocode**	A_{fi}	A_{si}	$T_{ei}^{\frac{1}{\theta}}$	$T_{mi}^{\frac{1}{\theta}}$
Armenia	ARM	0.68	0.41	0.20	0.25
Australia	AUS	0.97	0.82	0.76	0.73
Austria	AUT	0.76	0.95	0.44	0.72
Bahamas	BHS	0.65	1.40	0.24	0.29
Baltics	BAL	0.65	1.19	0.24	0.60
Bangladesh	BGD	0.44	0.87	0.11	0.29
Barbados	BRB	0.58	1.14	0.26	0.30
BeNeLux	BNL	0.80	1.06	0.40	0.34
Belarus	BLR	0.61	0.47	0.21	0.66
Belize	BLZ	0.39	0.41	0.18	0.55
Benin	BEN	0.43	0.50	0.07	0.15

Continued on next page. . .

Table D.1 – Continued

Country	**Isocode**	A_{fi}	A_{si}	$T_{ei}^{\frac{1}{\theta}}$	$T_{mi}^{\frac{1}{\theta}}$
Bhutan	BTN	0.74	1.01	0.11	0.26
Bolivia (Plurinational State of)	BOL	0.51	0.64	0.05	0.28
Botswana	BWA	0.67	1.80	0.16	0.08
Brazil	BRA	0.50	1.26	0.27	0.53
Bulgaria	BGR	0.52	0.90	0.12	0.49
Burkina Faso	BFA	0.33	0.46	0.06	0.04
Burundi	BDI	0.23	0.32	0.04	0.12
Cambodia	KHM	0.39	0.88	0.03	0.07
Cameroon	CMR	0.38	0.48	0.06	0.32
Canada	CAN	0.84	0.99	0.60	0.54
Central African Rep.	CAF	0.28	0.43	0.07	0.14
Chile	CHL	0.74	1.09	0.14	0.28
China, Hong Kong, Macao	CHM	0.46	0.93	0.21	0.41
Colombia	COL	0.51	0.78	0.19	0.64
Costa Rica	CRI	0.54	0.98	0.13	0.58
Cyprus	CYP	0.85	1.33	0.24	0.66
Czech Rep.	CZE	0.71	1.02	0.09	0.53
Cte d'Ivoire	CIV	0.38	0.66	0.10	0.14
Denmark	DNK	0.72	1.06	0.40	0.47
Dominican Rep.	DOM	0.63	1.00	0.25	0.60
Eastern Europe	FSB	0.64	1.03	0.18	0.57
Egypt	EGY	0.68	1.04	0.16	0.55
Ethiopia	ETH	0.45	0.70	0.02	0.12
Fiji	FJI	0.64	1.19	0.09	0.28
Finland	FIN	0.76	1.12	0.77	0.69
France	FRA	0.86	1.04	0.78	0.76
Gambia	GMB	0.45	0.65	0.05	0.10
Georgia	GEO	0.49	0.36	0.08	0.56
Germany	DEU	0.80	0.91	0.75	0.73
Greece	GRC	0.84	1.10	0.43	0.69
Guatemala	GTM	0.53	0.94	0.22	0.49
Honduras	HND	0.41	0.71	0.14	0.37
Hungary	HUN	0.61	0.98	0.22	0.50
Iceland	ISL	0.62	0.68	0.22	0.39
India	IND	0.41	0.73	0.12	0.46
Indonesia	IDN	0.52	1.23	0.19	0.38
Ireland	IRL	0.63	1.61	0.76	0.47
Israel	ISR	0.73	1.07	0.46	0.61
Italy	ITA	0.76	1.31	0.74	0.80
Jamaica	JAM	0.55	1.04	0.24	0.43
Japan	JPN	0.82	0.95	0.86	0.66
Jordan	JOR	0.70	1.03	0.13	0.66
Kazakhstan	KAZ	0.71	0.56	0.27	0.26
Kyrgyzstan	KGZ	0.44	0.24	0.08	0.33
Lesotho	LSO	0.46	0.68	0.08	0.15
Madagascar	MDG	0.35	0.49	0.03	0.19
Malawi	MWI	0.26	0.45	0.03	0.20
Malaysia-Singapore	SGM	0.62	1.31	0.21	0.40
Maldives	MDV	1.19	1.60	0.27	0.25
Mali	MLI	0.36	0.53	0.07	0.11
Mauritius	MUS	0.66	1.38	0.14	0.51
Mexico	MEX	0.73	1.03	0.17	0.55
Morocco	MAR	0.44	1.37	0.09	0.44
Mozambique	MOZ	0.26	0.37	0.05	0.13
Namibia	NAM	0.58	1.44	0.16	0.14
Nepal	NPL	0.44	0.61	0.04	0.19
New Zealand	NZL	0.78	0.78	0.47	0.59
Niger	NER	0.33	0.41	0.06	0.17
Pakistan	PAK	0.53	0.94	0.12	0.42

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Table D.1 – Continued

Country	**Isocode**	A_{fi}	A_{si}	$T_{ei}^{\frac{1}{\theta}}$	$T_{mi}^{\frac{1}{\theta}}$
Panama	PAN	0.75	0.88	0.08	0.34
Paraguay	PRY	0.49	0.86	0.08	0.38
Peru	PER	0.60	0.96	0.16	0.59
Philippines	PHL	0.47	1.04	0.17	0.41
Poland	POL	0.69	0.82	0.19	0.71
Portugal	PRT	0.67	1.35	0.33	0.68
Rep. of Korea	KOR	0.65	1.02	0.51	0.73
Rep. of Moldova	MDA	0.55	0.36	0.11	0.42
Romania	ROU	0.69	1.40	0.26	0.47
Russian Federation	RUS	0.61	0.54	0.33	0.77
Rwanda	RWA	0.31	0.37	0.06	0.21
Saint Vincent and the Grenadines	VCT	0.64	1.16	0.18	0.35
Sao Tome and Principe	STP	0.58	1.49	0.12	0.22
Senegal	SEN	0.37	0.61	0.07	0.25
South Africa	ZAF	0.55	1.17	0.27	0.52
Spain	ESP	0.74	1.28	0.63	0.80
Sri Lanka	LKA	0.66	1.15	0.12	0.45
Sweden	SWE	0.69	0.75	0.74	0.72
Switzerland	CHE	0.83	1.04	0.47	0.68
TFYR of Macedonia	MKD	0.73	1.19	0.14	0.32
Thailand	THA	0.50	1.15	0.19	0.47
Togo	TGO	0.35	0.54	0.05	0.08
Tunisia	TUN	0.59	1.85	0.07	0.40
Turkey	TUR	0.69	1.34	0.43	0.72
USA	USA	1.00	1.00	1.00	1.00
Uganda	UGA	0.35	0.92	0.06	0.20
Ukraine	UKR	0.48	0.34	0.06	0.53
United Kingdom	GBR	0.87	1.10	0.61	0.55
United Rep. of Tanzania	TZA	0.39	0.97	0.02	0.15
Uruguay	URY	0.60	1.10	0.17	0.59
Viet Nam	VNM	0.45	0.87	0.07	0.19
Yemen	YEM	0.48	0.62	0.07	0.27