International Trade and Composition of Capital Across Countries

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Abstract

Most of the world's equipment is produced in a small number of rich countries. Poor countries import much of their equipment. Structures are mostly domestically produced. In this paper, I ask the following question: What is the quantitative relationship between international trade in capital goods and the cross-country capital composition? To answer this question, I construct a multi-country model of trade. Within this framework, the equipment share of capital stock in a country is a function of the country-specific productivity parameters and the pattern of bilateral trade. I calibrate the model by picking country-specific parameters and trade costs so that the pattern of trade implied by the model matches the data in a sample of 76 countries. The calibrated model generates over 80% of the observed cross-country variation in equipment share of capital stock. Through counterfactual exercises, I find that if trade is shut down, cross-country variation in equipment capital increases by 13%, poor countries' welfare loss is 13% and rich countries' welfare loss is 3%. Elimination of all barriers to trade reduces variance in capital composition by 28%, increases poor countries' welfare by 34% and increases rich countries' welfare by only 8%. By facilitating an efficient allocation of capital across countries, reductions in barriers to trade allow poor countries to gain relative to rich countries.

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1 Introduction

Most of the world's equipment is produced in a small number of rich countries. In 1996, countries in top quartile of the cross-country income distribution produced 78% of world equipment and countries in the bottom quartile produced only 1.3%. Rich and poor countries also differ significantly in their dependence on the imports for equipment. Share of equipment in imports is over 25% for poor countries and 10% for rich countries. While Nigeria imported 76% of its equipment, Japan imported less than 6% of its equipment (see figures 1 and 2 in the Appendix). Structures on the other hand, are largely domestically produced. Nigeria and Japan respectively produced 73% and 98% of their structures. The world pattern of production and trade in equipment and structures is potentially an important determinant of composition of capital across countries.

While it has been documented in the literature that aggregate capital-output ratio is correlated with economic development (Hall and Jones (1999); Caselli (2005)), capital composition is also systematically different across countries. The equipment capital-output ratio differs by a factor of 6.3 between rich and poor countries, and structures capital-output ratio differs only by a factor of 1.8. If we decompose the physical capital into equipment capital and structures capital, and conduct a standard development accounting exercise, equipment capital accounts for 26% of the observed variation in income, while structures capital accounts for 11%.[1]

In this paper, I ask the following question: What is the quantitative relationship between international trade in capital goods and the composition of capital across countries? To answer this question, I construct a multi-country model of trade. There are three tradable sectors: equipment, structures and intermediate goods, all with constant returns technologies. Each tradable sector has a continuum of goods. Similar to Dornbusch, Fischer and Samuelson (1977), production technologies differ across the continuum in the idiosyncratic productivity level. As in Eaton and Kortum (2002), I parameterize productivity levels with Type II extreme value distributions, which are independent across countries and across tradable goods. Countries differ in their average level of productivity for each of the tradable goods. International trade is subject to bilateral iceberg costs. Each country also has a final goods sector which produces a homogeneous non-tradable good with a constant returns technology common to all countries.

[1] For the purpose of this development accounting exercise, I assume a unitary elasticity of substitution between equipment and structures, i.e., $y = Ak_e^{\alpha_e} k_s^{\alpha_s} h^{1-\alpha_e-\alpha_s}$. y is output, A is TFP, k_e is equipment capital, k_s is structures capital and h denotes human capital. All variables are in per-worker terms except TFP. Following Krusell, Ohanian, Rios-Rull and Violante (2000), I set $\alpha_s = 0.117$, so $\alpha_e = 0.216$.

The theoretical model allows capital goods to flow across countries, and therefore the equipment capital and structures capital stocks are determined endogenously. Labor, thus, is the only factor of production which is immobile across countries. Within the realms of the model, pattern of capital goods trade affects capital accumulation in each country. The equipment share of capital stock in a country is a function of the country specific productivity parameters and the pattern of bilateral trade. This enables me to determine the quantitative relationship between international trade and the capital composition differences.

To quantify the model, I use a structural relationship implied by the model that connects the productivity parameters and trade costs to the pattern of bilateral trade. I specify the trade costs parsimoniously as a function of distance, shared border, language and an exporter effect. Incorporating this specification into the structural relationship, I recover the productivity parameters and trade costs for equipment, structures and intermediate goods from the bilateral trade data for a sample of 76 countries. My model fits the data on bilateral trade volumes well: the R^2 is 84% for equipment, 73% for structures and 76% for intermediate goods.

Equipped with productivity parameters and trade costs, I examine the implications of the model for capital composition differences. The calibrated model generates over 80% of the observed cross-country variation in equipment share of capital. The model also generates equipment capital-output ratio and structures capital-output ratio consistent with the data. The equipment capital - output ratio is a factor of 6.3 between rich and poor in the data and 7.16 in the model. The structures capital - output ratio is a factor of 1.8 in data and 1.43 in the model.

To examine the quantitative implications of international trade for capital composition across countries, I conduct several counterfactual exercises by adjusting trade costs. Reductions in trade barriers reduce cross-country differences in capital composition and result in significant welfare gains. In one experiment, I shut down all trade. This increases the cross-country variation in log equipment capital - output ratio by 13%. The welfare cost of autarky is higher for poor countries at 13% as compared to rich countries whose welfare cost is 3%. In another experiment, I eliminate all trade costs. Here, the variance of log equipment share of capital declines by 28%. Resulting increase in welfare is 34% for poor countries and 8% for rich countries. Since trade determines equipment flow to poor countries, distortions in the world trading system affect equipment share of capital in poor countries. If there were a central planner who efficiently allocated capital goods production and usage across countries, then she would allocate production to countries most efficient in producing capital goods and distribute the capital goods to the other countries. Eliminating trade barriers essentially accomplishes this in a decentralized manner, by facilitating an efficient allocation of world stock of capital across countries. My results demonstrate that barriers to capital goods trade are quantitatively important for economic development.

Relative to recent research by Eaton and Kortum (2001), the key distinctions are the question that I address and the quantitative results implied by my model. Eaton and Kortum (2001) model trade in equipment only and focus on the price of equipment and cross-country productivity differences. I model trade in equipment and structures and study the effect on capital composition differences across countries. As in Eaton and Kortum (2001), trade costs in my model are reflected in the price of capital goods. Eaton and Kortum (2001) focus on a sample of 34 countries which are mostly rich OECD countries. My sample of countries is larger and more suited to study economic development questions as 15 out of 76 countries are in the lowest quartile of world income distribution. I use equilibrium conditions in the model and show that there are considerable gains to poor countries associated with changes in the world trading system.

The paper proceeds as follows: section 2 describes the model and an equilibrium. Section 3 describes the calibration methodology and section 4 presents the results. Section 5 concludes.

2 Model

There are N countries in the world economy. Each country has three tradable sectors: equipment, structures and intermediate goods; and a non-tradable final good sector. Within each country i, there is a measure of consumers, L_i. Each consumer has one unit of time, which is supplied inelastically in the domestic labor market. Equipment capital, structures capital and labor are used to produce the flow of equipment goods, structures, intermediate goods and the final good. In short, my model augments the static trade model in Waugh (2009) to three sectors and allows for trade in equipment and structures in addition to trade in intermediate goods. Thus, labor is the only factor which is immobile across countries. In the following, all variables for country i are normalized relative to workforce in country i, L_i.

2.1 Production Technology for Tradable Goods

As in Dornbusch et al. (1977), there is a continuum of goods within each tradable sector indexed by $x^J \in [0,1]$, where $J = E, S, M$ denotes equipment, structures and intermediate goods sector. In country i, equipment capital k_i^E, structures capital k_i^S, labor l_i and aggregate tradable good Q_i^J are combined by the following nested Cobb-Douglas production function to produce quantity $q_i^J(x^J)$ of the good x^J:

$$q_i^J(x^J) = z_i^J(x^J)^{-\theta} \left(\left[\mu k_i^{E\,\frac{\sigma-1}{\sigma}} + (1-\mu) k_i^{S\,\frac{\sigma-1}{\sigma}} \right]^{\left(\frac{\sigma}{\sigma-1}\right)\alpha} l_i^{1-\alpha} \right)^{\beta^J} Q_i^{J\,1-\beta^J}$$

Across goods x^J, production technology within a tradable sector differs only in idiosyncratic productivity level $z_i^J(x^J)^{-\theta}$. Power terms α, β^J, σ and θ, and share μ are common to all countries. All firms in country i have access to the technology for good x^J with idiosyncratic productivity level $(z_i^J)^{-\theta}$.

The aggregate tradable good Q_i^J is produced by aggregating individual tradable goods within each tradable sector J according to a standard Dixit-Stiglitz technology with elasticity of substitution $\eta > 0$.

$$Q_i^J = \left[\int_0^1 q_i^J(x^J)^{\frac{\eta-1}{\eta}} dx^J \right]^{\frac{\eta}{\eta-1}}$$

2.1.1 Distribution of Productivity Levels

Following Eaton and Kortum (2002), I assume that the idiosyncratic productivities in each tradable sector are realizations of a random variable z_i^J. As in Alvarez and Lucas (2007), I assume that z_i^J is distributed independently and exponentially with parameter λ_i^J, which differs across countries and across sectors.

Under this distributional assumption, $(z_i^J)^{-\theta}$ follows a Fréchet distribution. For each country, mean of this distribution is proportional to $(\lambda_i^J)^\theta$ and θ is the coefficient of variation. A country with a higher λ_i^J, on average, can produce the goods in sector J more efficiently. In this respect, λ_i^J governs absolute advantage of country i in tradable sector J. Parameter θ controls the dispersion of productivity levels around the mean. A larger θ implies that there is more variation relative to the mean. As Eaton and Kortum (2002) point out, θ controls the degree of comparative advantage. Intuitively, a larger θ implies more heterogeneity in productivity levels and hence, larger gains from trade.

Given above structure, without loss of generality, each good x^J may be relabeled by its productivity level, z_i^J. Thus the aggregate tradable good in sector J can be written as:

$$Q_i^J = \left[\int_0^1 q_i^J(z_i^J)^{\frac{\eta-1}{\eta}} \psi^J(z_i^J) dz^J\right]^{\frac{\eta}{\eta-1}}$$

where ψ^J is the joint density of productivities for all countries in sector J:

$$\psi^J(z^J) = \left(\prod_{n=1}^{N} \lambda_n^J\right) exp\left(-\sum_{n=1}^{N} \lambda_n^J z_n^J\right)$$

2.2 Final Goods Sector

In each country, there is a representative firm producing a homogenous final good that is non-tradable. Each firm has access to the following nested Cobb-Douglas production function that combines equipment capital k_i^E, structures capital k_i^S, labor l_i and aggregate intermediate good Q_i^M:

$$y_i^f = \left(\left[\mu {k_i^E}^{\frac{\sigma-1}{\sigma}} + (1-\mu){k_i^S}^{\frac{\sigma-1}{\sigma}}\right]^{\left(\frac{\sigma}{\sigma-1}\right)\alpha} l_i^{1-\alpha}\right)^{\gamma} {Q_i^M}^{1-\gamma}$$

where α, γ are the factor shares and same across countries.

2.3 Capital Stocks

Equipment and structures capital stocks are linear functions of current flows of equipment and structures. That is, $k_i^E = \frac{I_i^E}{\delta}$ and $k_i^S = \frac{I_i^S}{\delta}$, where $\delta \epsilon (0, 1)$ and is common to all countries. I_i^E and I_i^S are functions aggregate equipment and aggregate structures respectively (more details in section 3). This relationship between flows and stocks resembles a steady state relationship in the neoclassical growth model, although my model is not dynamic. This assumption enables me to study the relationship between current volume of trade and capital stock composition in a static framework.

2.4 Trade Costs

Trade costs are assumed to be of the iceberg type. $\tau_{in}^J > 1$ of good z^j must be shipped from country n for one unit to arrive in country i so, $(\tau_{in}^J - 1)$ units 'melt away' in the transit. τ_{in}^J comprises both of policy and non-policy barriers to trade. It also represents the adjustment costs, if any, associated with adaptation of an imported equipment and structures to domestic production conditions. For consistency, $\tau_{ii}^J = 1$ for each country and for each sector.

2.5 Firm Optimization

In country i, let w_i denote the wage rate, r_i^E denote the rental rate for equipment capital, r_i^S denote the rental rate for structures capital and P_i^J denote the price of aggregate tradable good in sector J. These prices are determined in a general equilibrium (described in the next section) and they are internationally comparable.

Given the prices, wage rate and rental rates for equipment and structures capital, the representative firm producing individual good z_i^J in country i minimizes the cost of supplying $q_i^J(z_i^J)$.

The representative firm producing aggregate tradable good Q_i^J in each sector J optimizes by purchasing $q_i^J(z_i^J)$ from the lowest cost producer across all countries. Solution to this problem yields the following price of aggregate tradable good in sector J:

$$P_i^J = \left[\int_0^\infty p_i^J(z_i^J)^{1-\eta}\phi^E(z_i^J)dx^J\right]^{\frac{1}{1-\eta}}$$

where $p_i^J(z^J) = \min\{p_{i1}^J(z^J), p_{i2}^J(z^J), ..., p_{iN}^J(z^J)\}$ and $p_{in}^J(z^J)$ is the price country i can purchase good x^J from country n including the trade costs.

The representative firm's problem in final goods sector is to minimize the cost of supplying y_i^f given the factor prices w_i, r_i^E, r_i^S and P_i^M.

2.6 Equilibrium

Each economy is characterized by exogenous country-specific productivity parameters and trade costs. The equilibrium allocations, prices and trade shares are all functions of these primitives given that the firms optimize and international trade is balanced. In equilibrium, allocations and prices are functions of price of equipment, structures, intermediate good, wages and trade shares. Once these are known, the equilibrium is completely determined.

Price Indices: Each country faces the following price index of aggregate good in sector J:

$$P_i^J = \Gamma^J \left\{ \sum_{n=1}^{N} \left\{ \left(\left[\mu^\sigma {r_i^E}^{1-\sigma} + (1-\mu)^\sigma {r_i^S}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \right)^{\alpha\beta^J} {w_i}^{(1-\alpha)\beta^J} {P_i^J}^{1-\beta^J} \tau_{in}^J \right\}^{-\frac{1}{\theta}} \lambda_n^J \right\}^{-\theta} \tag{1}$$

$$\Gamma^J = \beta^J \gamma^{-\beta^J \gamma} (\beta^J (1-\gamma))^{-\beta^J (1-\gamma)} (1-\beta^J)^{-(1-\beta^J)} S(\theta,\eta)^{\frac{1}{1-\eta}} \tag{2}$$

where $S(\theta, \eta)$ is gamma function evaluated at $1 + \theta(1 - \eta)$. The derivation of price index is given in the Appendix.

The price indices of equipment, structures and intermediate good summarize how the states of technology around the world, input costs across countries and geographic barriers govern the prices in each country. As Eaton and Kortum (2002) point out, international trade enlarges each country's effective state of technology. With no geographic barriers, above price index is same in each country and the law of one price holds.

Trade Shares: Let π_{in}^J denote the share of country n in country i's total expenditure in sector J. Since there is a continuum of goods, π_{in}^J is also the fraction of goods in sector J that country i imports from country n. Given the distributional assumption for productivities, this boils down to finding the probability that country n is lowest cost supplier of goods in sector J to country i. This results in following expression for trade shares in sector J for $n = 1, 2, ..., N$ (see Appendix for details):

$$\pi_{in}^J = \frac{\left\{ \left(\left[\mu^\sigma r_n^{E\,1-\sigma} + (1-\mu)^\sigma r_n^{S\,1-\sigma} \right]^{\frac{1}{1-\sigma}} \right)^{\alpha\beta^J} w_n{}^{(1-\alpha)\beta^J} P_n^{J\,1-\beta^J} \tau_{in}^J \right\}^{-\frac{1}{\theta}} \lambda_n^J}{\Sigma_{v=1}^N \left\{ \left(\left[\mu^\sigma r_v^{E\,1-\sigma} + (1-\mu)^\sigma r_v^{S\,1-\sigma} \right]^{\frac{1}{1-\sigma}} \right)^{\alpha\beta^J} w_v{}^{(1-\alpha)\beta^J} P_v^{J\,1-\beta^J} \tau_{iv}^J \right\}^{-\frac{1}{\theta}} \lambda_v^J} \tag{3}$$

Thus, the home trade share (fraction of goods that country i produces domestically) for sector J in country i is:

$$\pi_{ii}^J = \frac{\left\{ \left(\left[\mu^\sigma r_i^{E\,1-\sigma} + (1-\mu)^\sigma r_i^{S\,1-\sigma} \right]^{\frac{1}{1-\sigma}} \right)^{\alpha\beta^J} w_i{}^{(1-\alpha)\beta^J} P_i^{J\,1-\beta^J} \right\}^{-\frac{1}{\theta}} \lambda_i^J}{\Sigma_{v=1}^N \left\{ \left(\left[\mu^\sigma r_v^{E\,1-\sigma} + (1-\mu)^\sigma r_v^{S\,1-\sigma} \right]^{\frac{1}{1-\sigma}} \right)^{\alpha\beta^J} w_v{}^{(1-\alpha)\beta^J} P_v^{J\,1-\beta^J} \tau_{iv}^J \right\}^{-\frac{1}{\theta}} \lambda_v^J}$$

Note that the sum of trade shares over all countries within each tradable sector is equal to 1. Also, if all trade costs are equal to 1 (no trade barriers), trade shares are independent of the importing country. That is, in a zero gravity world, all countries would import an equal fraction of each tradable good from the same source.

These trade shares are important objects as they map the pattern of trade to productivity parameters, trade costs and factor prices in each country. Since trade shares are measurable, these expressions for trade shares can be employed in the estimation of productivity parameters and trade costs. I will provide details of the procedure in the sections that follow.

Wages: An equilibrium wage vector is computed from the trade shares given balanced trade. Country i's imports are defined as

$$L_i \left(P_i^E Q_i^E \sum_{v \neq i}^{N} \pi_{iv}^E + P_i^S Q_i^S \sum_{v \neq i}^{N} \pi_{iv}^S + P_i^M Q_i^M \sum_{v \neq i}^{N} \pi_{iv}^M \right)$$

Exports may be defined as:

$$\sum_{v \neq i}^{N} L_v P_v^E Q_m^E \pi_{vi}^E + \sum_{v \neq i}^{N} L_v P_v^S Q_v^S \pi_{vi}^S + \sum_{v \neq i}^{N} L_v P_v^M Q_v^M \pi_{vi}^M$$

Including each country's consumption of tradable goods produced at home and imposing balanced trade implies the following relationship:

$$L_i \left(P_i^E Q_i^E + P_i^S Q_i^S + P_i^M Q_i^M \right) = \sum_{v=1}^{N} L_v P_v^E Q_v^E \pi_{vi}^E + \sum_{v=1}^{N} L_v P_v^S Q_v^S \pi_{vi}^S + \sum_{v=1}^{N} L_v P_v^M Q_v^M \pi_{vi}^M \quad (4)$$

Capital Stocks: In equilibrium, a fraction $1 - \beta^E$ of the aggregate equipment good is allocated to production of individual equipment goods and a fraction β^E is allocated to equipment capital: $I_i^E = \beta^E Q_i^E$. Similarly for structures, $I_i^S = \beta^S Q_i^S$. Hence, equipment and structures capital stocks are given by:

$$k_i^E = \frac{\beta^E Q_i^E}{\delta} \text{ and } k_i^S = \frac{\beta^S Q_i^S}{\delta}$$

Allocations: In equilibrium, all firms optimize by minimizing cost of production given the prices and technologies. Allocations rules for equipment capital, structures capital, labor are easy to compute once the wages, trade shares and price indices for equipment, structures, intermediate good are known.

2.7 Empirical Implications

In this section, I derive a theoretical expression for the equipment share of capital stock. In the sections that follow, I will employ this relation to study the quantitative implications of trade for capital composition.

Throughout the rest of the paper, I set $\beta^E = \beta^S = \beta$. For a meaningful interpretation of the theoretical expressions that I derive in this section, we need to know the value of the elasticity of substitution between equipment and structures, σ. As outlined later in section 4, the value of σ is such that $1 - \sigma < 0$.

Composition of Capital: To quantify the relationship between capital goods trade and capital stock composition, I derive an equilibrium relationship which connects the share of equipment in capital to the country-specific productivity parameters for equipment and structures, and the pattern of bilateral trade.

Rearranging (3) and using (1) for equipment provides the following expression for country i's home trade share for equipment:

$$\pi_{ii}^E = \frac{\left(\left\{\left[\mu^\sigma r_i^{E(1-\sigma)} + (1-\mu)^\sigma r_i^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right\}^{\alpha\beta^E} w_i^{(1-\alpha)\beta^E} P_i^{E1-\beta^E}\right)^{\frac{-1}{\theta}} \lambda_i^E}{P_i^{E\frac{-1}{\theta}} \phi}$$

Further rearrangement leads to following expression for the price of aggregate equipment:

$$P_i^E = \phi^{\frac{\theta}{\beta^E}} \left(\left\{\left[\mu^\sigma r_i^{E1-\sigma} + (1-\mu)^\sigma r_i^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right\}^{\alpha\beta^E} w_i^{(1-\alpha)\beta^E}\right)^{\frac{1}{\beta^E}} \left(\frac{\lambda_i^E}{\pi_{ii}^E}\right)^{-\frac{\theta}{\beta^E}} \tag{5}$$

Similarly price of aggregate structures is given by:

$$P_i^S = \phi^{\frac{\theta}{\beta^S}} \left(\left\{\left[\mu^\sigma r_i^{E1-\sigma} + (1-\mu)^\sigma r_i^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right\}^{\alpha\beta^S} w_i^{(1-\alpha)\beta^S}\right)^{\frac{1}{\beta^S}} \left(\frac{\lambda_i^S}{\pi_{ii}^S}\right)^{-\frac{\theta}{\beta^S}} \tag{6}$$

The theoretical model also implies that:

$$\frac{P_i^E k_i^E}{P_i^S k_i^S} = \left(\frac{P_i^E}{P_i^S}\right)^{1-\sigma} \tag{7}$$

We can use the price of equipment and structures from (5) and (6) in (7) to derive an expression for the share of equipment in capital stock of a country:

$$\frac{P_i^E k_i^E}{P_i^E k_i^E + P_i^S k_i^S} = \frac{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}}}{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}} + \frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}} \tag{8}$$

Similar to (8), share of structures in capital is given by:

$$\frac{P_i^S k_i^S}{P_i^E k_i^E + P_i^S k_i^S} = \frac{\frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}}{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}} + \frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}} \tag{9}$$

These expressions enable me to quantify the role played by international trade in determining capital composition across countries. In a closed economy, when trade costs are infinite, countries must consume what is produced at home. That is, $\pi_{ii}^J = 1$ for all sectors J. The equipment share of capital is determined solely by country's average productivity in equipment relative to structures:

$$\left(\frac{P_i^E k_i^E}{P_i^E k_i^E + P_i^S k_i^S}\right)_{closed} = \frac{\lambda_i^{E^{-\frac{\theta(1-\sigma)}{\beta}}}}{\lambda_i^{E^{-\frac{\theta(1-\sigma)}{\beta}}} + \lambda_i^{S^{-\frac{\theta(1-\sigma)}{\beta}}}}$$

When trade costs are finite (open economy), countries are able to import equipment and structures from relatively more efficient producers. That is, $\pi_{ii}^E < 1$ and $\pi_{ii}^S < 1$. So, a country that has a low λ_i^E relative to λ_i^S, but imports more equipment relative to structures, would have a higher share of equipment in capital than it would under autarky. Also, if the world economy is characterized by a larger θ and hence, a higher degree of comparative advantage, trade will matter more for capital composition than otherwise.

The theoretical model implies that the equipment capital-output ratio is also a function of country specific parameters:

$$\frac{k_i^E}{y_i} = \left\{\frac{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}}}{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}} + \frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}}\right\} \frac{I_i}{y_i} \frac{w_i}{(1-\gamma)\delta}$$

where I_i is the investment rate and y_i is the income per worker given as follows:

$$I_i = \frac{P_i^E I_i^E + P_i^S I_i^S}{P_i^f y_i}$$

$$y_i = \psi \ \text{TFP}_i \left[\mu k_i^{E^{\frac{\sigma-1}{\sigma}}} + (1-\mu) k_i^{S^{\frac{\sigma-1}{\sigma}}}\right]^{\frac{\sigma}{\sigma-1}(\alpha-(1-\alpha)\gamma)}$$

$$\text{TFP}_i = \left[\mu \left(\frac{\pi_{ii}^E}{\lambda_i^E}\right)^{\frac{\sigma-1}{\sigma}\frac{\theta}{\beta}} + (1-\mu)\left(\frac{\pi_{ii}^S}{\lambda_n^S}\right)^{\frac{\sigma-1}{\sigma}\frac{\theta}{\beta}}\right]^{-\frac{\gamma\sigma}{\sigma-1}} \left(\frac{\pi_{ii}}{\lambda_i^M}\right)^{-\frac{\theta(1-\gamma)}{\beta M}}$$

Similarly, structures capital-output ratio is given by the following expression:

$$\frac{k_i^S}{y_i} = \left\{ \frac{\frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}}{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}} + \frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}} \right\} \frac{I_i}{y_i} \frac{w_i}{(1-\gamma)\delta}$$

3 Calibration

3.1 Methodology

The country-specific productivity parameters and trade costs determine equilibrium allocations and the prices in the model economy. In order to explore the quantitative relationship between international trade and composition of capital, I need to estimate country-specific productivity parameters and trade costs. In this section, I outline the methodology I employ to estimate these unknown parameters from the pattern of bilateral trade.

To derive a structural relationship between the pattern of trade, productivity parameters and trade costs, I use the following compact expression for trade shares in sector J from equation (3):

$$\pi_{in}^J = \frac{(c_n^J \tau_{in}^J)^{\frac{-1}{\theta}} \lambda_n^J}{\Sigma_{v=1}^N (c_v^J \tau_{iv}^J)^{-\frac{1}{\theta}} \lambda_v^J}, \qquad n = 1, 2, ..., N$$

where $c_n^J = \left(\left[\mu^\sigma {r_n^E}^{1-\sigma} + (1-\mu)^\sigma {r_n^S}^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \right)^{\alpha\beta^J} {w_n}^{(1-\alpha)\beta^J} {P_n^J}^{1-\beta^J}$ is the unit cost of producing goods in sector J in country n. Clearly, country i's home trade share is:

$$\pi_{ii}^J = \frac{{c_i^J}^{-\frac{1}{\theta}} \lambda_i^J}{\Sigma_{v=1}^N (c_v^J \tau_{iv}^J)^{-\frac{1}{\theta}} \lambda_v^J}$$

As discussed in Eaton and Kortum (2002), the framework here nests a 'gravity equation' relationship between the trade shares, productivity parameters and trade costs. To derive this relationship, divide trade share π_{in}^J with home trade share π_{ii}^J:

$$\frac{\pi_{in}^J}{\pi_{ii}^J} = \frac{(c_n^J \tau_{in}^J)^{-\frac{1}{\theta}} \lambda_n^J}{{c_i^J}^{-\frac{1}{\theta}} \lambda_i^J} \tag{10}$$

Taking logs on both sides yields the following relationship for each of the tradable sectors:

$$log\left(\frac{\pi_{in}^J}{\pi_{ii}^J}\right) = F_n^J - F_i^J - \frac{1}{\theta} log \tau_{in}^J, \qquad J = E, S, M \tag{11}$$

where $F_i^J = c_i^{J^{-\frac{1}{\theta}}} \lambda_i^J$.

This equation describes a structural relationship between trade shares, productivity parameters and trade costs for each of the tradable goods. Hence, it can be used to estimate the productivity parameters and trade costs. For each tradable sector, N productivity parameters λ_i^J's need to be estimated. Also, for each tradable sector there are $N^2 - N$ bilateral trade relations, so $(N^2 - N)$ trade costs need to be estimated. But, there are only $N^2 - N$ measurable bilateral trade shares for each tradable sector. To mitigate the high data requirement, I specify the trade costs parsimoniously as:

$$log \tau_{in}^J = dis_s + b_{in} + lang_{in} + ex_{in}^J + \varepsilon_{in}^J \tag{12}$$

where the trade costs are a logarithmic function of distance, shared border effect and an exporter fixed effect. dis_s captures the effect of distance (in miles) between country i's capital city and country n's capital city, lying in the sth distance interval. The intervals are [0, 375), [375, 750), [750, 1500), [1500, 3000), [3000, 6000) and [6000, maximum). b_{in} is the effect of a shared border. $lang_{in}$ is the effect of shared official language. An exporter effect, ex_{in}^J, is included to capture the role played by exporter competitiveness. I assume that ε_{in}^J represents barriers to trade arising from other factors and is orthogonal to the ones considered.

Combining equation (11) and (12) leads to following:

$$log\left(\frac{\pi_{in}^J}{\pi_{ii}^J}\right) = F_n^J - F_i^J - \frac{1}{\theta}\left[dis_s + b_{in} + lang_{in} + ex_{in}^J + \varepsilon_{in}^J\right] \tag{13}$$

I estimate equation (13) for all tradable sectors with F_i^J's recovered as coefficients on country-specific dummy variables. Given the estimated regression coefficients and an assumed value for θ, τ_{in}^J's can be recovered using equation (12). Using the estimated F_i^J's and τ_{in}^J's, the price index in sector J is computed as:

$$P_i^J = \Gamma^J \left\{\sum exp(F_i^J) \tau_{in}^{J^{-\frac{1}{\theta}}}\right\}^{-\theta} \tag{14}$$

where Γ^J from equation (2) is constant across countries. Then, given the P_i^J's, λ_i^J's are computed from the following system of equations:

$$
\begin{aligned}
L_i\left(P_i^E Q_i^E + P_i^S Q_i^S + P_i^M Q_i^M\right) = \sum_{v=1}^{N} L_v P_v^E Q_v^E \pi_{vi}^E + \sum_{v=1}^{N} L_v P_v^S Q_v^S \pi_{vi}^S + \sum_{v=1}^{N} L_v P_v^M Q_v^M \pi_{vi}^M \\
\ldots \textit{Trade Balance} \\
F_i^J = c_i^{J\frac{-1}{\theta}} \lambda_i^J \quad \ldots 3N \;\; \textit{equations} \\
c_i^J = \left(\left[\mu^\sigma r_i^{E^{1-\sigma}} + (1-\mu)^\sigma r_i^{S^{1-\sigma}}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^J} w_i^{(1-\alpha)\beta^J} P_i^{J^{1-\beta^J}} \quad \ldots 3N \;\; \textit{equations} \\
k_i^E = \frac{I_i^E}{\delta} \quad \ldots 3N \;\; \textit{equations} \\
k_i^S = \frac{I_i^S}{\delta} \quad \ldots 3N \;\; \textit{equations} \\
I_i = P_i^E I_i^E + P_i^S I_i^S \quad \ldots 3N \;\; \textit{equations} \\
r_i^E = \frac{\gamma}{1-\gamma}\left[\mu k_i^{E^{\frac{\sigma-1}{\sigma}}} + (1-\mu) k_i^{S^{\frac{\sigma-1}{\sigma}}}\right]^{-1} k_i^{E^{-\frac{1}{\sigma}}} w_i \quad \ldots 3N \;\; \textit{equations} \\
r_i^S = \frac{\gamma}{1-\gamma}\left[\mu k_i^{E^{\frac{\sigma-1}{\sigma}}} + (1-\mu) k_i^{S^{\frac{\sigma-1}{\sigma}}}\right]^{-1} k_i^{S^{-\frac{1}{\sigma}}} w_i \quad \ldots 3N \;\; \textit{equations}
\end{aligned}
\tag{15}
$$

3.2 Data

The model year is 1996 and number of countries considered for the current exercise is 76. For estimation purposes, I assume that all the good categories in Standard International Trade Classification (SITC) Rev. 2 apart from equipment and structures, correspond to intermediate goods sector. The final goods sector is thought of as the sector producing all final goods and services for each economy.

Trade shares for each of the sectors have been constructed following Bernard, Eaton, Jensen and Kortum (2003), as follows:

$$
\pi_{in}^J = \frac{(\text{Value of country } i\text{'s imports from country } n)^J}{\text{Domestic production}^J + \text{Imports}^J \text{ - Exports}^J}
$$

This is a way to map production and trade data into the unit interval, by dividing inputs from country n used in country i with total inputs in country i. Country i's home trade share is constructed as follows:

$$\pi_{ii}^J = 1 - \sum_{v \neq i}^{J} \pi_{iv}^J$$

The data necessary for construction of trade shares is compiled from various sources. The production data is from INDSTAT 4 and INDSTAT 3 which is maintained by UNIDO. The bilateral trade data is compiled from Feenstra, Lipsey, Deng, Ma and Mo (2005). I took construction data from the World Bank compilation of national accounts. The INDSTAT data is arranged according to International Standard of Industrial Classification 4-digit Rev.2 and trade data is arranged according to SITC 4-digit Rev.2. In order to construct the trade shares, I established concordance between these two classification systems.

Tables 1 and 2 present equipment and structures trade shares for selected countries. Rich and poor countries differ in their dependence on imports for equipment. While US, UK and Japan domestically produce a large fraction of their equipment, countries like Senegal produce only 28% at home. Another key feature is that poor countries import a larger volume of equipment from rich countries, than rich import from poor. Structures are mostly domestically produced, both in rich and poor countries.

The bilateral distance measure used to estimate trade costs is in miles from capital cities of the trading partners. These measures, border and language data are from the Centre Dtudes Prospectives Et Dnformations Internationales (http://www.cepii.fr). I constructed labor endowment data from information in Heston, Summers and Aten (2002).

An implication of my model is that, in aggregate, every country purchases some non-zero amount of goods from all other countries. However, in reality, the bilateral trade matrix has many zeros. For the sample of 76 countries and 3 sectors, there are 17,100 possible trading combinations. Of these, 1,639 for intermediate goods, 2,761 for equipment and 4,221 for structures show no trade. This presents both an estimation issue and a computational issue.

For estimation, I deal with this issue by omitting any zero observed trade flows from estimation of equation (13). This has been a standard approach in empirical trade literature. Silva and Tenreyro (2006) propose a poisson pseudo maximum likelihood estimator to lessen any bias resulting from log-linearizing of equation (13) and from omission of zero observed trade flows. It has been noted that any bias resulting from omission of zero observed trade flows is quantitatively small (see Helpman, Melitz and Rubinstein (2007)).

The estimation yields trade costs for country pairs for whom bilateral trade data is available. However, for computation I need trade costs for all the $N^2 - N$ country pairs, including the instances where there are no trade flows between countries. I set the trade cost in such instances to twice the highest trade cost in my estimates.

3.3 Parameter Estimates

Common Parameters: Calibrated parameter values, common to all countries, are summarized in the following table:

Parameter	Description	Value
α	k's share	1/3
β^M	k and $\imath$'s share in intermediate goods production	0.33
β	k and $\imath$'s share in equipment and structures production	0.41
γ	k and $\imath$'s share in final goods production	0.72
η	elasticity of substitution in the aggregator	2
μ	output share of equipment	0.194
θ	variation in efficiency levels	0.15
σ	elasticity between k^E and k^S	1.58

I have calibrated parameter values as follows. Value of α is set at 1/3 in accordance with Gollin (2002). Following Alvarez and Lucas (2007), I have set θ equal to 0.15 and η equal to 2. I estimated the elasticity of substitution σ and the share parameter μ from US data (available on BEA website). An elasticity of 1.58 implies that equipment and structures are not perfect substitutes. This estimate contradicts the underlying assumption behind aggregation of equipment and structures to arrive at the total capital stock of a country. An elasticity of 1 is also used commonly in the literature (Krusell et. al (2000)), implying a Cobb-Douglas relation for the production technology.

Trade Costs: The parameter estimates are presented in Tables 3-8 of appendix. Reconstructed trade costs are inputs into the model and determine the price levels countries face. Consistent with the gravity literature, distance is an impediment to trade and the trade cost estimate increases as the distance between trading partners increases. Also, a shared border and common official language reduce the trade cost between any two trading partners. The exporter fixed effect is negatively correlated with the level of development. Rich countries have a trade cost advantage in the international market. The correlation between exporter effect and log income per worker is -0.46 for intermediate goods, -0.24 for equipment and -0.13 for structures.

Productivity Parameters: Tables 9-11 in the appendix present the estimates for productivity parameters. Consistent with the trade patterns, richer countries have better technologies and hence, have a competitive advantage in international trade of all goods. This technology advantage is more pronounced in case of equipment. While the productivity parameter for equipment differs between rich and poor countries by a factor of over 2.5, for rest of the goods it differs only by a factor of 1.6. This is consistent with Eaton and Kortum (2001) and Caselli and Wilson (2004). Another important feature is that productivity parameter for structures shows little variation with the level of development. The correlation between structures productivity parameter and income per-worker is 0.18. This corresponds well with the observation that structures are largely domestically produced.

4 Results

4.1 Composition of Capital

What role does capital goods trade play in determining cross-country capital composition differences? To answer this question, I use the framework outlined in section 2.7. As discussed, I can express equipment share of capital as a function of country-specific productivity parameters and home trade shares. Specifically the expression for equipment share of capital, as derived in equation (8), is:

$$\frac{P_i^E k_i^E}{P_i^E k_i^E + P_i^S k_i^S} = \frac{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}}}{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}} + \frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}}$$

The results are presented in following table:

	Log Variance	90/10 ratio
Data	0.37	3.29
Model	0.29	2.76

In the data, equipment constitute over 21% of the capital in rich countries and only 8% in poor countries. The cross-country variance of log equipment share of capital is 0.37. My model generates over 80% of the observed cross-country variation in equipment share of capital.

The calibrated model also matches well with data on equipment capital-output ratio and structures capital-output ratio. Following table gives summary statistics for cross-country variation in the data and in the calibrated model:

		Log Variance	90/10 ratio
Equipment Capital-Output ratio	Data	1.09	6.3
	Model	1.26	7.16
Structures Capital-Output ratio	Data	0.73	1.8
	Model	0.58	1.43

The model slightly over-predicts both the 90/10 percentile ratio and variance of log relative equipment capital-output ratio and accordingly, under-predicts corresponding summary statistics for structures capital-output ratio.

As an alternative measure of composition of capital, I consider the dispersion of equipment capital relative to structures capital across countries. Model implies the following expression for this measure, relative to the US:

$$\frac{P_i^E k_i^E / P_i^S k_i^S}{P_{US}^E k_{US}^E / P_{US}^E k_{US}^S} = \frac{\lambda_i^E}{\lambda_{US}^E}^{\frac{-\theta(1-\gamma)}{\beta}} \frac{\lambda_{US}^S}{\lambda_i^S}^{\frac{-\theta(1-\gamma)}{\beta}} \frac{\pi_{ii}^E}{\pi_{USUS}^E}^{\frac{\theta(1-\gamma)}{\beta}} \frac{\pi_{USUS}^S}{\pi_{ii}^S}^{\frac{\theta(1-\gamma)}{\beta}}$$

The variance of log of equipment capital relative to structures capital is 0.216 in data. My model generates over 78% of the observed variation, of which international trade accounts for over 47%.

International trade plays a considerable role in reducing the cross-country dispersion in composition of capital. Underlying the current pattern of trade are distortions that affect the pattern of observed π_{in}^J. If these distortions go down, the pattern of trade in capital goods would be altered. In turn, this would affect the cross-country composition of capital, thereby suggesting quantitative implications for not only capital composition. In the next section, I conduct such counterfactual exercises.

4.2 Role of Trade

International trade in capital goods plays a quantitatively significant role in determining cross-country capital composition. As noted in the previous section, reductions in barriers to trade can reduce the cross-country dispersion in equipment share of capital stock and consequently have significant welfare implications. The trade distortions alter world general equilibrium in at least two ways. One, since the distribution of equipment across countries is determined by international trade, any distortion to trade affects equipment flows to poor countries. Two, distortions in trade may also reflect a distorted allocation of production across countries.[2] Reductions in trade costs working through these two channels may have important welfare implications. To explore quantitative relationship between trade and capital composition, and study associated welfare implications, I perform counterfactual exercises by adjusting trade costs while keeping the estimated productivity parameters fixed.

4.2.1 Autarky

In the first counterfactual experiment, I shut down all trade and assess the associated welfare costs. This counterfactual world simulates a scenario where the trade costs are infinitely high and hence, prohibit trade. For purposes of computation, I assume $\tau_{in}^{J} = 15$ and compute the world general equilibrium. Welfare loss is defined as the percentage change in consumption from the baseline equilibrium to the counterfactual equilibrium. If trade is shut down, the cross-country differences in capital composition would increase by up to 13%. The equipment capital-output ratio would be factor of more than 9 between rich and poor countries. Following table summarizes the results:

Capital-Output ratio

		Log Variance	90/10 ratio
Equipment capital - output ratio	Baseline	1.26	7.16
	Autarky	1.42	9.3
Structures capital - output ratio	Baseline	0.58	1.43
	Autarky	0.63	1.56

The welfare costs of autarky would be very high for poor countries relative to rich countries. Poor countries welfare would decrease by 13% and rich countries welfare would decrease by only 3%.

Welfare Loss

[2]Waugh (2009) motivates reallocation of production of intermediate goods resulting from reduction in trade costs as a source of gains from trade. In my model, reductions in trade barriers change the pattern of capital goods trade, which is an additional source of welfare gains.

	Poor	Rich
Baseline	-	-
Autarky	-13%	-3%

In autarky, since poor countries can no longer import capital goods, they rely on domestic production of capital goods. Poor countries, on average, are less productive than rich countries in the production of equipment. In the absence of trade, this inefficiency in domestic equipment sector of poor countries alters the allocation of factors to various sectors. The size of overall pie decreases that results in high welfare costs for poor countries

4.2.2 Elimination of Trade Barriers in Equipment

In the second counterfactual experiment, I eliminate barriers to equipment trade, $\tau_{in}^{E} = 1$. For numerical computation of model, trade costs for structures and intermediate goods are kept at their baseline levels. The productivity parameters are also kept fixed at their calibrated levels. Using these parameters, I compute the general equilibrium of counterfactual world and arrive at the new set of prices, factor allocations, capital stocks and consumption levels for each of the 76 countries. Welfare gain is calculated as the percentage increase in consumption from the baseline equilibrium to the counterfactual equilibrium. The results are summarized in tables below:

Capital-Output Ratio

		Log Variance	90/10 ratio
Equipment capital - output ratio	Baseline	1.26	7.16
	$\tau_{in}^{E} = 1$	1.12	6.7
Structures capital - output ratio	Baseline	0.58	1.43
	$\tau_{in}^{E} = 1$	0.55	1.31

Welfare Gains

	Poor	Rich
Baseline	-	-
$\tau_{in}^{E} = 1$	9%	1.4%

With the elimination of equipment trade barriers, cross-country dispersion of both equipment capital-output ratio and structures capital-output ratio would decline. The equipment capital - output ratio would be a factor of 6.7 in this counterfactual world while it is 7.16 in the baseline case. Structures capital - output ratio would also reduce to a factor of 1.31 from 1.43 in the baseline case. Poor countries would experience a welfare increase of 9% while rich countries gain would be 1.4%. The overall world welfare gain would be 3%.

4.2.3 Elimination of Trade Barriers in Structures

In the third experiment, I eliminate trade costs in structures, $\tau_{in}^S = 1$. In this experiment, I keep the trade costs for equipment and intermediate goods fixed at the calibrated values from their baseline model, given by tables 3, 4, 7 and 8. The productivity parameters used for computation are also same as in the baseline model, given by tables 9-11. With the new set of parameters, I recompute the model and assess welfare gains associated with elimination of barriers in structures only. The results are summarized in tables below:

Equipment Capital - Output Ratio

	Log Variance	90/10 ratio
Baseline	1.26	7.16
$\tau_{in}^E = 1$	1.12	6.7
$\tau_{in}^S = 1$	1.29	7.3

Structures Capital - Output Ratio

	Log Variance	90/10 ratio
Baseline	0.58	1.43
$\tau_{in}^E = 1$	0.55	1.31
$\tau_{in}^S = 1$	0.57	1.43

With $\tau_{in}^S = 1$, cross-country capital composition difference would increase, but only marginally. In this counterfactual world, the equipment capital - output ratio would be a factor of 7.3 between rich and poor while it is a factor of 7.16 in the baseline model. The structures capital - output ratio would be a factor of 1.43 in the counterfactual world and is 1.43 in the baseline model. Hence, reduction in barriers to structures trade would not significantly alter the cross-country capital composition. Removal of barriers to equipment trade, on the other hand, play a significant role in reducing capital composition differences across countries. Equipment capital-out ratio would be a factor of 6.7 when $\tau_{in}^E = 1$ and 7.3 when $\tau_{in}^S = 1$. The associated welfare gains are summarized in the following table:

Welfare Gains

	Poor	Rich
Baseline	-	-
Autarky	-13%	-3%
$\tau_{in}^{E} = 1$	9%	1.4%
$\tau_{in}^{S} = 1$	1.5%	0.8%

Poor countries welfare gain would be 1.5% and rich countries welfare gain would be 0.8%. The welfare gains in this counterfactual world are significantly smaller than the case when barriers to equipment trade are eliminated. Poor countries gain relative to rich both when $\tau_{in}^{E} = 1$ and $\tau_{in}^{S} = 1$, but the gain is nearly 4 times larger in the former case.

4.2.4 Elimination of Trade Barriers in Intermediate Goods and Zero Gravity

In this section, I consider two more counterfactual exercises: elimination of trade barriers in intermediate goods and zero gravity. For the first one, I set $\tau_{in}^{M} = 1$ and trade barriers for equipment and structures are kept fixed at the baseline levels. For the zero gravity experiment, barriers in all three tradable sectors are eliminated, i.e., $\tau_{in}^{J} = 1,\ J = E, S, M$. This counterfactual world simulates a zero gravity world as geographic variables cease to be impediments to trade and the goods flow across borders as they flow within a country. This exercise is, admittedly, extreme. But, it does capture the potential of international trade in affecting capital composition.[3]

Using the trade costs and productivity parameters for two counterfactual experiments, I compute the respective equilibria and assess the implications for cross-country capital composition and welfare. The results are presented in following tables.

Equipment Capital - Output Ratio

	Log Variance	90/10 ratio
Baseline	1.26	7.16
$\tau_{in}^{E} = 1$	1.12	6.7
$\tau_{in}^{M} = 1$	1.02	6.1
$\tau_{in}^{J} = 1$ (zero gravity)	0.91	5.6

[3]Certain caveats behind the counterfactual results must be mentioned. The trade costs are modeled as iceberg costs to trade and not as tariffs. So, the goods that 'melt away' in transit are not accounted for like tariff revenue as being rebated to agents in each country.

Structures Capital - Output Ratio

	Log Variance	90/10 ratio
Autarky	0.63	1.56
$\tau_{in}^{E} = 1$	0.55	1.31
$\tau_{in}^{M} = 1$	0.52	1.27
$\tau_{in}^{J} = 1$ (zero gravity)	0.49	1.21

Equipment capital-output ratio is a factor of 7.16 between rich and poor in the baseline model, 6.7 when $\tau_{in}^{E} = 1$, 6.1 when $\tau_{in}^{M} = 1$ and 5.6 when $\tau_{in}^{J} = 1$. Hence, reduction in cross-country capital composition differences would be largest when all trade barriers are eliminated. A noteworthy observation is that the elimination of barriers in intermediate goods trade would have a larger impact on cross-country capital composition than the elimination of equipment trade barriers. I'll elaborate more on this in a bit.

Welfare Gains

	Poor	Rich
Baseline	-	-
$\tau_{in}^{E} = 1$	9%	1.4%
$\tau_{in}^{M} = 1$	22%	5%
$\tau_{in}^{J} = 1$ (zero gravity)	34%	8%

Poor countries would gain relative to rich both when $\tau_{in}^{M} = 1$ and $\tau_{in}^{J} = 1$. Poor countries welfare increase would be 22% and rich countries welfare increase would be 5% when trade barriers in intermediate goods are eliminated. In case of zero gravity, the welfare improvement for poor countries would be 34% and for rich countries is 8%.

Another noteworthy observation is that poor countries welfare gain would be 34% when all trade barriers are eliminated, 9% when barriers only to equipment trade are eliminated, and 22% when barriers only to intermediate goods trade are eliminated. Does this imply that most of the gains associated with elimination of barriers come from intermediate goods trade and not from equipment trade? This implication must be understood in light of following two facts. One, equipment is traded less as compared to intermediate goods. Equipment comprises roughly 25% of total imports for poor countries and less than 10% for rich countries. Two, the results here satisfy balanced trade. When barriers to equipment trade are eliminated, poor countries can import equipment cheaply. But, because of balanced trade, the increase in volume of equipment imports is limited by their capacity to export intermediate goods. On the other hand, when barriers to intermediate goods trade are eliminated, sufficient trade surplus is generated to finance a larger quantity of equipment imports. This results in a larger reduction in capital composition differences and a larger overall size of the pie when $\tau_{in}^{M} = 1$ and hence, larger welfare gains.

Since poor countries mostly import their equipment and trade determines equipment flows to poor countries, distortions in world trading system affect the cross-country variation in equipment share of capital. Eliminating trade barriers facilitates an efficient allocation of world stock of capital across countries. In my model, productivity parameters and trade costs together determine both capital goods trade and allocation of capital goods production across countries. In a world with lower trade barriers, reallocation of world capital to poor countries enables them to gain relative to rich countries. Hence, the barriers to capital goods trade are quantitatively important for economic development.

4.3 Sensitivity Analysis

The results presented in sections 4.1 and 4.2 hinge on the calibrated values of parameters that I use in numerical computations of the model. In the calibration exercise, I pin down values for the common parameters based on information from the existing literature and my estimates of the elasticity of substitution and the share parameter from US data. Then, using these values, I calibrate country-specific parameters to the data on bilateral trade, bilateral distance, border and language. In this section, I assess the sensitivity of results presented in sections 4.1 and 4.2 to the choice of parameter values for elasticity of substitution between equipment and structures, and the depreciation rate.

Elasticity of substitution: To assess the sensitivity of results to the elasticity of substitution between equipment and structures, I recalibrate the model for the case when $\sigma = 1$. A unitary elasticity of substitution between equipment and structures is commonly used in the literature (see Krusell et. al. (2000)). For purposes of this analysis, I use the values from Krusell et al (2000). To calibrate the country-specific parameters, I use the method outlined in section 3.1. Specifically, the coefficients from estimation of equation (13) remain unchanged with the change in elasticity of substitution. Thus, the trade costs and price implications (eqn. (14)) are the same as in the case with $\sigma = 1.58$. The productivity parameters are then arrived at by solving the system of equations in (15). The model implied capital-output ratios for the case of $\sigma = 1$ are presented in the following table:

Capital - Output ratio

		Log Variance	90/10 ratio
Equipment	Data	1.09	6.3
	Baseline ($\sigma = 1.58$)	1.26	7.16
	$\sigma = 1$	0.81	4.7
Structures	Data	0.73	1.8
	Baseline ($\sigma = 1.58$)	0.58	1.43
	$\sigma = 1$	0.62	1.5

The calibrated model in the case of unitary elasticity explains approximately 74% of observed variation in equipment share of capital. Thus, the explanatory power of the model declines marginally.

The results for autarky experiment are in the following tables.

Autarky Counterfactual Experiment: Capital - Output Ratio

		Log Variance	90/10 ratio
Equipment capital - output ratio	Baseline ($\sigma = 1.58$)	1.42	9.3
	$\sigma = 1$	1.03	6.1
Structures capital - output ratio	Baseline ($\sigma = 1.58$)	0.63	1.56
	$\sigma = 1$	0.71	1.58

Autarky Counterfactual Experiment: Welfare Loss

	Poor	Rich
Baseline $\sigma = 1.58$	-13%	-3%
$\sigma = 1$	-7.1%	-1.6%

Similar to the predictions of the baseline case, if trade is shut down, the cross-country capital composition differences would increase. While the baseline model predicts that if trade is shut down, cross-country dispersion in equipment capital-output ratio would increase by nearly 29%, the unitary elasticity case predicts this increase would be 27%. With regard to welfare change, the direction of change is same as in the baseline model, but the numerical values of welfare losses are substantially lower.

Depreciation rate: I also assess the importance of depreciation rate for model's ability to reproduce observed cross-country variation in capital composition and incomes. In the baseline case, I assume both equipment and structures depreciate at 6%. In this exercise, I assume that equipment depreciates at 15% and structures depreciate at 4%. These values are in accordance with the Penn World Table. I use the method outlined in section 3.1 to calibrate the trade costs and productivity parameters. As in the previous case, the estimated coefficients from equation (13) are same as in the baseline case. Consequently, the trade costs and price implications remain unchanged. The productivity parameters are then arrived at by solving the system of equations in (15). The capital-output ratios implied by this calibrated model are presented in the following table:

Capital-Output ratio

		Log Variance	90/10 ratio
Equipment	Data	1.09	6.3
	Baseline ($\delta^E = \delta^S$)	1.26	7.16
	$\delta^E \neq \delta^S$	1.31	7.92
Structures	Data	0.73	1.8
	Baseline ($\delta^E = \delta^S$)	0.58	1.43
	$\delta^E \neq \delta^S$	0.55	1.31

The results from the calibrated model are not very sensitive to the change in depreciation rate. The explanatory power of the model slightly worsens in case of capital-output ratios. The log variance of equipment capital-output ratio is 1.26 in the baseline model and 1.31 when $\delta^E \neq \delta^S$. The results for autarky experiment are presented in the following tables.

Autarky Counterfactual Experiment: Capital-Output Ratio

		Log Variance	90/10 ratio
Equipment capital - output ratio	Baseline ($\delta^E = \delta^S$)	1.42	9.3
	$\delta^E \neq \delta^S$	1.56	9.7
Structures capital - output ratio	Baseline ($\delta^E = \delta^S$)	0.63	1.56
	$\delta^E \neq \delta^S$	0.6	1.43

Autarky Counterfactual Experiment: Welfare Loss

	Poor	Rich
Baseline $\delta^E = \delta^S$	-13%	-3%
$\delta^E \neq \delta^S$	-14.3%	-3.1%

As in the baseline case, autarky would increase the cross-country capital composition differences. In this economy, the cross-country capital composition differences would increase by 28%. The direction of welfare change is also same as in the baseline model and the numerical values of welfare losses are not substantially altered.

5 Conclusion

This paper examines the role played by trade in determining capital composition across countries. In a general equilibrium model of trade, I examine the quantitative relationship between international trade and cross-country capital composition. Calibrating the model to match bilateral trade pattern in 76 countries, I generate several interesting results. I show that trade is quantitatively important in explaining cross-country capital composition differences. Various trade liberalizations were considered and the welfare benefits are substantial with poor countries gaining relatively more than rich countries.

Understanding the implications of capital goods trade for cross-country capital composition and economic development is an important topic for continued research. Trade in capital goods is distinct from trade in other manufactures as trade in capital goods can transmit benefits of embodied technological progress across borders. In this respect, trade in equipment and structures would have stronger linkages with economic development.

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7 Appendix: Derivation of Price Indices and Trade Shares

In this section, I derive the expressions for the price index for tradable goods and the trade shares. The derivations here largely follow Alvarez and Lucas (2007).
Given tradable good producing firms behave optimally, price of individual tradable good z_i^J is as follows:

$$P_i^J(z^J)^{\frac{1}{\theta}} = \Gamma^{J\frac{1}{\theta}} min_v \left\{ \left[\left(r_i^{E1-\sigma} + r_i^{S1-\sigma} \right)^{\alpha\beta^J} w_i^{(1-\alpha)\beta^J} P_i^{J1-beta^J} \tau_{iv}^J \right]^{\frac{1}{\theta}} z_v^J \right\}$$

According to the distributional assumption for productivities, z_i^J is distributed exponentially with parameter λ_i^J. Following properties of the distribution are used in the derivation of price index and trade share:

- If $z \sim exp(\lambda), \kappa > 0 \rightarrow \kappa z \sim \left(\frac{\lambda}{\kappa}\right)$
- If $z = min(x, y), x \sim exp(\mu)$ and $y \sim exp(\xi) \rightarrow z \sim exp(\mu + \xi)$

This implies the distribution of prices faced by each country is:

$$P_i^J(z^J)^{\frac{1}{\theta}} \sim exp(\xi_i^J)$$

$$\text{where } \xi_i^J = \Gamma^{J-\frac{1}{\theta}} \sum_v^N \left[\left(r_i^{E1-\sigma} + r_i^{S1-\sigma} \right)^{\alpha\beta^J} w_i^{(1-\alpha)\beta^J} P_i^{J1-\beta^J} \tau_{iv}^J \right]^{\frac{-1}{\theta}} \lambda_v^J$$

This implies that price index in tradable sector J is:

$$(P_i^J)^{1-\eta} = \int_0^\infty \left\{ \xi_i^J p_i^J(z^J)^{1-\eta} exp\{-\xi_i^J p_i^J(z^J)^{\frac{1}{\theta}}\} dp_i^{J\frac{1}{\theta}} \right\}$$

Let $s = \xi_i^J p_i^J(z^J)^{\frac{1}{\theta}}$. Then the above expression modifies to:

$$(P_i^J)^{1-\eta} = (\xi_i^J)^{-1(1-\eta)\theta} \int_0^\infty s^{\theta(1-\eta)} exp(-s) ds$$

where the integral is the gamma function. Hence,

$$P_i^J = \Gamma^J S(\theta,\eta)^{\frac{1}{1-\eta}} \left\{ \sum_v^N \left[\left(r_i^{E1-\sigma} + r_i^{S1-\sigma} \right)^{\alpha\beta^J} w_i^{(1-\alpha)\beta^J} P_i^{J1-\beta^J} \tau_{iv}^J \right]^{\frac{-1}{\theta}} \lambda_v^J \right\}^{-\theta}$$

$S(\theta,\eta)$ is the gamma function evaluated at $1+\theta(1-\eta)$. For existence of $S(\theta,\eta)$, it is assumed that $1>\theta(1-\eta)$.

Trade share is given by the probability that some country n is the lowest cost supplier to country i. Following fact about exponential distribution aid in finding an expression for this probability:

- If x and y are independent and $x \sim exp(\mu)$ and $y \sim exp(\xi)$, then $\text{prob}(x \leq y) = \frac{\mu}{\mu+\xi}$

Note that:

$$\text{prob}[p_n^J(z^J) \leq \min_{n\neq v}\{p_v^J(z^J)\}] = \text{prob}[p_n^J(z^J)^{\frac{1}{\theta}} \leq \min_{n\neq v}\{p_v^J(z^J)^{\frac{1}{\theta}}\}]$$

This implies that,

$$\pi_{in}^J = \frac{\left(\left[r_n^{E\,1-\sigma} + r_n^{S\,1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^J} w_n{}^{(1-\alpha)\beta^J} P_n^{J\,1-\beta^J} \tau_{in}^J{}^{-\frac{1}{\theta}} \lambda_n^J}{\Sigma_{v=1}^N \left(\left(\left[r_v^{E\,1-\sigma} + r_v^{S\,1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^J} w_v{}^{(1-\alpha)\beta^J} P_v^{J\,1-\beta^J} \tau_{iv}^J\right)^{-\frac{1}{\theta}} \lambda_v^J} \tag{16}$$

8 Appendix: Figures

Figure 1: $\frac{\text{Equipment imports}}{\text{Domestic Production + Imports - Exports}}$

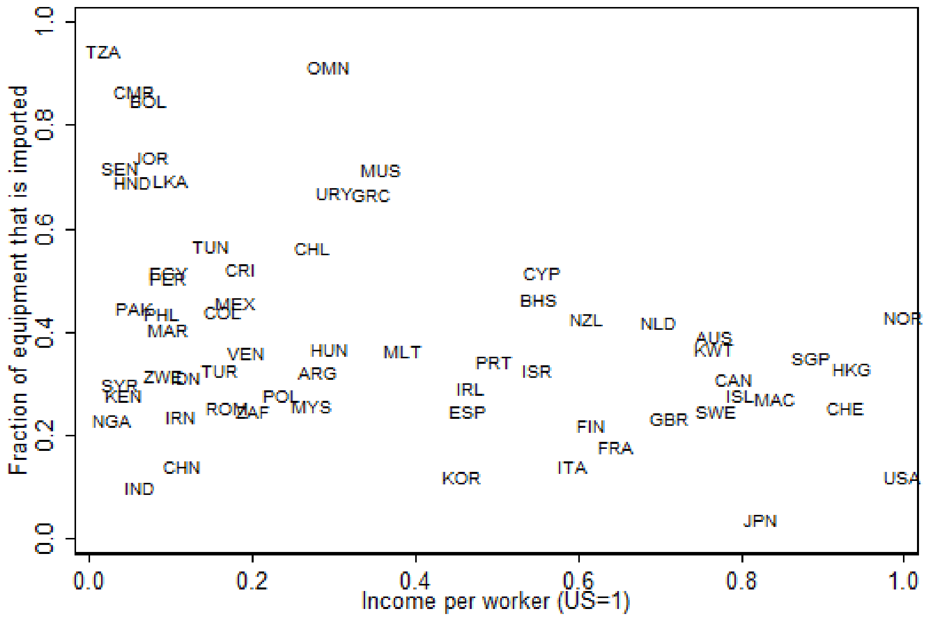
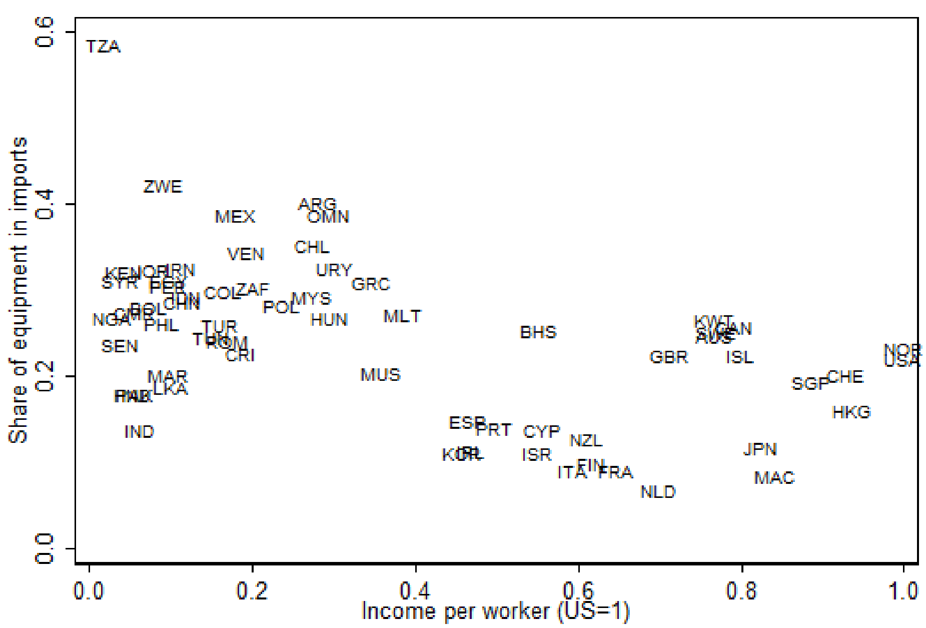


Figure 2: Share of Equipment in Total Imports



9 Appendix: Tables

Table 1: Trade Shares for Equipment, π_{in}^{E}

	USA	UK	Japan	Can.	Mauritius	Arg.	India	Egypt	Senegal	Zim.
USA	87.2	0.8	6.7	0.7	0.07	0.02	0.1	0	0	0
UK	10.8	71.8	4.9	0.4	0.05	0.04	0.16	0	0	0
Japan	1.6	0.1	96.2	0.2	0	0	0	0	0	0
Canada	30.7	1.9	4.8	55.8	0	0.12	0	0	0	0
Mauritius	3.4	9.3	11.6	0.3	20.7	0.1	0.5	0	0	0
Argentina	7.3	5.1	4.6	0.1	0.2	64.9	0.1	0	0	0
India	2.3	1.2	3.6	0.1	0.1	0	89.9	0	0	0
Egypt	11.0	6.1	8.7	0	0	0	0	48.2	0.8	0.17
Senegal	1.2	3.5	6.2	0.1	0	0	0	1.2	28.2	0.8
Zimbabwe	5.8	11.3	2.0	0.5	0	0	0	0.9	0.4	68.5

Note: Zeros indicate the value is less than 10^{-3}. Entry in row i, column n, is the fraction of equipment country i imports from country n.

Table 2: Trade Shares for Structures, π_{in}^S

	USA	UK	Japan	Can.	Mauritius	Arg.	India	Egypt	Senegal	Zim.
USA	98.4	0.06	0.01	0.4	0	0	0	0	0	0
UK	0.003	96.8	0.12	0.06	0	0	0	0	0	0
Japan	0	0	98.1	0.01	0	0	0	0	0	0
Canada	2.1	0.4	0.8	93.5	0	0	0	0	0	0
Mauritius	0.15	0.09	0.12	0.1	92.5	0	0.3	0	0	0
Argentina	0.6	0.3	0.2	0	0	97.1	0	0	0	0
India	0.09	0.3	0.5	0.01	0.1	0	98.7	0	0	0
Egypt	0.8	1.3	0.9	0.06	0	0	0	92.2	0.11	0.03
Senegal	0.95	0.26	0.67	0	0	0	0	0.12	88.7	0.01
Zimbabwe	1.3	3.7	1.1	0.05	0	0	0	0.17	0.07	72.7

Note: Zeros indicate the value is less than 10^{-3}. Entry in row i, column n, is the fraction of structures country i imports from country n.

Table 3: Geographic Barriers for Intermediate Goods Trade

$$log\tau_{ni}^{M} = dis_s + b_{ni} + lang_{ni} + ex_{ni}^{M} + \varepsilon_{ni}^{M}$$

Barrier	Coefficient	S.E.
Distance [0, 375)	-8.63	0.28
Distance [375, 750)	-8.65	0.16
Distance [750, 1500)	-8.98	0.09
Distance [1500, 3000)	-9.18	0.06
Distance [3000, 6000)	-9.19	0.06
Distance [6000, max)	-9.27	0.04
Shared Border	0.32	0.14
Common Official Language	-0.05	0.08

Table 4: Geographic Barriers for Equipment Trade

$$log\tau_{ni}^{E} = dis_s + b_{ni} + lang_{ni} + ex_{ni}^{E} + \varepsilon_{ni}^{E}$$

Barrier	Coefficient	S.E.
Distance [0, 375)	-7.76	0.28
Distance [375, 750)	-8.33	0.16
Distance [750, 1500)	-8.5	0.1
Distance [1500, 3000)	-8.82	0.07
Distance [3000, 6000)	-8.84	0.07
Distance [6000, max)	-9.05	0.06
Shared Border	0.59	0.14
Common Official Language	0.14	0.09

Table 5: Geographic Barriers for Structures Trade

$$log\tau_{ni}^{S} = dis_s + b_{ni} + lang_{ni} + ex_{ni}^{S} + \varepsilon_{ni}^{S}$$

Barrier	Coefficient	S.E.
Distance [0, 375)	-7.42	0.33
Distance [375, 750)	-8.22	0.2
Distance [750, 1500)	-8.7	0.13
Distance [1500, 3000)	-9.36	0.11
Distance [3000, 6000)	-9.82	0.11
Distance [6000, max)	-10.14	0.1
Shared Border	0.65	0.16
Common Official Language	0.42	0.11

Table 6: Exporter Dummy Coefficients for Intermediate Goods Trade

$$log\tau_{ni}^{M} = dis_s + b_{ni} + lang_{ni} + ex_{ni}^{M} + \varepsilon_{ni}^{M}$$

Country	Exporter Coefficient	S.E.
USA	-4.25	0.32
Albania	12.13	0.23
Argentina	-1.8	0.42
Australia	-2.11	0.24
Azerbaijan	0.57	0.24
Belgium & Lux	-0.87	0.37
Bulgaria	-0.19	0.22
Bolivia	0.09	0.25
Canada	-1.8	0.34
Switzerland	-2.15	0.23
Chile	-1.03	0.23
China & Hongkong	-2.06	0.25
Cameroon	2.54	0.22
Colombia	-1.25	0.31
Costa Rica	0.97	0.26
Cyprus	0.56	0.31
Germany	-3.71	0.29
Egypt	-1.25	0.23
Spain	-3.05	0.28
Estonia	5.8	0.22
Finland	-1.72	0.32
France	-3.01	0.23
United Kingdom	-2.95	0.23
Greece	-1.17	0.22
Honduras	2.59	0.23
Hungary	-0.76	0.33
Indonesia	-1.19	0.25
India	-2.29	0.24
Ireland	2.19	0.24
Iran	-0.23	0.24
Iceland	0.97	0.28
Israel	-0.74	0.32
Italy	-2.72	0.24
Jordan	-0.14	0.23
Japan	-4.05	0.31
Kazakhstan	2.59	0.23
Kenya	-0.93	0.28
Kyrgyzstan	3.68	0.31

Country	Exporter Coefficient	S.E.
Korea, Republic of	-2.43	0.41
Kuwait	4.21	0.23
Sri Lanka	1.26	0.3
Lithuania	0.97	0.29
Latvia	1.89	0.32
Morocco	-0.39	0.33
Republic of Moldova	1.49	0.25
Mexico	-0.28	0.37
TFYR of Macedonia	1.05	0.24
Malta	1.84	0.37
Myanmar	2.12	0.32
Mauritius	1.15	0.34
Malaysia & Singapore	2.35	0.35
Nigeria	2.72	0.24
Netherlands	4.21	0.28
Norway	1.32	0.22
New Zealand	-0.62	0.24
Oman	2.47	0.26
Pakistan	-0.12	0.29
Panama	2.19	0.25
Peru	-1.09	0.3
Philippines	-0.57	0.27
Poland	-1.6	0.25
Portugal	-1.72	0.23
Romania	-2.08	0.23
Russian Fed.	-1.88	0.24
Senegal	0.8	0.23
Slovenia	-0.63	0.35
Sweden	-1.04	0.25
Syria	-1.06	0.23
Tunisia	-0.42	0.3
Turkey	-2.03	0.27
Tanzania	0.93	0.23
Ukraine	-1.13	0.39
Uruguay	-0.65	0.3
Venezuela	0.24	0.29
South Africa	-1.25	0.27
Zimbabwe	0.5	0.25

Table 7: Exporter Dummy Coefficients for Equipment Trade

$$log\tau_{ni}^{E} = dis_s + b_{ni} + lang_{ni} + ex_{ni}^{E} + \varepsilon_{ni}^{E}$$

Country	Exporter Coefficient	S.E.
USA	-2.85	0.5
Albania	5.17	0.24
Argentina	-1.35	0.96
Australia	-1.84	0.28
Azerbaijan	2.69	0.26
Belgium & Lux	-1.25	0.7
Bulgaria	-1.34	0.24
Bolivia	0.61	0.29
Canada	-2.24	0.78
Switzerland	-1.67	0.24
Chile	-0.31	0.24
China & Hongkong	2.84	0.3
Cameroon	2.26	0.24
Colombia	-0.92	0.63
Costa Rica	1.37	0.31
Cyprus	9.58	0.42
Germany	-2.67	0.32
Egypt	-0.73	0.22
Spain	-2	0.31
Estonia	0.9	0.24
Finland	-1.72	0.4
France	-3.05	0.25
United Kingdom	-2.7	0.23
Greece	0.03	0.22
Honduras	2.13	0.26
Hungary	-0.2	0.53
Indonesia	-1.69	0.26
India	-2.61	0.27
Ireland	-1.28	0.26
Iran	-1.83	0.26
Iceland	1.24	0.36
Israel	-1.21	0.37
Italy	-2.27	0.26
Jordan	0.83	0.23
Japan	-3.75	0.39
Kazakhstan	0.5	0.24
Kenya	-0.82	0.41
Kyrgyzstan	3.75	0.45

Country	Exporter Coefficient	S.E.
Korea, Republic of	-2.58	0.65
Kuwait	1.1	0.25
Sri Lanka	1.02	0.34
Lithuania	0.58	0.37
Latvia	0.22	0.38
Morocco	-0.24	0.41
Republic of Moldova	8.83	0.32
Mexico	-0.05	0.54
TFYR of Macedonia	0.59	0.27
Malta	0.23	0.38
Myanmar	9.01	0.33
Mauritius	3.11	0.58
Malaysia & Singapore	-1.74	0.45
Nigeria	-1.5	0.25
Netherlands	-1.03	0.43
Norway	-0.5	0.23
New Zealand	-1.14	0.26
Oman	2.18	0.3
Pakistan	-0.14	0.34
Panama	2.62	0.3
Peru	-0.88	0.34
Philippines	-0.78	0.32
Poland	-1.69	0.29
Portugal	-1.85	0.26
Romania	-2.02	0.26
Russian Fed.	-2.24	0.27
Senegal	1.24	0.25
Slovenia	0.3	0.62
Sweden	-1.19	0.28
Syria	-0.75	0.24
Tunisia	-0.14	0.45
Turkey	-1.66	0.37
Tanzania	4.33	0.25
Ukraine	-1.55	0.5
Uruguay	1.44	0.33
Venezuela	-1.47	0.42
South Africa	-1.8	0.32
Zimbabwe	-1.46	0.26

Table 8: Exporter Dummy Coefficients for Structures Trade

$$log\tau^S_{ni} = dis_s + b_{ni} + lang_{ni} + ex^S_{ni} + \varepsilon^S_{ni}$$

Country	Exporter Coefficient	S.E.
USA	0.89	1.25
Albania	-0.7	0.28
Argentina	-0.61	0.98
Australia	0.43	0.45
Azerbaijan	1.02	0.36
Belgium & Lux	0.05	0.91
Bulgaria	1.02	0.31
Bolivia	0.07	0.36
Canada	0.44	0.91
Switzerland	-0.83	0.33
Chile	-0.57	0.32
China & Hongkong	0.14	0.43
Cameroon	2.28	0.3
Colombia	-1.68	1.28
Costa Rica	0.78	0.54
Cyprus	-0.32	1.25
Germany	-0.27	0.57
Egypt	-0.2	0.26
Spain	-0.31	0.56
Estonia	0.27	0.3
Finland	0.36	0.71
France	-0.53	0.32
United Kingdom	0.24	0.27
Greece	-1.8	0.26
Honduras	0.28	0.4
Hungary	-0.6	1.28
Indonesia	-0.8	0.43
India	-1.27	0.55
Ireland	-0.72	0.38
Iran	-0.84	0.37
Iceland	0.83	0.67
Israel	-1.24	0.75
Italy	0.39	0.4
Jordan	0.91	0.27
Japan	-0.84	0.77
Kazakhstan	2.63	0.32
Kenya	-0.19	0.77
Kyrgyzstan	1.15	1.27

Country	Exporter Coefficient	S.E.
Korea, Republic of	1.25	0.96
Kuwait	0.67	0.31
Sri Lanka	1.09	0.55
Lithuania	-2.25	1.24
Latvia	-0.63	0.78
Morocco	-0.85	0.95
Republic of Moldova	-0.17	0.62
Mexico	-0.23	1.29
TFYR of Macedonia	-0.72	0.37
Malta	1.49	0.94
Myanmar	-0.93	0.8
Mauritius	1.48	1.31
Malaysia & Singapore	1.69	0.7
Nigeria	2.2	0.35
Netherlands	-0.16	0.62
Norway	0.47	0.27
New Zealand	1.13	0.33
Oman	0.36	0.39
Pakistan	-0.24	0.91
Panama	0.36	0.9
Peru	-1.35	0.76
Philippines	0	0.75
Poland	-0.83	0.49
Portugal	0.17	0.34
Romania	-0.63	0.41
Russian Fed.	-1.3	0.41
Senegal	1.84	0.33
Slovenia	-0.64	0.94
Sweden	1.13	0.47
Syria	2.48	0.29
Tunisia	-0.53	1.29
Turkey	-0.96	0.57
Tanzania	1.1	0.34
Ukraine	-1.44	1.02
Uruguay	-3.81	0.44
Venezuela	-2.09	1.28
South Africa	1.18	0.92
Zimbabwe	-0.17	0.33

Table 9: Productivity Parameters for Intermediate Goods λ_i^M

Country	$\hat{F}_i$	S.E.	$\left(\frac{\lambda_{US}}{\lambda_n}\right)^\theta$	Country	$\hat{F}_i$	S.E.	$\left(\frac{\lambda_{US}}{\lambda_n}\right)^\theta$
USA	4.86	0.23	1.00	Korea, Republic of	2.64	0.27	1.99
Albania	-13.13	0.16	3.19	Kuwait	-2.29	0.16	2.74
Argentina	2.4	0.27	1.10	Sri Lanka	-1.35	0.18	2.50
Australia	2.23	0.17	1.19	Lithuania	-1.34	0.2	2.57
Azerbaijan	-1.26	0.16	2.80	Latvia	-2.11	0.22	2.61
Belgium & Lux	0.85	0.24	1.82	Morocco	0.22	0.24	1.99
Bulgaria	0.16	0.16	3.75	Republic of Moldova	-2.12	0.17	3.08
Bolivia	-0.66	0.17	1.15	Mexico	0.38	0.26	1.81
Canada	2.08	0.23	2.69	TFYR of Macedonia	-1.68	0.17	3.16
Switzerland	2.01	0.16	2.93	Malta	-2.19	0.26	4.75
Chile	1.46	0.16	2.81	Myanmar	-2.28	0.21	2.82
China & Hongkong	2.34	0.18	5.50	Mauritius	-1.34	0.24	3.61
Cameroon	-2.24	0.15	2.09	Malaysia & Singapore	-2.35	0.23	1.52
Colombia	1.27	0.22	6.39	Nigeria	-2.32	0.17	3.77
Costa Rica	-0.88	0.18	5.63	Netherlands	-4.1	0.19	1.79
Cyprus	-0.86	0.22	5.65	Norway	-1.16	0.15	2.87
Germany	4.36	0.2	1.56	New Zealand	0.76	0.17	1.55
Egypt	0.68	0.16	2.13	Oman	-2.28	0.19	2.18
Spain	3.14	0.2	2.56	Pakistan	0.21	0.19	3.10
Estonia	-5.86	0.16	3.56	Panama	-1.73	0.18	3.58
Finland	1.45	0.23	2.44	Peru	1.04	0.21	3.56
France	3.45	0.17	1.61	Philippines	0.32	0.19	2.36
United Kingdom	3.18	0.16	1.48	Poland	1.73	0.17	2.78
Greece	0.99	0.16	2.58	Portugal	1.56	0.16	2.18
Honduras	-2.26	0.17	2.71	Romania	1.9	0.16	2.79
Hungary	0.54	0.22	2.18	Russian Fed.	1.98	0.17	2.95
Indonesia	1.24	0.17	1.35	Senegal	-1.1	0.16	2.34
India	2.5	0.17	1.86	Slovenia	0.2	0.21	2.75
Ireland	-2.32	0.17	3.35	Sweden	1.03	0.17	1.58
Iran	0.51	0.17	2.21	Syria	1.12	0.16	1.98
Iceland	-1.11	0.2	2.45	Tunisia	0.36	0.2	2.67
Israel	0.45	0.24	2.33	Turkey	2.01	0.18	2.14
Italy	3.12	0.17	1.62	Tanzania	-1.56	0.16	3.56
Jordan	-0.14	0.16	2.92	Ukraine	1.03	0.24	2.91
Japan	4.64	0.21	1.07	Uruguay	0.35	0.21	2.95
Kazakhstan	-2.3	0.16	3.07	Venezuela	0.04	0.2	3.99
Kenya	0.52	0.2	2.11	South Africa	1.53	0.18	3.79
Kyrgyzstan	-4.48	0.22	2.16	Zimbabwe	-0.05	0.17	4.51

Table 10: Productivity Parameters for Equipment λ_i^E

Country	$\hat{F}_i$	S.E.	$\left(\frac{\lambda_{US}}{\lambda_n}\right)^\theta$	Country	$\hat{F}_i$	S.E.	$\left(\frac{\lambda_{US}}{\lambda_n}\right)^\theta$
USA	4.67	0.26	1.00	Korea, Republic of	3.75	0.27	1.27
Albania	-6.04	0.17	9.77	Kuwait	-1.35	0.19	3.86
Argentina	1.41	0.29	15.09	Sri Lanka	-1.75	0.2	9.53
Australia	2.03	0.19	3.78	Lithuania	-1.25	0.22	5.62
Azerbaijan	-2.71	0.19	4.70	Latvia	-1.31	0.25	6.15
Belgium & Lux	1.78	0.28	7.00	Morocco	-0.37	0.24	2.19
Bulgaria	0.85	0.18	1.20	Republic of Moldova	-10.47	0.21	10.84
Bolivia	-2.9	0.22	3.05	Mexico	0.59	0.28	3.58
Canada	2.85	0.25	2.40	TFYR of Macedonia	-1.39	0.19	7.65
Switzerland	2.48	0.18	2.31	Malta	-0.46	0.25	15.90
Chile	0.23	0.18	6.27	Myanmar	-9.44	0.22	10.15
China & Hongkong	-1.87	0.19	6.18	Mauritius	-2.89	0.27	6.74
Cameroon	-3.3	0.17	7.59	Malaysia & Singapore	2.13	0.27	1.72
Colombia	0.59	0.26	1.05	Nigeria	0.99	0.17	3.37
Costa Rica	-1.56	0.19	2.46	Netherlands	1.63	0.21	1.69
Cyprus	-9.39	0.27	3.34	Norway	1.11	0.17	8.03
Germany	4.5	0.22	1.02	New Zealand	1.06	0.19	7.46
Egypt	0.36	0.15	1.88	Oman	-1.49	0.22	4.74
Spain	2.85	0.2	1.31	Pakistan	-0.08	0.22	31.32
Estonia	-1.58	0.17	5.91	Panama	-1.5	0.21	22.81
Finland	2.3	0.26	1.66	Peru	0.26	0.22	7.97
France	4.16	0.19	1.70	Philippines	1.04	0.2	5.20
United Kingdom	3.83	0.16	1.25	Poland	1.92	0.21	4.71
Greece	0.2	0.16	2.20	Portugal	1.76	0.19	5.81
Honduras	-2.21	0.19	9.61	Romania	2.16	0.2	15.30
Hungary	0.3	0.28	0.80	Russian Fed.	2.32	0.2	1.04
Indonesia	1.84	0.2	3.82	Senegal	-2.54	0.17	5.14
India	2.67	0.19	2.44	Slovenia	-0.2	0.26	0.17
Ireland	1.85	0.2	5.19	Sweden	1.99	0.22	0.83
Iran	1.54	0.19	11.33	Syria	0.02	0.18	9.26
Iceland	-1.64	0.22	6.40	Tunisia	-0.35	0.22	10.02
Israel	1.55	0.26	6.14	Turkey	1.79	0.22	3.21
Italy	3.82	0.2	2.67	Tanzania	-4.65	0.18	33.42
Jordan	-1.65	0.16	3.78	Ukraine	0.87	0.32	11.52
Japan	5.49	0.21	1.07	Uruguay	-1.73	0.23	34.64
Kazakhstan	-1.69	0.19	20.31	Venezuela	1.24	0.21	15.36
Kenya	0.09	0.22	4.50	South Africa	1.83	0.21	22.00
Kyrgyzstan	-3.36	0.23	81.33	Zimbabwe	0.44	0.18	67.68

Table 11: Productivity Parameters for Structures λ_i^S

Country	$\hat{F}_i$	S.E.	$\left(\frac{\lambda_{US}}{\lambda_n}\right)^\theta$
USA	2.55	0.31	1.00
Albania	-0.97	0.21	18.35
Argentina	0.74	0.49	7.34
Australia	0.58	0.25	3.45
Azerbaijan	-0.87	0.26	20.74
Belgium & Lux	1.13	0.59	2.27
Bulgaria	-0.7	0.25	1.40
Bolivia	-2.28	0.28	52.76
Canada	1.07	0.36	2.51
Switzerland	1.87	0.25	0.75
Chile	-0.14	0.27	2.50
China & Hongkong	1.18	0.24	4.02
Cameroon	-1.44	0.23	39.65
Colombia	0.47	0.34	25.32
Costa Rica	-1.45	0.27	70.10
Cyprus	-0.53	0.36	12.57
Germany	3.17	0.3	3.25
Egypt	-0.02	0.19	0.78
Spain	1.67	0.25	1.81
Estonia	-0.4	0.24	6.00
Finland	1	0.38	2.36
France	2.67	0.26	0.89
United Kingdom	2.16	0.21	3.39
Greece	1.24	0.2	3.04
Honduras	-1.15	0.25	1.11
Hungary	0.24	0.36	2.10
Indonesia	0.58	0.27	3.27
India	1.59	0.22	1.98
Ireland	0.87	0.26	2.76
Iran	0.86	0.3	6.11
Iceland	-1.05	0.3	1.36
Israel	0.6	0.29	3.59
Italy	2.19	0.25	1.70
Jordan	-1.08	0.2	1.21
Japan	3.97	0.28	1.07
Kazakhstan	-1.6	0.25	3.83
Kenya	-1.56	0.29	1.43
Kyrgyzstan	-2.53	0.31	1.11

Country	$\hat{F}_i$	S.E.	$\left(\frac{\lambda_{US}}{\lambda_n}\right)^\theta$
Korea, Republic of	1.26	0.39	2.44
Kuwait	-1.02	0.24	3.44
Sri Lanka	-0.4	0.25	2.53
Lithuania	0.45	0.29	2.13
Latvia	-0.88	0.34	1.22
Morocco	0.23	0.36	3.01
Republic of Moldova	-1.85	0.29	2.78
Mexico	0.6	0.54	1.79
TFYR of Macedonia	-0.89	0.25	1.57
Malta	-1.18	0.35	2.01
Myanmar	-1.45	0.4	1.03
Mauritius	-1.91	0.37	2.21
Malaysia & Singapore	-0.87	0.34	2.05
Nigeria	-2.59	0.22	1.17
Netherlands	1.46	0.28	2.00
Norway	0.52	0.2	3.06
New Zealand	-0.78	0.25	1.42
Oman	-1.42	0.26	11.10
Pakistan	-0.74	0.29	1.56
Panama	-1.44	0.27	2.19
Peru	-0.35	0.29	2.19
Philippines	0	0.25	2.37
Poland	1.19	0.25	1.19
Portugal	0.07	0.25	1.46
Romania	0.71	0.3	1.32
Russian Fed.	1.73	0.26	2.09
Senegal	-2.14	0.22	1.17
Slovenia	-0.01	0.38	1.20
Sweden	0.84	0.29	1.98
Syria	-0.72	0.24	2.86
Tunisia	-0.67	0.29	1.85
Turkey	1.05	0.3	2.00
Tanzania	-1.17	0.24	1.07
Ukraine	0.65	0.61	1.07
Uruguay	-0.29	0.26	2.36
Venezuela	0.77	0.29	2.30
South Africa	-0.84	0.29	2.47
Zimbabwe	-2.53	0.24	2.39