International Trade and Cross-Country Capital Composition Differences

JOB MARKET PAPER

Piyusha Mutreja *

(http://myweb.uiowa.edu/pmutreja)

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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 questions: What is the quantitative relationship between international trade in capital goods and the cross-country capital composition? What are the resulting quantitative implications for economic development? To answer these questions, I construct a multi-country model of trade. Within this framework, the equipment share of capital 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 70% of the observed cross-country variation in equipment share of capital, of which 52% is explained by the pattern of capital goods trade. My model also generates cross-country differences in investment rates, income per worker and prices consistent with the data. Through counterfactual exercises, I find that eliminating all barriers to trade reduces variance in capital composition by 28%, poor countries' welfare increases by 34% and rich countries' welfare increases 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.

Keywords: international trade, capital goods, development

JEL Classifications: F1; F2; F4; O4

*Department of Economics, The University of Iowa, piyusha-mutreja@uiowa.edu. I am grateful to my advisor, Prof. B. Ravikumar for his invaluable encouragement and support. I'm thankful to Prof. Raymond Riezman for useful discussions and support. I also thank Prof. Gustavo Ventura, Prof. Guillaume Vandenbroucke, Prof. Srihari Govindan and seminar participants at the University of Iowa, 2009 Midwest Trade and Theory Conference and 2009 Midwest Macro Meetings for helpful comments.

1 Introduction

Most of the world's equipment is produced in a small number of rich countries. In 1996, countries in top quartile of 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 imports for equipment. While Nigeria imported 76% of its equipment, Japan imported less than 6% of its equipment. Structures on the other hand, are largely domestically produced. Nigeria and Japan respectively produced 73% and 98% of their structures. 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 between rich and poor countries differs by a factor of 6.3 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] To put it differently, according to this simple accounting exercise, if all countries had the same equipment capital-output ratio as that of the US, the resulting cross-country variation in income would reduce by 22%. If instead all countries had same structures capital-output ratio as the US, cross-country income variation would reduce by only 7%.

In this paper, I ask and answer the following questions: What is the quantitative relationship between international trade in capital goods and the cross-country capital composition? What are the resulting quantitative implications for economic development?

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

[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 $\alpha_e = 0.216$.

trade is subject to bilateral iceberg costs. Each country also has a final goods sector which produces a homogeneous non-tradable good with constant returns technology common to all countries.

According to the theoretical model, 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 quantify the contribution of capital goods trade in determining the capital composition differences. The model also implies that a country's income per worker relative to US can be expressed as a function of its equipment capital-output ratio, structures capital-output ratio and a total factor productivity (TFP) term, all relative to US. The TFP term is a function of exogenous productivity parameters and a trade term. Thus, TFP is *endogenous* in the model.

To quantify the model, I use a structural relationship implied by the model that connects the productivity parameters and trade costs to the bilateral pattern of 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.

I examine the implications of the model for certain aspects of the data that I did not use to calibrate the model. Specifically, I focus on the implications for capital composition, economic development and price of capital goods. First, my model generates over 70% of the observed cross-country variation in equipment share of capital, of which 52% is explained by the pattern of capital goods trade. The model also generates equipment capital-output ratio and structures capital-output ratio consistent with the data.

Second, my model matches well the data on per worker income. It generates 76% of the observed cross-country variation in income per worker. The trade factor accounts for over 26% of the variation in the relative TFP differences. Third, the calibrated model accounts for 68% of the observed variation in aggregate investment rate across countries.

Finally, my model also produces prices consistent with the data. Barriers to trade affect the prices of equipment and structures in my model. The observed cross-country variation in price of equipment is almost zero. My model implies that the elasticity of price of equipment with respect to per worker income is approximately -0.09. The income elasticity of price of structures, on the other hand, is 0.29 in the data and 0.19 in the model. Price of capital goods relative to consumption, as pointed out by Hsieh and Klenow (2007), exhibits a strong negative correlation with income per worker. The income elasticity of price of equipment relative to consumption is -2.1 in the data and -2.8 in the model. The corresponding elasticity for structures is -4.4 in the data and -5.2 in the model.

I conduct several counterfactual exercises by adjusting trade costs to examine the quantitative implications of capital goods trade for cross-country capital composition and economic development. Reductions in trade barriers reduce cross-country differences in capital composition and result in significant welfare gains. With a 10% reduction in trade costs, the variance of log of equipment share of capital declines by nearly 19%. The ensuing reduction in variance of log income per worker is approximately 10%. The welfare gain experienced by poor countries is 18% while the overall gain in world welfare is 7%. In a second experiment, all trade costs are eliminated. Here, variance of log equipment share of capital declines by 28% and poor countries' welfare increases by 34%. Since trade determines equipment flows to poor countries, distortions in 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, price of equipment and structures, and productivity differences across countries. As in Eaton and Kortum (2001), trade costs in my model are reflected in the price of capital goods. As Hsieh and Klenow (2007) criticize, the results in Eaton and Kortum (2001) are inconsistent with the fact that absolute price of investment shows little variation across countries. For the sample of countries in Eaton and Kortum (2001), the income elasticity of price of equipment in the data is 0.04. While Eaton and Kortum (2001) price estimates imply an elasticity of -1.6, my price estimates have an income elasticity of only 0.05. Further, Eaton and Kortum (2001) focus on a sample 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 empirical implications of the model. Section 4 presents the calibration methodology. Sections 5 and 6 present the results. Section 7 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 $x^J \epsilon [0,1]$, 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 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 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 the gains from trade would be larger.

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 which is non-tradable. Each firm has access to the following nested Cobb-Douglas production function combining 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:

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

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

$$\pi_{in}^{J}=\frac{\left\{\left(\left[\mu^{\sigma}r_{n}^{E1-\sigma}+(1-\mu)^{\sigma}r_{n}^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^{J}}w_{n}{}^{(1-\alpha)\beta^{J}}P_{n}^{J1-\beta^{J}}\tau_{in}^{J}\right\}^{-\frac{1}{\theta}}\lambda_{n}^{J}}{\Sigma_{v=1}^{N}\left\{\left(\left[\mu^{\sigma}r_{v}^{E1-\sigma}+(1-\mu)^{\sigma}r_{v}^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^{J}}w_{v}{}^{(1-\alpha)\beta^{J}}P_{v}^{J1-\beta^{J}}\tau_{iv}^{J}\right\}^{-\frac{1}{\theta}}\lambda_{v}^{J}} \qquad (2)$$

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

$$\pi_{ii}^{J}=\frac{\left\{\left(\left[\mu^{\sigma}r_{i}^{E1-\sigma}+(1-\mu)^{\sigma}r_{i}^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^{J}}w_{i}{}^{(1-\alpha)\beta^{J}}P_{i}^{J1-\beta^{J}}\right\}^{-\frac{1}{\theta}}\lambda_{i}^{J}}{\Sigma_{v=1}^{N}\left\{\left(\left[\mu^{\sigma}r_{v}^{E1-\sigma}+(1-\mu)^{\sigma}r_{v}^{S1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^{J}}w_{v}{}^{(1-\alpha)\beta^{J}}P_{v}^{J1-\beta^{J}}\tau_{iv}^{J}\right\}^{-\frac{1}{\theta}}\lambda_{v}^{J}}$$

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 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 given trade shares and imposing 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:

$$L_i\left(P_i^E Q_i^E + P_i^S Q_i^S + P_i^M Q_i^M\right) = \sum_{v=1}^{N} L_v P_v^E Q_v^E \pi_{vi}^E + \sum_{v=1}^{N} L_v P_v^S Q_v^S \pi_{vi}^S + \sum_{v=1}^{N} L_v P_v^M Q_v^M \pi_{vi}^M \quad (3)$$

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.

3 Empirical Implications

In this section, I derive the theoretical expressions for equipment share of capital, income per worker and investment rate. In the sections that follow, I will employ these relations to study the quantitative implications of trade for capital composition, economic development and prices of capital goods.

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 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 country-specific productivity parameters for equipment and structures, and the pattern of bilateral trade.

Rearranging (2) 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:

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

Similarly price of aggregate structures is given by:

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

The theoretical model also implies that:

$$\frac{P_i^E k_i^E}{P_i^S k_i^S} = \left(\frac{P_i^E}{P_i^S} \right)^{1-\sigma} \tag{4}$$

We can use the price of equipment and structures in (4) to derive an expression for the share of equipment in capital stock of a country:

$$\frac{P_i^E k_i^E}{P_i^E k_i^E + P_i^S k_i^S} = \frac{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}}}{\frac{\lambda_i^E}{\pi_{ii}^E}^{-\frac{\theta(1-\sigma)}{\beta}} + \frac{\lambda_i^S}{\pi_{ii}^S}^{-\frac{\theta(1-\sigma)}{\beta}}} \tag{5}$$

Similar to (5), share of structures in capital is given by:

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

These expressions enable me to quantify the role played by international trade in determining cross-country capital composition differences. 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.

Income per worker: Real income per worker in country i is:

$$y_i = \frac{w_i}{P_i^f} + \frac{r_i^E k_i^E}{P_i^f} + \frac{r_i^S k_i^S}{P_i^f}$$

As in Waugh (2009), using the expression for price of final good and the expressions for trade shares (2), income-per worker is given by the following:

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

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

where ψ is a collection of constants that do not depend upon the country. Income in a country depends on its TFP, and its equipment and structures capital stock. TFP is determined by the country's exogenous productivity parameters and endogenous trade shares.

Investment Rate: Using the expression for investment levels and income per worker, the aggregate investment rate in country i is as follows:

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

4 Calibration

4.1 Methodology

Equilibrium allocations and prices in the model economy are characterized by country-specific productivity parameters and the trade costs. In order to explore the quantitative relationship between capital goods trade and cross-country capital composition, and the resulting implications for economic development, 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 pattern of trade, productivity parameters and trade costs, I use the following compact expression for trade shares in sector J from equation (2):

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

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 trade shares, productivity parameters and trade costs. To derive this relationship, divide trade share π_{in}^J with home trade share π_{ii}^J:

$$\frac{\pi_{in}^J}{\pi_{ii}^J} = \frac{(c_n^J \tau_{in}^J)^{-\frac{1}{\theta}} \lambda_n^J}{c_i^{J\,-\frac{1}{\theta}} \lambda_i^J} \tag{6}$$

Taking logs on both sides of (6) yields the following relationship for each of the tradable sectors:

$$log \left(\frac{\pi_{in}^J}{\pi_{ii}^J} \right) = F_n^J - F_i^J - \frac{1}{\theta} log \tau_{in}^J \tag{7}$$

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, (7) 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:

$$log\tau_{ni}^J = dis_s + b_{ni} + lang_{ni} + ex_{ni}^J + \varepsilon_{ni}^J \tag{8}$$

where 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 n capital city and country i 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_{ni} is the effect of a shared border. $lang_{ni}$ is the effect of shared official language. An exporter effect, ex_{ni}^J, is included to capture the role played by exporter competitiveness. I assume that ε_{ni}^J represents barriers to trade arising from other factors and is orthogonal to the ones considered.

Combining equation (7) and (8) leads to following:

$$log\left(\frac{\pi_{in}^J}{\pi_{ii}^J}\right) = F_n^J - F_i^J - \frac{1}{\theta}[dis_s + b_{ni} + lang_{ni} + ex_{ni}^J + \varepsilon_{ni}^J] \tag{9}$$

I estimate equation (9) for all tradable sectors goods 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 (8). Using F_i^J's and τ_{in}^J's, the price index in sector J is then computed as:

$$P_i^J = \Gamma^J \left\{\sum exp(F_i^J)\tau_{in}^{J^{-\frac{1}{\theta}}}\right\}^{-\theta} \tag{10}$$

Then, given the P_i^J's, λ_i^J's are computed from the following system of equations:

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

$$F_i^J = c_i^{J\frac{-1}{\theta}} \lambda_i^J \quad \ldots \textit{3N equations}$$

$$c_i^J = \left(\left[\mu^\sigma r_i^{E\,1-\sigma} + (1-\mu)^\sigma r_i^{S\,1-\sigma}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^J} w_i^{(1-\alpha)\beta^J} P_i^{J\,1-\beta^J} \quad \ldots \textit{3N equations}$$

$$k_i^E = \frac{I_i^E}{\delta} \quad \ldots \textit{3N equations}$$

$$k_i^S = \frac{I_i^S}{\delta} \quad \ldots \textit{3N equations}$$

$$I_i = P_i^E I_i^E + P_i^S I_i^S \quad \ldots \textit{3N equations}$$

$$r_i^E = \frac{\gamma}{1-\gamma}\left[\mu k_i^{E\frac{\sigma-1}{\sigma}} + (1-\mu) k_i^{S\frac{\sigma-1}{\sigma}}\right]^{-1} k_i^{E-\frac{1}{\sigma}} w_i \quad \ldots \textit{3N equations}$$

$$r_i^S = \frac{\gamma}{1-\gamma}\left[\mu k_i^{E\frac{\sigma-1}{\sigma}} + (1-\mu) k_i^{S\frac{\sigma-1}{\sigma}}\right]^{-1} k_i^{S-\frac{1}{\sigma}} w_i \quad \ldots \textit{3N equations} \tag{11}$$

4.2 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. 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 divided by total inputs in country i. Country i's home trade share is then, constructed as:

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

The data necessary for construction of trade shares is compiled from various sources. I took the production data 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.

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 used labor endowment data from Caselli (2005) which are constructed from information in Heston, Summers and Aten (2002).

An implication of my model is that, in aggregate, every country should purchase some non-zero amount of goods from all other countries. However, 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 (9). 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 (9) and from omission of zero observed trade flows. It has been noted in the literature that any bias resulting from omission of zero observed trade flows is quantitatively small (see Helpman, Melitz and Rubinstein (2007)). I also estimated equation (9) using left truncated OLS, as in Eaton and Kortum (2001). The results from two estimations are very similar.

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.

4.3 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	0.216
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. The share parameter μ has been set at 0.216, following (Krusell et. al (2000)). I estimated the elasticity of substitution between equipment and structures 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 equipments and structures to arrive at 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 equipments. 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 the least variation with 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.

5 Results

5.1 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 3. 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 (5), is:

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

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 70% of the observed cross-country variation in equipment share of capital, of which capital goods trade accounts for 52%.

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

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

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

Capital goods trade plays a considerable role in reducing the cross-country dispersion in composition of capital. Underlying the current pattern of international trade are distortions and trade costs affecting 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, but also for economic development. In section 6, I conduct such counterfactual exercises.

5.2 Income Differences and Investment Rate

Income Differences: As an assessment of the model, I consider the model's ability to replicate observed cross-country differences in income. The model implies that a country's per-worker income relative to US can be expressed as a function of its equipment capital-output ratio, structures capital-output ratio and a total factor productivity (TFP) term, all relative to US:

$$\frac{y_i}{y_{US}} = \frac{\text{TFP}_i}{\text{TFP}_{US}} \left(\frac{\mu k_i^{E^{\frac{\sigma-1}{\sigma}}} + (1-\mu) k_i^{S^{\frac{\sigma-1}{\sigma}}}}{\mu k_{US}^{E^{\frac{\sigma-1}{\sigma}}} + (1-\mu) k_{US}^{S^{\frac{\sigma-1}{\sigma}}}} \right)^{\frac{\sigma}{\sigma-1}(\alpha-(1-\alpha)\gamma)}$$

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

With productivity parameters and trade costs recovered from the pattern of trade, I compute each country's income per worker. Given the definition of income, the natural empirical analog is purchasing power parity adjusted income per worker taken from Heston, Summers and Aten (2002). Following table provides some summary statistics: the variance of log income per worker and the 90/10 percentile ratio.

	Var(log y)	y_{90}/y_{10}
Data	1.19	21.31
Model	0.96	18.07

The model only slightly under-predicts cross-country variation in income.

My results show that differences in equipment and structures capital stocks explain roughly 38% of the cross-country variation in income. The rest is due to the TFP term. The TFP term is a function of exogenous productivity parameters and endogenous trade terms. The trade terms account for 26% of relative TFP differences and hence, for 16% of the relative income differences.

Investment Rate: As another assessment of the model, I look at model's ability to replicate the cross-country dispersion in investment rates. With estimated productivity parameters and trade costs, and computed income levels, I determine the investment rates in each country as defined in section 3:

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

The empirical counterpart for investment rates are taken from Heston, Summers and Aten (2002). Figure 1 plots the investment rate implied by model to the ones observed in data. The model accounts for 74% of the variation in investment rate.

5.3 Prices of Capital Goods

Barriers to trade affect the prices of equipment and structures in my model. Prices recovered from the calibration exercise, vary negatively with the level of development. Figures 2 and 3 respectively plot absolute price of equipment and structures. The price of equipment is only slightly higher for poor countries as compared to rich countries. The elasticity with respect to income is -0.13 in the data and -0.09 in the model. The income elasticity of price of structures is 0.29 in the data and that implied by the model is 0.19.

The model is also able to generate price of equipment and structures relative to consumption that is consistent with the data. The income elasticity of price of equipment relative to consumption is -2.1 in the data and -2.8 in the model. The corresponding elasticity for structures is -4.4 in the data and -5.2 in the model. Figures 4 and 5 plot model implied relative price of equipment and structures against the relative prices in data. Consistent with data, in model economy poor countries face substantially higher price for equipment relative to structures. Price of equipment relative to structures is plotted in Figure 6.

Hsieh and Klenow (2007) criticize the results of Eaton and Kortum (2001) in their study of investment prices and real investment rates. According to Hsieh and Klenow (2007), Eaton and Kortum (2001) capture the fact price of investment relative to consumption is negatively correlated with income per worker, but their results are inconsistent with the fact that absolute price of capital shows little variation across countries. For the sample of countries in Eaton and Kortum (2001), the income elasticity of price of equipment in the data is 0.04. While Eaton and Kortum (2001) price estimates imply an elasticity of -1.6, my price estimates have an income elasticity of only 0.05. Thus, the prices generated by my model are more consistent with the data than the prices in Eaton and Kortum (2001).

6 Counterfactual Analysis and Gains from Trade

International trade in capital goods plays a quantitatively significant role in determining cross-country capital composition. As noted in section 5, reductions in barriers to capital goods trade can reduce the cross-country dispersion in equipment share of capital and consequently affect economic development. 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 play an important role for economic development. To explore quantitative relationship between trade, capital composition and economic development, I perform two counterfactual exercises by adjusting trade costs while keeping the estimated productivity parameters fixed. Following table presents the results of the counterfactual exercises:

Income Differences and Welfare Gains

[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.

	var [log(y)]	y_{90}/y_{10}	Welfare Gains		
			Poor	Rich	World
Baseline	0.96	18.07	-	-	-
10% reduction	0.88	17.1	18%	3%	7%
$\tau_{in}^J = 1$	0.71	15.3	34%	8%	16%

In the first exercise, I reduce the trade costs across the board by 10%. The trade costs are computed as ${\tau_{in}}' = 1 + 0.9 \times (\tau_{in} - 1)$ for each tradable good. With the new trade costs, the variance of log of equipment share of capital declines by nearly 19%. The ensuing reduction in variance of log income per worker is approximately 10% relative to the baseline model. The 90/10 percentile ratio of income per worker reduces to 17.1 in the counterfactual world. The welfare gain experienced by poor countries is 18% while the overall gain in world welfare is 7%.[3] All countries gain but poor countries gain relatively more.

In the second experiment, all trade costs are eliminated. Here, variance of log equipment share of capital declines by 28%. In this world, the variation in log income per worker is 0.71. The 90/10 percentile ratio of income per worker is 15.3. The poor countries experience a welfare increase of 34% while overall world welfare increase is 11%. Again, poor countries gain relatively more than rich countries. This exercise is, admittedly, extreme. However, it points towards the potential of international trade in affecting capital composition and economic development.[4]

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.

[3]Welfare gains are defined as the percentage increase in consumption across two equilibria.

[4]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.

7 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. The calibrated model does well in replicating the investment rate, the income per worker and prices of capital goods in the data. Finally, 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.

8 References

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9 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:

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

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:

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

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

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,

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

$S(\theta,\eta)$ 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 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,

$$\pi_{in}^J = \frac{\left(\left[r_n^{E^{1-\sigma}} + r_n^{S^{1-\sigma}}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^J} w_n{}^{(1-\alpha)\beta^J} P_n^{J^{1-\beta^J}} \tau_{in}^J{}^{-\frac{1}{\theta}} \lambda_n^J}{\Sigma_{v=1}^N \left(\left(\left[r_v^{E^{1-\sigma}} + r_v^{S^{1-\sigma}}\right]^{\frac{1}{1-\sigma}}\right)^{\alpha\beta^J} w_v{}^{(1-\alpha)\beta^J} P_v^{J^{1-\beta^J}} \tau_{iv}^J\right)^{-\frac{1}{\theta}} \lambda_v^J} \tag{12}$$

Figure 1: Investment rate: Model vs Data. (US=1)

Figure 2: Price of Equipment (US=1)

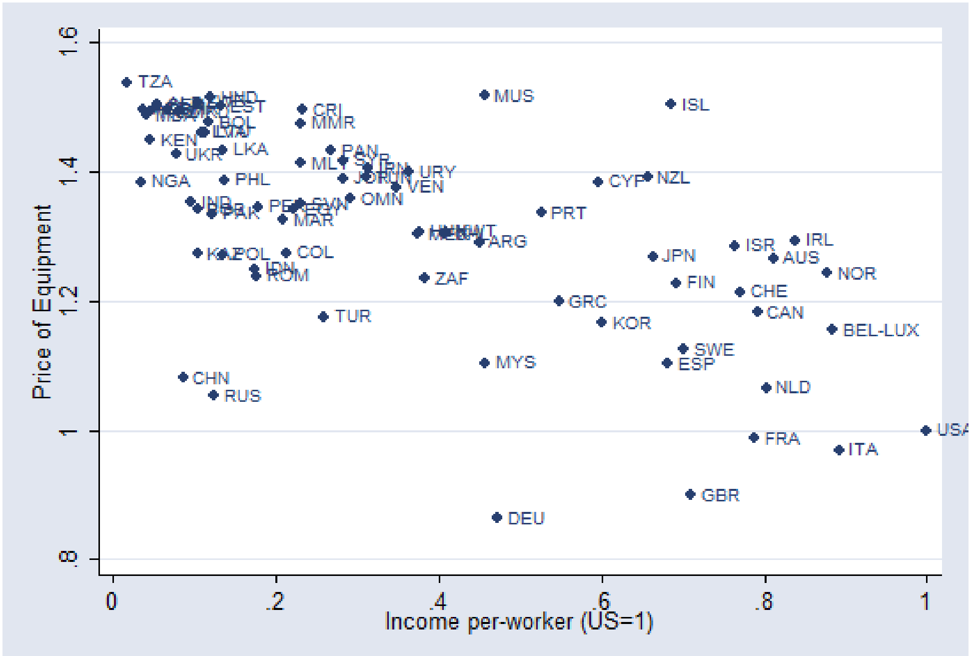

Figure 3: Price of Structures (US=1)

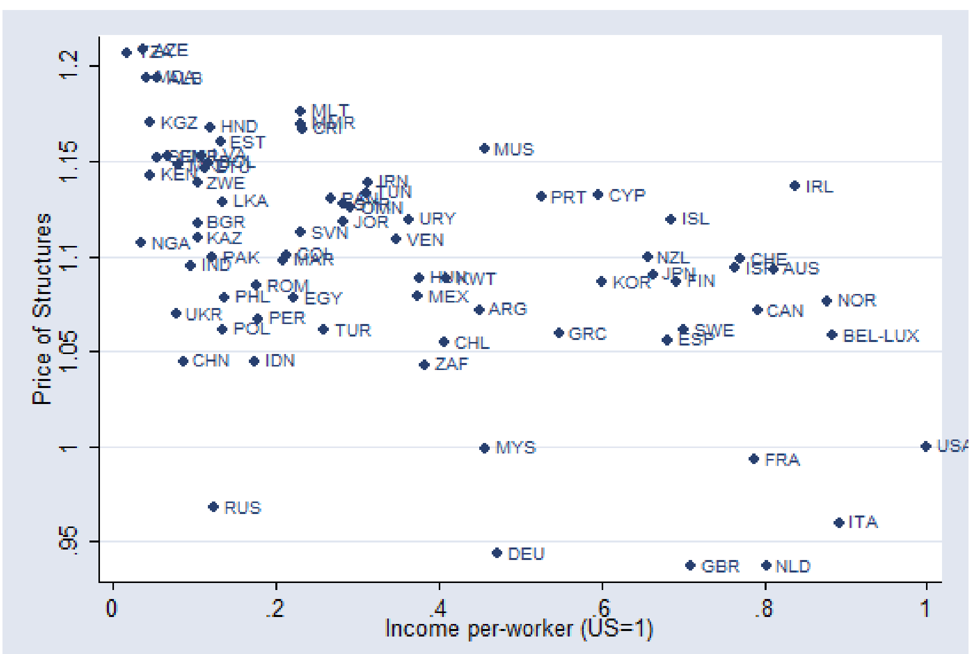

Figure 4: Price of Equipment relative to Consumption (US=1): Model vs Data

Figure 5: Price of Structures relative to Consumption (US=1): Model vs Data

Figure 6: Price of Equipment relative to Structures (US=1)

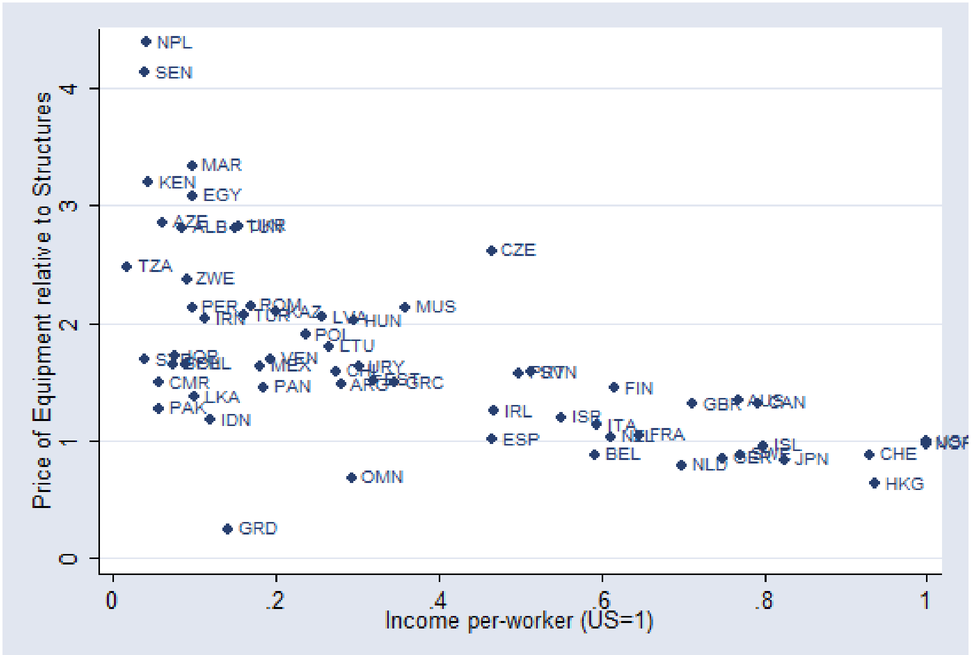

Table 1: Trade Shares for Equipment, π_{in}^{E}

	USA	UK	Japan	Mauritius	Albania	Tanzania	Senegal
USA	87.16	0.70	0.60	0	0	0	0
UK	1.30	71.77	1.20	0	0	0	0
Japan	0.34	0.15	96.24	0	0	0	0
Mauritius	0.21	0.38	0.87	20.74	0	0	0
Albania	3.68	9.82	3.42	0	19.51	0	0
Tanzania	0.96	0.26	0.42	0	0	1.84	0
Senegal	0.12	0.35	6.16	0	0	0	28.22

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	Mauritius	Albania	Tanzania	Senegal
USA	98.41	0.06	0.01	0	0	0	0
UK	0	96.78	0.12	0	0	0	0
Japan	0	0	99.84	0	0	0	0
Mauritius	0.15	0.09	0.12	92.49	0	0	0
Albania	0	0.17	0	0	93.45	0	0
Tanzania	0	0	0	0	0	97.92	0
Senegal	0.96	0.26	0.67	0	0	0	88.67

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

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

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

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

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