Composition of Capital and Gains from Trade in Equipment

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Abstract

Composition of capital varies systematically with incomes: rich countries have higher equipment capital shares than poor countries. Also, equipment production is highly concentrated and most countries import equipment. I investigate the quantitative importance of equipment trade for capital composition and how it affects incomes through capital composition. In a multi-country trade model, I show that equipment trade accounts for one-quarter of the cross-country variation in equipment capital share. The decline in equipment trade barriers during 1985-2005 resulted in income gains for all countries. Digging into these income gains reveals that capital composition is an important transmission mechanism: changes in capital composition alone account for 45 percent of the gains.

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Keywords: Equipment capital, Structures capital, Capital composition, Trade, Income, Capital goods, Equipment goods

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1 Introduction

Income differences across countries are enormous. One of the most robust relationships in economic growth literature is that physical capital intensity is systematically related to income across countries. The capital-output ratio in rich countries is over three times the capital-output ratio in poor countries. This has led economists to examine the determinants of physical capital intensity and the resulting implications for cross-country incomes. The broad consensus is that low productivity levels in poor countries, either due to production inefficiency or misallocation of factors, are mainly responsible for low capital-output ratios and, thus, low incomes (see, for instance, Restuccia and Urrutia, 2001; Hsieh and Klenow, 2007; Greenwood, Sanchez, and Wang, 2013). In this paper, I offer a new understanding of physical capital intensity and incomes by focussing on the composition of physical capital.

Rich countries have higher equipment capital intensity than poor countries. Twenty-one percent of the capital stock in rich is in equipment, and the remainder is in structures or buildings.[1] Equipment capital share in poor is only seven percent (for rich versus poor comparisons, I use 90th and 10th percentiles of the world income per worker distribution to represent rich and poor, respectively). While the equipment capital-output ratio in rich is six times the equipment capital-output ratio in poor, the 90th to 10th percentile ratio for structures capital-output ratio is only 1.7 (see Mutreja, 2014, for details).[2] Thus, cross-country differences in the equipment capital-output ratio are larger than those of structures. Another stylized fact is that the world equipment production is highly concentrated, and most countries import their equipment (see Eaton and Kortum, 2001). In my sample, 78.3 percent of the world equipment is produced in seven countries, and the correlation between equipment import share and income per worker is -0.19.[3]

In this paper, I bring above facts together and investigate the role of equipment trade in determining cross-country composition of capital. Quantitatively, I find that equipment trade plays a key role in determining capital composition. Overall, equipment trade accounts for 23 percent of the cross-country variation in the equipment capital share. This is the first contribution of this paper. Rich reap efficiency gains from trade by specializing in equipment, and poor benefit by trading their comparative advantage good for equipment,

[1] Equipment comprise fabricated metal products, electrical and non-electrical machinery, transport equipment, communication equipment, office machinery, and professional and scientific equipment. Structures include residential and non-residential buildings.

[2] The data used in this paper are for a sample of 65 countries in 2005. Mutreja (2014) presents facts on capital composition for a larger sample of 119 countries.

[3] Equipment import share is computed as $\frac{\text{Imports}}{\text{Production}-\text{Exports}+\text{Imports}}$.

which is inefficiently produced at home. In the absence of equipment trade, all countries have much smaller equipment capital stocks, and their equipment capital shares reduce to about one-half. Second, I study the implications for incomes. Capital composition is a quantitatively significant channel through which equipment trade affects incomes. Income gains from the fall in equipment trade barriers during 1985-2005 are large, and changes in capital composition account for 35 percent of the income gain in rich and 64 percent in poor. To the best of my knowledge, this is the first paper that studies the role of equipment trade in cross-country composition of capital and how trade affects incomes through capital composition.

One might argue that the *level* of capital stock, as compared to its *composition* is more important for determining income. An examination of the data reveals that while the cross-country gap in *levels* of aggregate capital-output ratio exhibits little change over time, significant changes have taken place in the *composition* of capital across countries. The equipment capital share has increased in rich countries, but it has declined in many poor countries. The implications for income have also evolved: in a standard income accounting exercise, the importance of capital composition for income has more than quadrupled overtime. Most models of economic growth focus on the aggregate capital-output ratios and inevitably ignore the changes in composition that have taken place over time. These changes are important because they potentially reflect the extent of investment-specific technological change that has taken place across countries. Textbooks on economic growth and development characterize the process of economic growth by rapid capital accumulation. One key feature of rapid capital accumulation has been the substantial rise of equipment capital intensity. Trade speeds up this process. Countries that gain the most from equipment trade do so not only because they accumulate more capital but also because they accumulate equipment capital at a faster rate than structures.

I begin by extending the multi-country Ricardian trade model in Eaton and Kortum (2002) and incorporate four sectors: equipment goods (tradable investment goods), structures (non-traded investment goods), tradable intermediate goods, and a non-traded final good. Countries differ in their average level of productivity for each of the tradable goods and in their final good productivity. International trade is subject to bilateral iceberg costs. A representative household consumes the final good and allocates its savings to investment in equipment goods and investment structures. The stocks of equipment and structures capital, as well as the equipment capital share, are determined endogenously in the world general equilibrium and are functions of a country's productivity levels, and home expenditure shares (fraction of expenditure on goods produced at home).

To quantify the multi-country model, I calibrate productivity levels and trade costs to the data on relative prices and bilateral trade flows in my sample. The quantitative model fits calibration targets well and is consistent with observed cross-country differences in equipment capital share, equipment and structures capital stocks and cross-country incomes. The model also matches cross-country variation in several other variables that are not specifically targeted in the calibration, for instance, the world pattern of equipment production.

The calibrated productivity levels imply that rich countries are highly productive in equipment. Rich have a comparative advantage in equipment, while poor have a comparative advantage in intermediate goods. The average equipment productivity in rich is 3.54 times that in poor. Similar to Waugh (2010), poor countries face higher trade costs than rich countries to export to all destinations. The correlation between average equipment trade cost and income per worker is -0.37.

In the structural framework, the equipment capital share in a country is a function of its average productivity in equipment, average productivity in intermediate goods, and trade flows. A variance decomposition exercise implies that equipment trade accounts for 23 percent of the cross-country dispersion in equipment's share. This is non-trivial. Equipment productivity differences account for 50 percent, and remaining variation in the equipment capital share is accounted for by intermediate goods productivity and trade flows.

To explore and quantify the mechanisms through which equipment trade affects capital composition and incomes, I conduct several counterfactual experiments by adjusting equipment trade costs. In one of the experiments, I assess the role of decline in equipment trade costs between 1985 and 2005 in the evolution of equipment capital shares and incomes across countries. For this, I calibrate equipment trade costs for 1985 and find that between 1985 and 2005, equipment trade costs declined by 71 percent, on average, with rich exporters experiencing a slightly larger decline. The results from the experiment imply that the 1985-2005 fall in equipment trade costs increased equipment capital share by 10 percent in rich and 3 percent in poor. Incomes also respond to the decline in trade costs: on average, incomes rose by 8.4 percent.

What is the source of these income gains? Income in my model is determined by a country's total factor productivity (henceforth, TFP), equipment and structures capital stocks, and a term that captures the effect of composition of capital. I find that capital composition is a significant channel through income gains from reduced equipment trade costs are transmitted. Between 1985 and 2005, the proportion of income gain stemming from the changes in capital composition is 35 percent in rich and 64 percent in poor. The remainder is due to the changes in TFP and capital stock (the TFP is partially endogenous and depends on the trade flows). In no way, these magnitudes are small. Moreover, the capital composition channel is quantitatively more important for poor countries.

The mechanics of the above gains lie in how *effective* equipment productivity responds to adjustments in equipment trade costs. The equipment sector has a continuum of goods. Relative to no-equipment trade, trade enables rich countries to specialize in production of those equipment goods along the continuum for which they have the highest idiosyncratic productivity draws and import the remainder. Reductions in trade costs lead to further specialization in equipment and a subset of the continuum is produced at home. Intuitively, *effective* equipment productivity captures a country's average productivity over this subset of the continuum. Poor countries also experience an increase in their *effective* equipment productivity as they reduce the production of equipment goods with low idiosyncratic productivity draws. The 1985-2005 fall in equipment trade costs led to specialization according to comparative advantage in all countries. As a result, the *effective* equipment productivity increased by a factor of 1.7 in rich and 1.5 in poor, translating into large increases in equipment capital share and income. Reductions in barriers to equipment trade allocate world resources towards more efficient outcomes and increase *effective* equipment productivity in all countries. These gains in *effective* productivity have significant implications for capital composition and incomes.

The literature on composition of capital is relatively small. Mutreja (2014) measures the effect of capital composition on cross-country incomes, but does not investigate the determinants of capital composition. While the existing literature has mainly focussed on investment composition and its determinants, this is the first paper to quantify the role of trade in capital composition. Caselli and Wilson (2004) study nine capital goods categories and explain investment composition based on efficiency and abundance of complementary factors inputs. Although they use imports in each category of capital as a proxy for the overall investment in that type of capital, they find no role for trade in investment composition. Bems (2008) presents facts on investment in tradable and non-tradable goods but does not shed light on the determinants of disaggregate investment levels.

The importance of equipment capital for economic growth is well known. Technological improvements are often embodied in improved equipment (see, for instance, Greenwood, Hercowitz, and Krusell, 1997), tend to be skill-biased and so, exhibit capital-skill complementarity (see, for instance, Krusell et al., 2000). Also, a growing body of research quantifies the role of equipment trade in economic growth and related outcomes. Eaton and Kortum (2001) and Mutreja, Ravikumar, and Sposi (2016) study the implications of equipment trade for incomes. Burstein, Cravino, and Vogel (2013), Parro (2013) and Raveh and Reshef (2016) assess the role of equipment trade in cross-country skill premium. The more recent quantitative models connect *endogenous* capital formation with equipment trade flows. A common finding of existing empirical and quantitative research on trade and incomes is that reductions in trade costs lead to large gains in economic well-being. My results reaffirm the significance of equipment capital and equipment trade for economic growth. However, this is not the purpose of my paper. My focus is on composition of capital, how equipment trade affects it, and the resulting implications for incomes. While I also find large income gains from reductions in trade costs, I dig into the black box of the source of these gains and quantify a new mechanism (namely, capital composition) through which countries reap these gains.

This paper relates to the section of economic growth literature that studies the role of trade in capital formation and income across countries. Eaton and Kortum (2001) employ a structural model of bilateral trade in equipment, and find that equipment trade barriers explain approximately 12.5 percent of the income differences. Capital is not endogenous in their model. I focus on capital composition and construct a multi-country general equilibrium model with both equipment and non-equipment (intermediate goods) trade. Capital stocks and capital composition are endogenous in my model. I find that during 1985-2005 approximately 45 percent of income gains from a removal of equipment trade costs are transmitted through the capital composition mechanism.

My paper is related to parallel research in Mutreja, Ravikumar, and Sposi (2016). Relative to Mutreja, Ravikumar, and Sposi (2016), the main distinctions are the question and the quantitative results. While both the papers highlight the role of equipment trade for capital formation across countries, I separate the the effect of composition of capital from its level. Mutreja, Ravikumar, and Sposi (2016) *analytically* argue that a large fraction of the income gains from trade are because of changes in capital stock. Using recent data on capital composition (from Mutreja, 2014), I *measure* the relative importance of *level* versus *composition* of capital for the transmission of gains from trade during 1985-2005. Additionally, my results show that capital composition is a quantitatively more important mechanism for poor countries for the transmission of the income gains.

The paper proceeds as follows. Section 2 presents motivating facts and addresses the level versus composition issue. Section 3 presents the multi-country trade model. In section 4, I present the quantification procedure, and in section 5, I present results from the quantitative model. Section 6 presents counterfactual experiments and measures the role of trade in capital composition and incomes. Section 7 concludes.

2 Motivating facts

Why should we focus on composition of capital? In this section, I present facts on capital composition and conduct exercises to motivate the significance of capital composition, in particular how this significance has evolved over time. The data on capital stocks and its composition correspond to 119 countries (see Mutreja, 2014).

The top panel in figure 1 plots aggregate capital-output ratios over time for the world, the 90th percentile country (representative rich) and the 10th percentile country (representative poor).[4] The capital-output ratios are plotted relative to their levels in 1960. The facts presented in this figure are already well known. Over the 45 year time period, the aggregate capital-output ratios show little upward movement and are essentially flat. Also, the gap in capital-output ratios between rich and poor has been persistent: the 90th to 10th percentile ratio falls in the range 3-4, though this gap has slightly widened overtime.

The picture looks different when we decompose aggregate capital stock into equipment and structures. The middle panel of figure 1 plots the evolution of aggregate, equipment and structures capital-output ratios for the world, all relative to their respective levels in 1960. The world stock of equipment capital has grown tremendously over the years. The equipment capital-output ratio in the world has increased by more than a factor of two, while the structures capital-output ratio has declined, albeit modestly.

Is the rise of equipment capital distributed equally across countries? The answer is no. Many poor countries experience a decline instead of an increase in their equipment capital shares. The bottom panel of the figure 1 plots the equipment capital share in the world, the representative rich country and the representative poor country. Over this time period, the equipment capital share increases by 84 percent in the rich country and it declines by 36 percent in the poor country. A majority of rich and poor countries exhibit this pattern. For instance, during this time period the equipment capital share more than triples in the US and it nearly doubles in Luxembourg. In Niger, equipment capital share declines by 65 percent and in Gambia, it declines by 44 percent. Countries growing at high rates experience episodes of steep rise in their equipment capital shares. Between 1960 and 1990, Korea's

[4] "World" comprises of 119 countries from Mutreja (2014).

structural transformation coincided with a growth of equipment capital share by 264 percent and since 1980, China's manufacturing growth has been accompanied by a near doubling of its equipment capital share.

Thus, while cross-country gap in the *level* of aggregate capital-output ratio is stable over the years, the *composition* of capital has changed substantially. Are these changes in composition important for incomes across countries? Here, I motivate the importance of capital composition through a standard income accounting exercise (see Caselli, 2005), though this question is answered much more rigorously in the remainder of the paper. Assuming a Cobb-Douglas production function with equipment capital, structures capital and human capital augmented labor as factors, the income per worker in country i is given by

$$y_i = A_i k_{ei}^{\mu\alpha} k_{si}^{(1-\mu)\alpha} h_i^{\alpha}$$

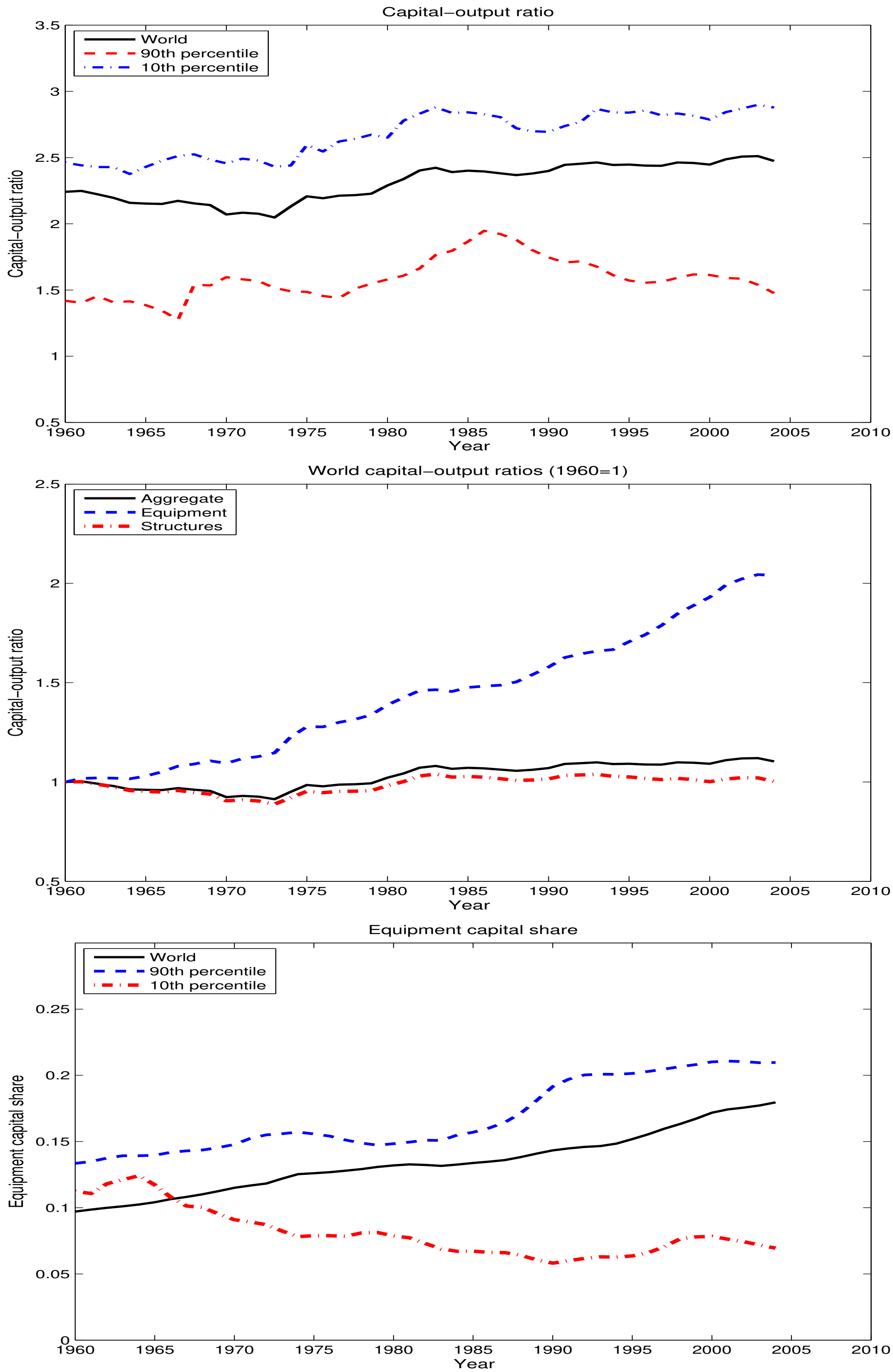
where A_i represents country i's TFP, k_{ei} and k_{si} are equipment and structures capital per worker and h_i denotes the average human capital per worker. α and μ are the factor shares. Using $\alpha = 1/3$ and $\mu = 0.56$ from Mutreja (2014), equipment and structures capital per worker account for 22.5 percent of the log variance in income per worker. The remaining 77.5 percent of the log variance is due to differences in residual TFP and h_i.

Defining equipment capital share in country i as $z_i = \frac{k_{ei}}{k_{ei}+k_{si}}$, the income per worker is:

$$y_i = A_i \left(k_{ei} + k_{si}\right)^{\alpha} \left\{z_i^{\mu}(1 - z_i)^{1-\mu}\right\}^{\alpha} h_i^{\alpha}.$$

The contribution of capital to incomes is given by the expression $(k_{ei}+k_{si})^{\alpha} \left\{z_i^{\mu}(1-z_i)^{1-\mu}\right\}^{\alpha}$. Of this, while the first term captures the contribution of the *level* of capital stock, the second term captures the effect of its composition. Consider the following numerical exercise. Suppose each country's total capital stock per worker, $k_{ei} + k_{si}$, is kept fixed and the equipment capital share, z_i, is adjusted to that in the US. This eliminates capital composition differences across countries while the differences in the level of capital stock remain. In the income accounting, this reduces the contribution of capital by 25 percent. Thus, composition differences are responsible for one-fourth of the overall contribution of capital in income accounting. Has the importance of capital composition evolved over time? Yes. If the same numerical exercise is conducted for prior years, the role of composition is smaller the further back we go. For instance in 1990 capital composition accounts for only 14 percent of the overall contribution of capital in income accounting and in 1980 it is much smaller at six percent. Clearly, differences in composition of capital matter, much more now than they used to 30 or so years ago.

Figure 1: Capital and its composition



In an online appendix to this paper, I show that a neoclassical growth model along the lines of Restuccia and Urrutia (2001) and Hsieh and Klenow (2007) is consistent with observed capital-output ratios but it fails to produce the observed differences in capital composition.[5] Most models of economic growth focus on aggregate capital-output ratios and inevitably ignore the changes in composition that have taken place over time. These changes are important because they potentially reflect the extent of investment-specific technological change that has taken place across countries. Additionally, equipment is the tradable component of capital. Over the years, capital composition has potentially emerged as a significant channel through which equipment trade affects incomes. Accordingly, in this paper, I study the role of equipment trade in determining capital composition and assess resulting implications for incomes.

3 Multi-Country Trade Model

The world economy consists of N countries. Each country has four sectors: equipment, investment structures, intermediate goods, and final good. Broadly, equipment correspond to producer durables, and investment structures correspond to residential and non-residential buildings (see also Mutreja, Ravikumar, and Sposi, 2016). Equipment and intermediate goods are tradable, while structures and final good are non-traded. Within each country i, there is a measure of consumers, L_i, that grows at the rate n. Each consumer has one unit of time, which is supplied inelastically in the domestic labor market. Stocks of equipment capital, structures capital, and labor are used to produce the flow of equipment, structures, intermediate goods, and final good. Factors are mobile across sectors, and labor is immobile across countries. In what follows, all variables for country i are normalized relative to the labor force in country i and denote per worker quantities. The country and time subscripts are omitted where they are understood.

3.1 Production Technology

3.1.1 Tradable Equipment Goods

Equipment goods sector has a continuum of goods that are indexed by $e \in [0, 1]$, and are produced via the following nested Cobb-Douglas production function between equipment capital k_e, structures capital k_s, labor l, and the aggregate intermediate good Q_m (described

[5] The online appendix is available at the author's webpage.

along with the production technology for intermediate goods):

$$q_e(e) = z_e(e)^{-\theta}[({k_e}^{\mu}{k_s}^{1-\mu})^{\alpha} l^{1-\alpha}]^{\gamma_e} {Q_m}^{1-\gamma_e},$$

where, similar to Dornbusch, Fischer, and Samuelson (1977), the production technology across individual goods differs only in the idiosyncratic productivity level, i.e., $z_e(e)^{-\theta}$. α, μ, and γ_e are the factor shares that are common across countries. Goods along the continuum are aggregated with a Dixit-Stiglitz technology with elasticity of substitution $\eta > 0$:

$$Q_e = \left[\int_0^1 q_e(e)^{\frac{\eta-1}{\eta}} de\right]^{\frac{\eta}{\eta-1}}$$

Productivity distribution: Following Alvarez and Lucas (2007), I assume that z_e are distributed independently and exponentially with parameter λ_e that differs across countries. Under this distributional assumption, the idiosyncratic productivity levels, $z_e^{-\theta}$, follow a Fréchet distribution, as used by Eaton and Kortum (2002). Parameter θ controls the dispersion of productivity levels around the mean. A larger θ implies more variation relative to the mean. I assume that θ is common to all countries.

The mean of the productivity distribution is proportional to λ_e^{θ}. λ_e governs the absolute advantage of country i in equipment. A country with a higher λ_e^{θ}, on average, can produce equipment more efficiently.

3.1.2 Non-traded Investment Structures

Each country has a structures sector, in which a representative firm produces homogeneous structures or buildings that are non-tradable across countries. Factors of production are combined via the following nested Cobb-Douglas production technology:

$$Q_s = [({k_e}^{\mu}{k_s}^{1-\mu})^{\alpha} l^{1-\alpha}]^{\gamma_s} {Q_m}^{1-\gamma_s},$$

where γ_s is the share of value added and is identical across countries.

3.1.3 Tradable Intermediate goods

The production technology for intermediate goods is similar to that for equipment goods. There are a continuum of goods indexed by $m \in [0, 1]$. Each individual good is produced via:

$$q_m(m) = z_m(m)^{-\theta}[({k_e}^{\mu}{k_s}^{1-\mu})^{\alpha} l^{1-\alpha}]^{\gamma_m} {Q_m}^{1-\gamma_m},$$

where $z_m(m)^{-\theta}$ is the idiosyncratic productivity level. γ_m is the factor share, which is the same across countries. The aggregate intermediate good is a C.E.S. aggregate of the individual goods with a constant elasticity of substitution $\eta > 0$:

$$Q_m = \left[\int_0^1 q_m(m)^{\frac{\eta-1}{\eta}} dm\right]^{\frac{\eta}{\eta-1}}$$

Productivity distribution: Similar to the equipment sector, z_m are distributed independently and exponentially with parameter λ_m that varies across countries. λ_m governs the absolute advantage of country i in intermediate goods. Comparative advantage is determined by relative average productivity across the two tradable sectors. A country with higher $(\lambda_e/\lambda_m)^\theta$ will have comparative advantage in the equipment sector relative to the intermediate goods sector. I assume that θ is identical across the two tradable sectors.[6]

3.1.4 Non-traded Final Good

In each country, there is a representative firm that employs factors and produces a non-tradable homogenous final good with the following production technology:

$$Q_c = A_c[({k_e}^{\mu}{k_s}^{1-\mu})^{\alpha} l^{1-\alpha}]^{\gamma_c} {Q_m}^{1-\gamma_c},$$

where γ_c is the factor share, which is common to all countries. A_c is country i's productivity in the final good.

3.2 Representative Household

Each country has a representative household that owns the labor endowment, as well as the stocks of both equipment and structures capital. In time period t, the representative household starts with k_e stock of equipment and k_s stock of structures and derives utility from consuming the final good:

$$\sum_{t=0}^{\infty} \beta^t \frac{c_{it}^{1-\sigma}}{1-\sigma},$$

where c_{it} is the consumption level of the final good in country i at time t. β is the period discount factor, which satisfies $\frac{1}{\beta} > 1+n$, and σ is the inter-temporal elasticity of substitution.

[6] Mutreja, Ravikumar, and Sposi (2016) estimate θ separately for capital goods and non-capital goods. The capital goods in Mutreja, Ravikumar, and Sposi (2016) are analogous to equipment in this paper. They find that θ is not significantly different across the two sectors.

Investment in time period t augments the existing capital stocks. Given prices, the representative household maximizes discounted lifetime utility subject to a budget constraint and two capital accumulation equations at time $t = 0, 1, ..., \infty$:

$$P_{cit}c_{it} + P_{eit}x_{eit} + P_{sit}x_{sit} = w_{it} + r_{eit}k_{eit} + r_{sit}k_{sit}$$

$$(1+n)k_{eit+1} = (1-\delta_e)k_{eit} + x_{eit}$$

$$(1+n)k_{sit+1} = (1-\delta_s)k_{sit} + x_{sit},$$

where δ_e and δ_s are the depreciation rates of equipment and structures, respectively. P_c, P_e, and P_s denote the prices of the final good, equipment, and structures, respectively. w is the wage rate, and r_e and r_s are the rental rates for equipment and structures, respectively. x_{eit} and x_{sit} denote investments in the two types of capital in country i in period t.

3.3 International Trade

Both equipment trade and intermediate goods trade are subject to iceberg trade costs, denoted by τ_{eij} and τ_{mij}, respectively. More than one unit of an equipment good must be shipped from country j for one unit to arrive in country i. That is, $\tau_{eij} - 1$ units are lost in the transit. Likewise, for τ_{mij}. τ_{eij} and τ_{mij} comprise both policy and non-policy barriers to trade. τ_{eij} also represents the adjustment costs, if any, associated with adaptation of imported equipment to domestic production conditions. For consistency, $\tau_{eii} = 1$ and $\tau_{mii} = 1$ for each country i.

3.4 Equilibrium

The competitive world general equilibrium is a set of prices, allocations, and trade shares such that, in each country i, the representative household maximizes utility, firms in four sectors minimize their costs, all goods and factors markets clear, and trade is balanced.

Country i purchases each tradable good from the least-cost supplier. The fraction of country i's expenditure in each tradable sector that is spent on goods produced in country

j is given by the following:

$$\pi_{eij} = \frac{\left[\left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha}\right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij}\right]^{-1/\theta} \lambda_{ej}}{\sum_l \left[\left(r_{el}^{\alpha\mu} r_{sl}^{\alpha(1-\mu)} w_l^{1-\alpha}\right)^{\gamma_e} P_{ml}^{1-\gamma_e} \tau_{eil}\right]^{-1/\theta} \lambda_{el}}$$

$$\pi_{mij} = \frac{\left[\left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha}\right)^{\gamma_m} P_{mj}^{1-\gamma_m} \tau_{mij}\right]^{-1/\theta} \lambda_{mj}}{\sum_l \left[\left(r_{el}^{\alpha\mu} r_{sl}^{\alpha(1-\mu)} w_l^{1-\alpha}\right)^{\gamma_m} P_{ml}^{1-\gamma_m} \tau_{mil}\right]^{-1/\theta} \lambda_{ml}}, \tag{1}$$

where π_{eij} and π_{mij} denote the bilateral trade shares. The price indices of aggregate equipment, Q_e, and aggregate intermediate good, Q_m, are:

$$P_{ei} = UV_e \left[\sum_l \left\{\left(r_{el}^{\alpha\mu} r_{sl}^{\alpha(1-\mu)} w_l^{1-\alpha}\right)^{\gamma_e} P_{ml}^{1-\gamma_e} \tau_{eil}\right\}^{-1/\theta} \lambda_{el}\right]^{-\theta}$$

$$P_{mi} = UV_m \left[\sum_l \left\{\left(r_{el}^{\alpha\mu} r_{sl}^{\alpha(1-\mu)} w_l^{1-\alpha}\right)^{\gamma_m} P_{ml}^{1-\gamma_m} \tau_{mil}\right\}^{-1/\theta} \lambda_{ml}\right]^{-\theta},$$

where V_e, V_m, and U are a collection of constants across countries. These are given by $V_e = (\alpha\mu\gamma_e)^{-\alpha\mu\gamma_e}(\alpha(1-\mu)\gamma_e)^{\alpha(\mu-1)\gamma_e}((1-\alpha)\gamma_e)^{(\alpha-1)\gamma_e}(1-\gamma_e)^{\gamma_e-1}$, $V_m = (\alpha\mu\gamma_m)^{-\alpha\mu\gamma_m}(\alpha(1-\mu)\gamma_m)^{\alpha(\mu-1)\gamma_m}((1-\alpha)\gamma_m)^{(\alpha-1)\gamma_m}(1-\gamma_m)^{\gamma_m-1}$, and $U = \Gamma(1+\theta(1-\eta))^{\frac{1}{1-\eta}}$, where $\Gamma(\cdot)$ is the gamma function (see appendix A for details). As in Eaton and Kortum (2002), I restrict parameters such that $U > 0$.

The prices of structures and final good are:

$$P_{si} = V_s \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha}\right)^{\gamma_s} P_{mi}^{1-\gamma_s}$$

$$P_{ci} = \frac{V_c}{A_c} \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha}\right)^{\gamma_c} P_{mi}^{1-\gamma_c},$$

where $V_s = (\alpha\mu\gamma_s)^{-\alpha\mu\gamma_s}(\alpha(1-\mu)\gamma_s)^{\alpha(\mu-1)\gamma_s}((1-\alpha)\gamma_s)^{(\alpha-1)\gamma_s}(1-\gamma_s)^{\gamma_s-1}$ and $V_c = (\alpha\mu\gamma_c)^{-\alpha\mu\gamma_c}(\alpha(1-\mu)\gamma_c)^{\alpha(\mu-1)\gamma_c}((1-\alpha)\gamma_c)^{(\alpha-1)\gamma_c}(1-\gamma_c)^{\gamma_c-1}$.

The two Euler equations from household optimization lead to the following equilibrium equipment and structures rental rates:

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

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

The optimal solution is characterized by trade balance:

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

The left-hand side denotes country i's imports of equipment and intermediate goods, while the right-hand side denotes country i's exports. This condition allows for trade imbalances at the sectoral level within each country: a country that is a net exporter of equipment will necessarily be a net importer of intermediate goods, and vice versa. The equipment and structures investment levels are given by:

$$x_{ei} = [(1+n) - (1-\delta_e)]k_{ei}$$
$$x_{si} = [(1+n) - (1-\delta_s)]k_{si}.$$

Composition of capital: A feature of the equilibrium is that the stocks of equipment and structures capital are endogenous. The equipment capital-output ratio and the structures capital-output ratio in equilibrium are (see appendix A for the derivations):

$$\frac{k_{ei}}{y_i} = \frac{\alpha\mu}{[\frac{1}{\beta} - (1-\delta_e)]W_e} \frac{1}{A_c} \left(\frac{\lambda_e}{\pi_{eii}}\right)^{\theta} \left(\frac{\lambda_m}{\pi_{mii}}\right)^{\frac{\theta(\gamma_c - \gamma_e)}{\gamma_m}}$$
$$\frac{k_{si}}{y_i} = \frac{\alpha(1-\mu)}{[\frac{1}{\beta} - (1-\delta_s)]W_s} \frac{1}{A_c} \left(\frac{\lambda_m}{\pi_{mii}}\right)^{\frac{\theta(\gamma_c - \gamma_s)}{\gamma_m}}, \qquad (2)$$

where $W_e = \frac{UV_e}{V_c}(UV_m)^{\frac{(\gamma_c - \gamma_e)}{\gamma_m}}$ and $W_s = \frac{V_s}{V_c}(UV_m)^{\frac{(\gamma_c - \gamma_s)}{\gamma_m}}$ are a collection of constants. $\pi_{ejj} = 1 - \sum_v \pi_{ejv}$ is the fraction of expenditure on equipment goods that is spent on home produced equipment (henceforth, home expenditure share). Likewise, $\pi_{mjj} = 1 - \sum_v \pi_{mjv}$. The share of equipment in capital is given by:

$$\frac{k_{ei}}{k_{ei} + k_{si}} = \frac{1}{1 + \frac{1-\mu}{\mu} \frac{\frac{1}{\beta} - (1-\delta_e)}{\frac{1}{\beta} - (1-\delta_s)} \frac{W_e}{W_s} \left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(\gamma_e - \gamma_s)}{\gamma_m}} \left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{-\theta}}, \qquad (3)$$

Thus, the capital-output ratios and the equipment capital share are functions of a country's productivity levels, as well as home expenditure shares in equipment and intermediate goods. Since $\pi_{eii} \leq 1$ and $\pi_{mii} \leq 1$, relative to autarky, a world economy with trade is associated with a higher share of equipment in capital in all countries. $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$ can be interpreted as country i's *effective* productivity in the equipment sector. Recall that the equipment sector has a continuum of goods along the unit interval. Within the equipment sector, a country experiences efficiency gains by producing at home only a fraction of the continuum for which it has the high productivity draws (π_{eii}) and by importing goods along the rest of the unit interval (1-π_{eii}). Reductions in equipment trade costs lead to further specialization along the unit interval and increase effective equipment productivity by lowering the home expenditure share in equipment. Likewise, higher effective productivity in intermediate goods, $\left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\theta}$, increases capital composition if $\gamma_e < \gamma_s$. The productivity in intermediate goods affects equipment capital share through the price of equipment and structures. An increase in the effective productivity of intermediate goods reduces its price. These are inputs into production of equipment and structures, so prices of both equipment and structures decline; the price of equipment declines by more if $\gamma_e < \gamma_s$, thereby increasing the desirability of equipment as an investment option.

Equipment can either be produced at home or imported. Productivity levels and trade costs govern which of these two is more relevant for a certain country. Absolute advantage determines the size of the equipment sector at home. A country with high productivity in equipment, λ_{ei}^{θ}, will tend to produce the bulk of equipment at home and, so, will have a large fraction of its capital in equipment. If equipment cannot be efficiently produced at home, comparative advantage and trade costs determine the quantity of imported equipment. Country i will tend to be a net exporter of intermediate goods (because of a comparative advantage in intermediate goods) if $\frac{\lambda_{mi}}{\lambda_{ei}} > \frac{\lambda_{mj}}{\lambda_{ej}}$ for some j, even if it has an absolute disadvantage in intermediate goods. For such a country, the export barriers control the export receipts from intermediate goods. This, along with country i's equipment import barriers, in turn, pin down the volume of i's equipment imports. Thus, the world pattern of absolute and comparative advantage, as well as trade costs, determine capital composition.

Income per worker: The real income per worker in this paper is defined as the per period earning of the representative household deflated by the price of final good:

$$y_i = \frac{w_i}{P_{ci}} + \frac{r_{ei}}{P_{ci}} + \frac{r_{si}}{P_{ci}}$$

Using equilibrium expressions for prices and trade shares, this implies that income per worker in country i is (see appendix A for the derivation):

$$y_i = \Lambda\, A_{ci} \left(\frac{\lambda_m}{\pi_{mii}}\right)^{\frac{\theta(1-\gamma_c)}{\gamma_m}} \left(k_{ei}^{\mu} k_{si}^{1-\mu}\right)^{\alpha},$$

where Λ is a collection of constants. Equivalently, in terms of the equipment capital share in country i, denoted by $z_i = \frac{k_{ei}}{k_{ei}+k_{si}}$:

$$y_i = \Lambda\, A_{ci} \left(\frac{\lambda_m}{\pi_{mii}}\right)^{\frac{\theta(1-\gamma_c)}{\gamma_m}} \, (k_{ei} + k_{si})^{\alpha} \, \{z_i^{\mu}(1-z_i)^{1-\mu}\}^{\alpha}. \tag{4}$$

Income per worker in country i is a function of three things: (i) TFP, $A_{ci}\left(\frac{\lambda_m}{\pi_{mii}}\right)^{\frac{\theta(1-\gamma_c)}{\gamma_m}}$, (ii) equipment and structures capital per worker, $(k_{ei} + k_{si})^{\alpha}$, and (iii) a capital composition term, $\{z_i^{\mu}(1-z_i)^{(1-\mu)}\}^{\alpha}$. Trade affects incomes through each of these, and equipment trade affects incomes through equipment capital per worker and the capital composition term. This paper focusses on the latter: capital composition. In what follows, I use this expression to quantify how equipment trade affects incomes through its impact on the capital composition term. Note that country i's income is positively related to its equipment capital share (z_i) if $z_i < \mu$. An easing of trade restrictions results in higher equipment capital shares and, therefore, higher incomes in all countries (if $z_i < \mu$ is satisfied).

To summarize, in the multi-country trade model (henceforth, model), countries differ in their labor endowment, L_i, final good productivity, A_{ci}, average equipment productivity, λ_{ei}^{θ}, average intermediate goods productivity, λ_{mi}^{θ}, and bilateral trade costs for equipment and intermediate goods, τ_{eij} and τ_{mij}. The capital stocks and the composition of capital are endogenous in the equilibrium, and trade affects incomes through the capital composition term. In the next section, I present the calibration procedure for common and country-specific parameters and discuss the fit of the quantitative model.

4 Calibration

I calibrate country-specific parameters by using data on a sample of 65 countries in 2005. This sample includes both rich and poor countries and accounts for 78 percent of the world GDP.[7] Appendix B contains the details on data sources and the procedure for the construction of the data (see table C.1 in appendix C for the list of countries).

To be consistent with the data on equipment and structures capital stocks employed in this paper, I map the equipment sector from the model to categories 381-385 of the International Standard Industrial Classification (ISIC) Revision 2 (see Mutreja, 2014, for details). These categories correspond to "Machinery and Equipment" in the World Bank's International Comparison Program (ICP). Structures correspond to residential and non-residential buildings. I, thus, map investment structures into the "Construction" category of ICP. The intermediate goods sector corresponds to traded manufactured goods other

[7] World GDP is computed from the Penn World Tables version 6.3 (Heston, Summers, and Aten, 2009).

than the equipment. The final good sector corresponds to all non-traded goods other than investment structures.

Common Parameters: Calibrated values for parameters common to all countries are in table 1.

Table 1: Parameters common across countries

Parameter	Description	Value
α	factor share of capital	1/3
μ	factor share of equipment in capital	0.56
δ_e	equipment depreciation rate	0.14
δ_s	structures depreciation rate	0.02
γ_e	share of value added in equipment	0.31
γ_m	share of value added in intermediate goods	0.29
γ_s	share of value added in structures	0.39
γ_c	share of value added in final good	0.75
θ	dispersion parameter	0.25
β	discount factor	0.96
σ	inter-temporal elasticity of substitution	1.5
η	elasticity of substitution in CES aggregator	2

Some of the common parameters are calibrated to be consistent with the economic growth and international trade literature. Using information on self-employed and salaried individuals for a wide cross-section of countries, Gollin (2002) finds that the factor share of labor is 2/3. This corresponds to $1 - \alpha$, and, so, I set the factor share of capital at 1/3. I set the factor share of equipment in capital, μ, at 0.56, in accordance with Greenwood, Hercowitz, and Krusell (1997).[8] They calibrate a model of investment-specific technological change to data on the US economy, and their estimates imply an equipment factor share of 0.56. The data on equipment and structures capital stocks employed in this paper are constructed using a 14 percent equipment depreciation rate and a 2 percent structures depreciation rate (see Mutreja, 2014, for details). I, thus, set $\delta_e = 0.14$ and $\delta_s = 0.02$. θ controls the dispersion in productivity levels. I use θ equal to 0.25, as in Simonovska and Waugh (2014).[9]

[8] In the literature, values for the factor share of equipment capital range between 0.54-0.65 (see Mutreja, 2014, for details). I used μ=0.5 and μ=0.6 to determine the sensitivity of results to this factor share parameter. The implications are qualitatively similar to the ones in the baseline specification.

[9] Simonovska and Waugh (2014) estimate a $\theta = 0.25$ for all tradable goods combined into one category. Conceivably, θ is different for equipment and intermediate goods. Mutreja, Ravikumar, and Sposi (2016) use the methodology in Simonovska and Waugh (2014) to estimate θ separately for capital and non-capital goods. They estimate $\theta_e = 0.23$ and $\theta_m = 0.25$. The results in this paper are not significantly altered if I instead use $\theta_e = 0.23$ and $\theta_m = 0.25$.

The parameters γ_e, γ_m, γ_s, and γ_c are, respectively, the share of value added in equipment, intermediate goods, investment structures, and final good production. To calibrate γ_e and γ_m, I use data on value-added and total output available in the INDSTAT 4 database (UNIDO, 2013). I calculate the share of value-added in equipment and non-equipment manufactured goods for all the available countries and average them across countries to arrive at γ_e and γ_m, respectively. For γ_s, I compute the average share of valued-added in gross output of construction for 32 OECD countries.[10] Alvarez and Lucas (2007) discuss that the share of value-added in final good production ranges in 0.7-0.8, depending on the source. I use $\gamma_c = 0.75$, in accordance with their baseline value.

The labor force growth rate, n, of 0.016 is computed by using the average geometric growth rate in the world population from 2000 through 2007. Following Alvarez and Lucas (2007), I set η equal to 2. As is common in the literature, the discount rate is set at 0.96. The inter-temporal elasticity of substitution, σ, is 1.5, as in Restuccia and Urrutia (2001). β, σ and η are quantitatively not important for the issues addressed in this paper. Note that these parameter values satisfy the following assumptions: $\frac{1}{\beta} > 1 + n$ and $1 + \theta(1 - \eta) > 0$.

Trade costs: To calibrate trade costs for equipment and intermediate goods, I use the methodology employed in Mutreja, Ravikumar, and Sposi (2016). The model implies the following structural relationships between trade costs, trade shares, and prices in each tradable sector:

$$\frac{\pi_{eij}}{\pi_{ejj}} = \left(\frac{P_{ej}}{P_{ei}}\right)^{-\frac{1}{\theta}} \tau_{eij}^{-\frac{1}{\theta}}$$
$$\frac{\pi_{mij}}{\pi_{mjj}} = \left(\frac{P_{mj}}{P_{mi}}\right)^{-\frac{1}{\theta}} \tau_{mij}^{-\frac{1}{\theta}}, \tag{5}$$

where π_{ejj} and π_{mjj} are the home expenditure shares. I use data on bilateral trade shares, home expenditure shares, and aggregate prices across countries along with equations in (5) to pin down bilateral trade costs (see appendix B for how I construct the trade shares in data).

There are many zeroes in the data. Of the 4160 possible bilateral country pairs, the volume of trade for 584 pairs in equipment and 263 pairs in intermediate goods is zero. To the country pairs where no trade exists I assign a high enough trade cost such that trade is effectively eliminated. Equipped with all the calibrated parameters, when I compute the

[10] Value added and gross output data for OECD countries are from STAN database available at http://stats.oecd.org/Index.aspx.

model equilibrium, the implied trade shares are extremely small for country pairs that have zeros in the trade data matrix. For instance, in data there are zero equipment exports from Argentina to Fiji. The calibrated model implies a trade share of 7.2×10^{-10}, which is negligible.

Similar to Waugh (2010), the calibrated trade costs are systematically higher for poor exporters. The correlation between average equipment trade cost and income per worker is -0.37, and that for intermediate goods is -0.44. The average equipment trade barrier for the poor exporter (10th percentile country) is 11.86 times the the average trade barrier faced by the rich exporter. For instance, fixing the US as the importer, the correlation between equipment trade cost and income per worker is -0.18. If the importer is fixed at China, then this correlation is -0.27. These correlations are more negative in the case of the intermediate goods. The trade costs in Waugh (2010) are estimated from a gravity equation with an exporter fixed effect. I do not assume either τ_e or τ_m to be exporter-specific. When calibrated to the data on prices and trade flows, they turn out to be higher for poor exporters. Both sets of trade costs are consistent with trade flows.

Productivity parameters: To calibrate the country-specific productivity parameters, I employ structural relationships from the model that connect productivity parameters to home expenditure shares and relative prices:[11]

$$\begin{aligned}
\frac{P_{ei}}{P_{mi}} &= W_m \left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{-\theta} \left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta\gamma_e}{\gamma_m}} \\
\frac{P_{ei}}{P_{ci}} &= W_e\, A_{ci} \left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{-\theta} \left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(\gamma_e-\gamma_c)}{\gamma_m}} \\
\frac{P_{si}}{P_{ci}} &= W_s\, A_{ci} \left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(\gamma_s-\gamma_c)}{\gamma_m}},
\end{aligned} \tag{6}$$

where $W_m = UV_e(UV_m)^{-\frac{\gamma_e}{\gamma_m}}$ is a constant (the derivations are in appendix A). I use data on the price of equipment relative to intermediate goods, $\frac{P_{ei}}{P_{mi}}$, the relative price of equipment, $\frac{P_{ei}}{P_{ci}}$, the relative price of structures, $\frac{P_{si}}{P_{ci}}$, and the home expenditure shares in equipment and intermediate goods to calibrate productivity parameters relative to US productivity levels.

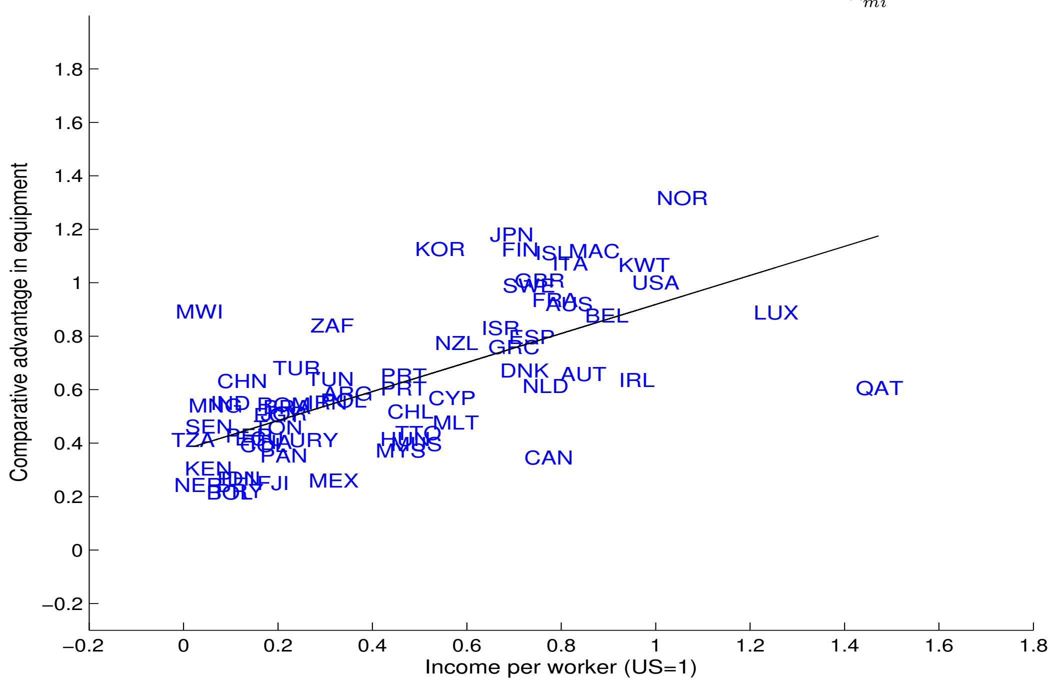
Cross-country differences in the calibrated productivity levels are higher for equipment than for intermediate goods (see table C.1, appendix C). The income elasticity of λ_e^θ is 0.50, and the income elasticity of λ_m^θ is 0.21. Recall that λ_{ei}^θ is country i's average equipment

[11] Mutreja, Ravikumar, and Sposi (2016) calibrate productivity parameters to relative prices and incomes in their sample. I do not use data on income per worker for the calibration.

productivity. The 90-10th percentile ratio of λ_e^θ is 3.54 and that of λ_m^θ is 0.87. Thus, rich countries have an absolute and comparative advantage in equipment, and poor countries have a comparative advantage in intermediate goods. Figure 2 plots $\left(\frac{\lambda_{ei}}{\lambda_{mi}}\right)^\theta$ against income per worker across countries. The comparative advantage in equipment systematically increases with incomes.

Herrendorf and Valentinyi (2012) measure sectoral TFP for 86 countries in 1996. They estimate the 90th-10th percentile ratio of equipment TFP to be 8.7. In my model, the analogue of this equipment TFP is the effective equipment productivity, $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^\theta$. The 90th to 10th percentile ratio of effective equipment productivity from the quantitative model is 4.43. Thus, the equipment productivity differences that are consistent with cross-country prices and trade flows, and, as I show later, equipment production, capital stocks, and capital composition, are smaller than the ones estimated by Herrendorf and Valentinyi (2012).

Figure 2: Comparative advantage in equipment, $\frac{\lambda_{ei}^\theta}{\lambda_{mi}^\theta}$



Model fit: Calibration targets are the ratios of absolute prices of equipment and intermediate goods, $\frac{P_{ej}}{P_{ei}}$ and $\frac{P_{mj}}{P_{mi}}$; the ratios of bilateral trade shares to exporter's home expenditure share in each bilateral country pair, $\frac{\pi_{eij}}{\pi_{ejj}}$; relative prices, $\frac{P_{ei}}{P_{mi}}$, $\frac{P_{ei}}{P_{ci}}$, and $\frac{P_{si}}{P_{ci}}$; and home expenditure shares in both tradable goods, π_{eii} and π_{mii}.

Equipped with productivity parameters and trade costs, I compute the equilibrium. The equilibrium implied allocations and prices fit calibration targets well. The income elasticity of price of equipment is 0.03 in the data and 0.03 in the model. The corresponding elasticities are 0.24 and 0.25 for intermediate goods. The income elasticity of the relative price of equipment is -0.48 in the data and -0.55 in the model, while those for the relative price of structures are -0.01 and -0.04, respectively. Finally, the income elasticity for the price of equipment relative to intermediate goods is -0.21 in the data and -0.23 in the model. The model also matches trade data reasonably well. The model and data correlation are 0.66 for $\frac{\pi_{eij}}{\pi_{ejj}}$ and 0.64 for $\frac{\pi_{mij}}{\pi_{mjj}}$. The correlations between home expenditure shares in the model and the data are 0.96 for equipment and 0.89 for intermediate goods.

The model is also consistent with prices that are not specifically targeted in the calibration. The income elasticity for the price of structures is 0.49 in the data and 0.54 in the model. The elasticities for the price of final good are 0.50 and 0.58 respectively. Thus, the quantitative model is consistent with the data on prices and trade flows.

The calibrated productivity levels deliver the observed pattern of equipment production. In the data, top seven countries produce 78.3 percent of the world equipment. This share is 75.5 percent in the model. The share of equipment produced in the bottom seven countries is 0.004 percent in the data and 0.008 percent in the model. Figure D.1 in appendix D plots the cumulative distribution of equipment production for the data and the model.

A remark is in order here. One might argue that relative to the existing literature, the model puts significantly more structure on the data. The model incorporates bilateral trade in both equipment equipment and intermediate goods. An alternative theoretical setup is a model of bilateral trade that does not differentiate between trade in equipment and non-equipment goods, as in Waugh (2010). Such a model, though consistent with bilateral trade flows, would fail to produce the pattern of equipment production across countries. Another alternative framework is a model that considers only bilateral trade in equipment, as in Eaton and Kortum (2001). Such a framework would be able to explain equipment production across countries but would be inconsistent with the overall trade flows.

5 Results

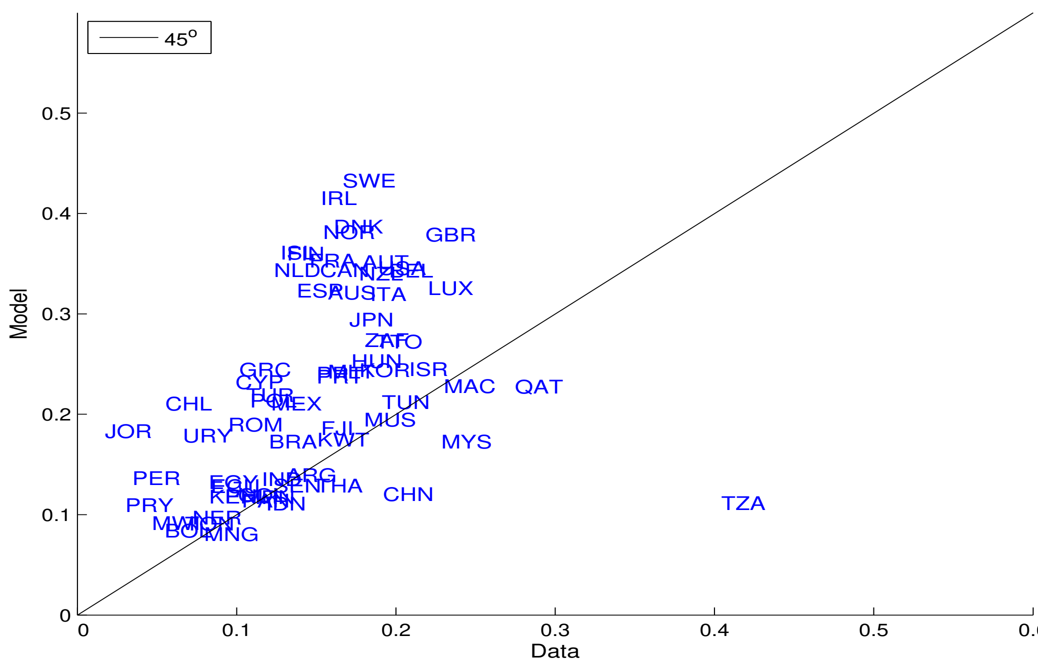
In this section, I first present the model-implied equipment capital shares, equipment and structures capital stocks, and incomes. Thereafter, I use the structural framework to examine the role of equipment trade in determining capital composition across countries.

Equipment share in capital: Figure 3 plots the equipment capital share from the model against those in the data, and table 2 presents summary statistics on cross-country differences in the equipment capital share. The model slightly over explains the equipment share in capital and reproduces 110 percent of the observed log variance. The model is also consistent with the observed equipment capital share in rich and poor. The share of equipment in the 90th percentile country is 21 percent in the data. The model implies a share of 34 percent. The share of equipment in the 10th percentile country is 7 percent in the data and 8.4 percent in the model.

Table 2: Equipment share in capital

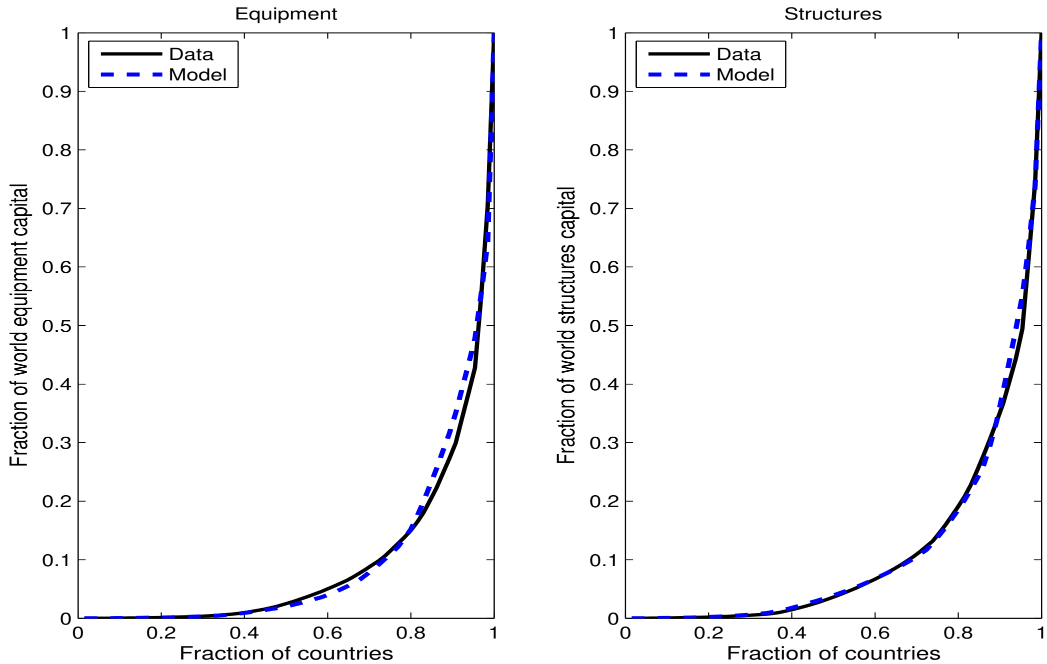
	Data	Model
Log variance	0.20	0.22
90-10 ratio	3.02	4.08

Figure 3: Equipment share in capital



Equipment and structures capital stocks: The quantitative model matches cross-country differences in equipment and structures capital. Figure 4 presents the world distribution of equipment and structures capital in the model and data. The correlation between

Figure 4: Cross-country distribution of capital



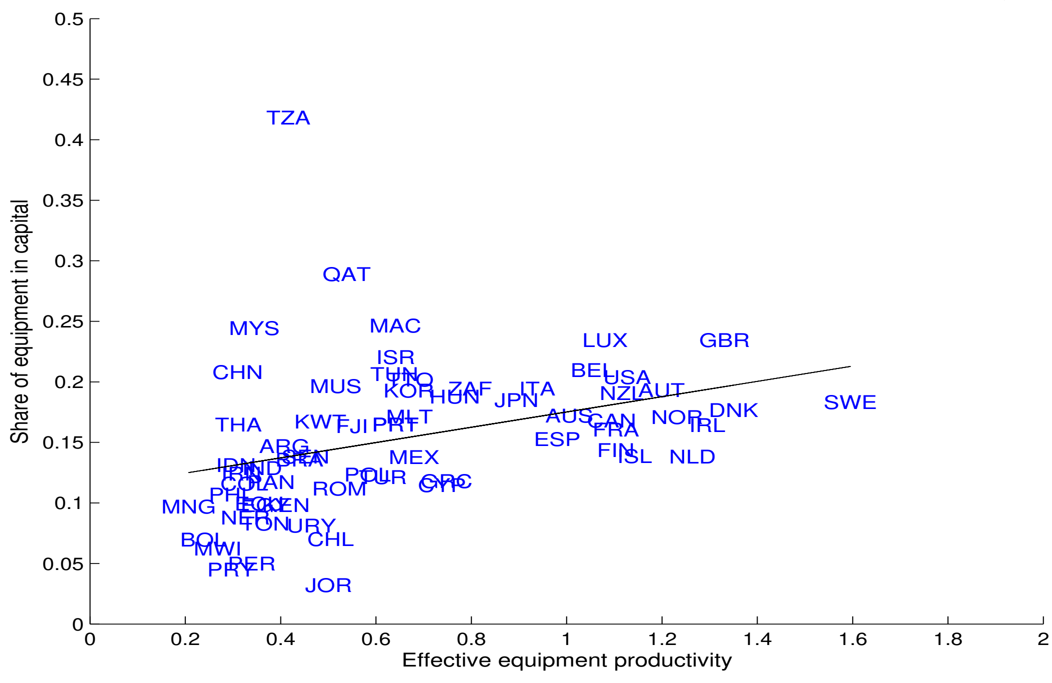
the model and data distribution for both kinds of capital is 0.99. Thus, the model reproduces the world distribution of capital almost perfectly.

The quantitative model also predicts capital-output ratios and capital per worker that are consistent with the data. Figure D.2 in appendix D plots the capital-output ratios from the model against the ones in data. The equipment capital-output ratio is a factor of 5.88 between rich and poor in the data and 5.69 in the model. The model also reproduces variation in structures capital across countries. The 90th-10th percentile ratio of structures capital-output ratio is 1.66 in the data and 1 in the model. Figure D.3 in appendix D presents equipment and structures capital per worker from the model and data. The 90th-10th percentile ratio of equipment capital per worker is 54.06 in the data and 58.57 in the model. The corresponding ratio for structures capital per worker is 15.22 in the data and 10.31 in the model.

Income per worker: The calibrated model is also consistent with observed income per worker differences. Recall that the calibration exercise does not employ data on incomes to calibrate any of the country-specific parameters. In the model, the income per worker in rich is 9.2 times the income per worker in poor. The corresponding ratio in the data is 10.29. World income distribution from data and model is plotted in figure D.4 in appendix D; the correlation between model and data is 0.99. The log variance of income per worker is 1.31 in the model and 0.96 in the data.

Implications: In the model, equipment capital share in a country is function of its productivity levels and trade flows. This relationship enables me to evaluate the role of equipment trade in determining cross-country capital composition. The differences in equipment capital share are entirely due cross-country variation in $\left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(\gamma_e-\gamma_s)}{\gamma_m}} \left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{-\theta}$ (see equation (3)). The log variance of this term is 1.09. Following the variance decomposition methodology commonly employed in the income differences literature, I decompose this log variance into the log variance of the four components: $\lambda_{mi}^{\frac{\theta(\gamma_e-\gamma_s)}{\gamma_m}}$, $\pi_{mii}^{\frac{-\theta(\gamma_e-\gamma_s)}{\gamma_m}}$, ${\lambda_{ei}}^{-\theta}$, and ${\pi_{eii}}^{\theta}$.[12] The sum of log variances of the four components is 0.59. The remaining log variance of 0.5 is split equally amongst the four components. Of the log variance of 1.09, variation in equipment productivity accounts for 52.6 percent. The equipment home expenditure share accounts for 22.7 percent. In no way, this is small. The remaining 24.7 percent is accounted for by intermediate goods productivity and home expenditure shares.

Figure 5: Equipment capital share and effective equipment productivity, $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$



Another way to interpret this variance decomposition is through the effective equipment

[12]This assumes that the four components are not complementary to each other.

productivity, $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$. The effective productivity in equipment accounts for over three fourths of the variation in equipment share across countries. Figure 5 plots equipment capital share against effective equipment productivity. Higher equipment productivity levels are associated with larger shares of equipment in capital. In other words, rich countries have higher equipment capital shares because they are more productive in equipment, and trade enables them to specialize in equipment production that results in higher effective equipment productivity.

To summarize, the quantitative model implies that rich have an absolute and comparative advantage in equipment, while poor have a comparative advantage in intermediate goods. The model successfully explains cross-country dispersion in capital composition, stocks of equipment and structures capital, and incomes. Rich countries have higher productivity in equipment and, thus, larger shares of equipment in capital. A variance decomposition of the model-implied equipment capital share suggests that the role of trade in accounting for capital composition is non-trivial. The variance decomposition exercise abstracts from complex interactions between capital composition, productivity levels and trade. I explore these interactions and consequent implications for incomes in the next section via counterfactual experiments.

6 Gains from Trade and Capital Composition

This section presents the counterfactual experiments, in which I adjust equipment trade costs from their baseline levels and study the resulting implications for capital composition and incomes.

Equipment trade costs affect the prices faced by poor countries versus rich countries and, thus, govern the equipment-structures investment tradeoff. Theoretically, a country i with $\frac{\lambda_{ei}}{\lambda_{mi}} > \frac{\lambda_{ej}}{\lambda_{mj}}$ for some j will tend to be a net exporter of equipment. The volume of equipment exports, however, depends on the trade cost i faces when exporting equipment to all such countries j. Therefore, trade costs influence the price at which i can supply equipment to j, and thus i's competitiveness in the world equipment market. Qualitatively, a reduction in equipment trade costs is similar to an increase in equipment productivity, since, given the factor resources, both increase the quantity of equipment goods in the world. This increases overall world equipment investment and thus, equipment capital and equipment capital share in the world. The distribution of this world equipment capital gain across countries determines the implications for capital composition and incomes. Do all countries gain? If so, what is the relative distribution of these gains between poor and rich?

Table 3: Increase in share of equipment relative to baseline (percent)

	Rich	Poor	Overall avg.
$\tau_{eij} = \tau_{eij}^{1985}$	-10.3	-2.7	-4.7
$\tau_{eij} = \infty$	-17.8	-3.9	-6.9
$\tau_{eij} = 1$	14.7	10.9	14.7

Table 4: Income gain/loss and contribution of trade via capital composition (percent)

	Change in income per worker			Fraction due to capital composition channel		
	Rich	Poor	Overall avg.	Rich	Poor	Overall avg.
$\tau_{eij} = \tau_{eij}^{1985}$	-12.5	-10.2	-8.4	35.1	64.2	45.1
$\tau_{eij} = \infty$	-20.3	-14.6	-12.3	46.9	70.9	49.1
$\tau_{eij} = 1$	17.6	62.6	49.2	16.8	23.2	20.1

Note: Rich and poor correspond to 90th and 10th percentiles of the world income per worker distribution, respectively.

The first counterfactual experiment focusses on the fall in equipment trade costs between 1985 and 2005. For this experiment, I calibrate the equipment trade costs for 1985 and measure the fall in equipment trade cost for each bilateral country pair. The second and third experiment explore extreme cases of autarky and zero gravity in equipment trade. In each experiment, I present the rich versus poor distribution of the changes in equipment capital share resulting from the changes in equipment trade costs relative to the baseline. I also discuss the income gains/losses that accrue to countries via the capital composition channel. Recall that income per worker is a function of TFP, capital per worker, and the capital composition term (see equation (4)). As trade costs change, so does a country's capital composition term due to the change in its equipment capital share. This leads to changes in income per worker. To quantify the importance of capital composition channel, I use the percentage of quantitative income gains/losses that are due to changes in the capital composition term. The results from counterfactual experiments are summarized in tables 3 and 4.[13]

[13] I conduct additional counterfactual experiments that are in the online appendix to this paper.

6.1 From 1985 to 2005

The concurrent rise in world equipment capital intensity and world equipment trade volumes has been facilitated, in part, by the declining trade costs. What role has the decline in equipment trade costs played in the evolution of equipment capital shares and incomes across countries? Is capital composition an important channel through income gains from declining equipment trade costs have been transmitted?

To answer these questions, I measure the fall in equipment trade costs that occurred between 1985 and 2005. I employ the methodology described in section 4 (see equation 5) along with the data for 1985 on equipment prices and equipment trade shares. Construction of trade shares requires data on production and bilateral trade volumes. These along with the data on equipment prices are available for a sample of 32 countries only.[14] Using the calibrated bilateral equipment trade costs for 32 countries in 1985, I calculate the average equipment trade cost for each exporter in 1985.[15] Subtracting these from the corresponding values in 2005, I arrive at the 1985-2005 fall in average equipment trade cost for each of the 32 exporters. Based on a regression of the 1985-2005 fall in average equipment export cost on income per worker for 32 exporters, I impute the average fall in equipment trade cost for all 65 exporters countries in the 2005 sample. Using the imputed 1985-2005 fall in trade costs as a mark-up, I arrive at the bilateral equipment trade costs in 1985 for the 65 country sample:

$$\widehat{\tau}_{eij}^{1985} = (1 + \widehat{\rho}_{ej})\, \tau_{eij}$$

where $\widehat{\tau}_{eij}^{1985}$ is the imputed equipment trade cost for 1985, $\widehat{\rho}_{ej}$ is the fall in average equipment trade cost for exporter j, and τ_{eij} is the baseline calibrated value of equipment trade cost in 2005. Thus, country j's fall in average equipment trade cost, $\widehat{\rho}_{ej}$, is applied uniformly to equipment trade cost for all the bilateral pairings where j is an exporter.

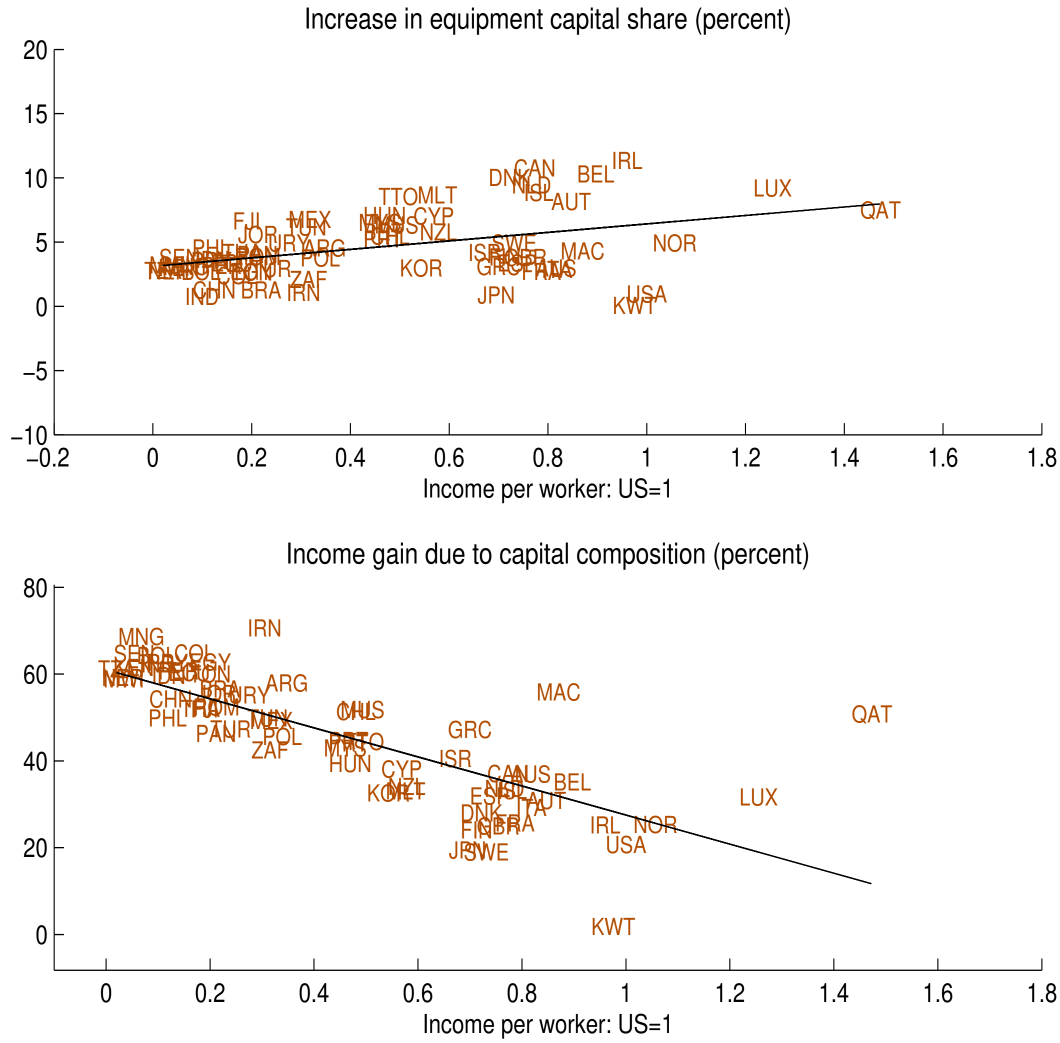
An examination of the measured trade costs (for 65 countries) reveals that the decline in equipment trade costs is slightly higher for rich exporters. During 1985-2005, equipment trade costs fall by 74 percent in rich countries and by 68.6 percent in poor countries, on average. As a result, relative to rich, poor exporters face slightly higher costs to export equipment in 2005. In 1985, the average equipment export cost for poor is 11.6 times the export cost in rich. In 2005, the corresponding ratio is only marginally higher at 11.86. Thus, while equipment trade costs have declined in all countries, their systematic variation

[14]See appendix B for the data sources and procedures as well as the list of 32 countries in the 1985 sample.

[15]The baseline calibrated equipment trade costs are exporter-specific, not importer-specific. This is why, a per-exporter average is computed here.

with an exporter's income level is essentially unchanged.

Figure 6: Declining equipment trade costs: 1985 to 2005



In the counterfactual experiment, I set bilateral equipment trade barriers at their 1985 levels, $\tau_{eij} = \widehat{\tau}_{eij}^{1985}$. Other parameters, viz., common parameters, equipment productivity, λ_{ei}^{θ}, intermediate goods productivity and trade costs, τ_{min} and λ_{mi}^{θ}, and final good productivity, A_{ci}, are set at their calibrated baseline levels. With this set of parameters, I re-compute the world general equilibrium. Note that this counterfactual simulates a situation where the only difference between 1985 and 2005 is in the equipment trade costs. Comparing between the counterfactual world and the baseline reveals the contribution of declining equipment trade costs to the evolution of capital composition and incomes across countries.

As equipment trade barriers fall between 1985 and 2005, rich specialize more in their comparative advantage good and focus resources away from the relatively inefficient intermediate goods sector. More equipment is produced at home and, so, investment in equipment capital increases. As a result, the equipment capital share in the rich increases by 10.3 percent from 24 percent in the counterfactual world to 34.3 percent in the baseline. Poor countries also gain. With the fall in barriers to import equipment, equipment becomes relatively less expensive and so, investment in equipment rises. The equipment capital share would have been lower at 5.7 percent in poor if the decline in equipment trade barriers had not taken place, compared to 8.4 percent in the baseline. Figure 6 plots the gain in equipment capital share associated with the 1985-2005 equipment trade cost decline. Cross-country differences in equipment capital share also reduced with the 1985-2005 decline in equipment trade cost: the log variance of equipment capital share is 0.29 compared to 0.22 in the baseline.

The 1985-2005 fall in equipment trade costs results in higher incomes in all countries. Overall, income per worker gain is 12.5 percent in the rich and 10 percent in the poor. A large fraction of these income gains stem from the changes in the capital composition term. The capital composition term alone accounts for 35 percent of the income gain in rich and 64 percent in poor. Figure 6 plots the contribution of the composition term to incomes gains (in percentage terms) against income per worker. Thus, between 1985 and 2005, capital composition is an important channel through which equipment trade affects income across countries.

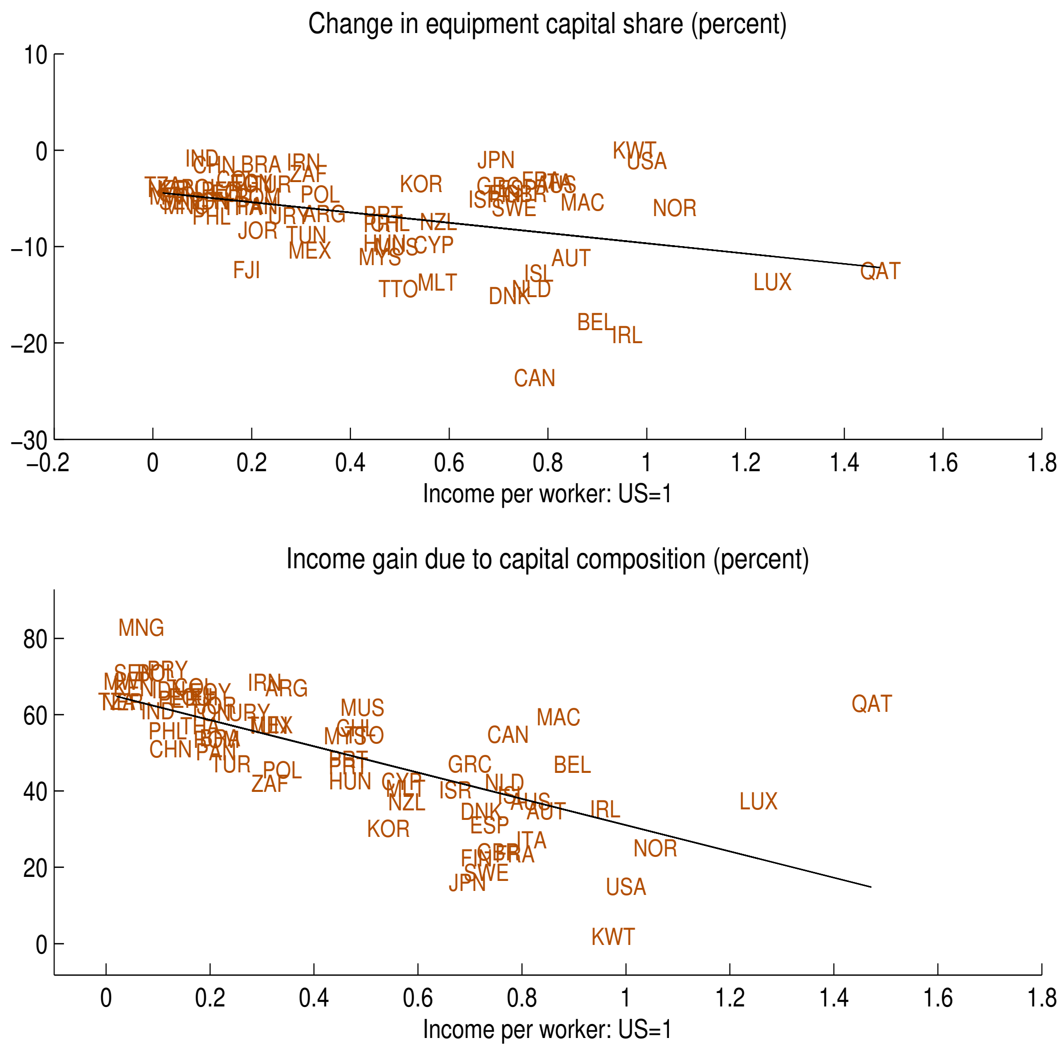
6.2 Autarky and Zero Gravity in Equipment

Autarky in equipment: In the autarky experiment, I shut down equipment trade by setting equipment trade barriers, τ_{eij}, at prohibitively high levels. I set the remaining parameters at their calibrated levels and re-compute the world equilibrium. That is, countries still trade intermediate goods, albeit restricted by the calibrated levels of intermediate goods trade costs. With this set of parameters, I re-compute the world general equilibrium.

In the absence of equipment trade, rich can no longer specialize in their comparative advantage good and have to divert resources to their relatively inefficient intermediate goods sector. Less equipment is produced at home and, so, investment in equipment capital declines. As a result, the equipment capital share in the rich falls to 16.5 percent from 34 percent in the baseline.

Poor countries are also adversely affected. With equipment autarky, they can no longer access the equipment produced in rich countries and the composition of their capital is determined by domestic equipment productivity levels only. The equipment capital share declines to 4.5 percent from 8.4 percent in the baseline. Thus, equipment share in capital reduces to about one-half in both rich and poor. Figure 7 plots the decline in equipment share because of autarky in equipment. Cross-country differences in equipment capital share also increase as the log variance of equipment share nearly doubles to 0.39.

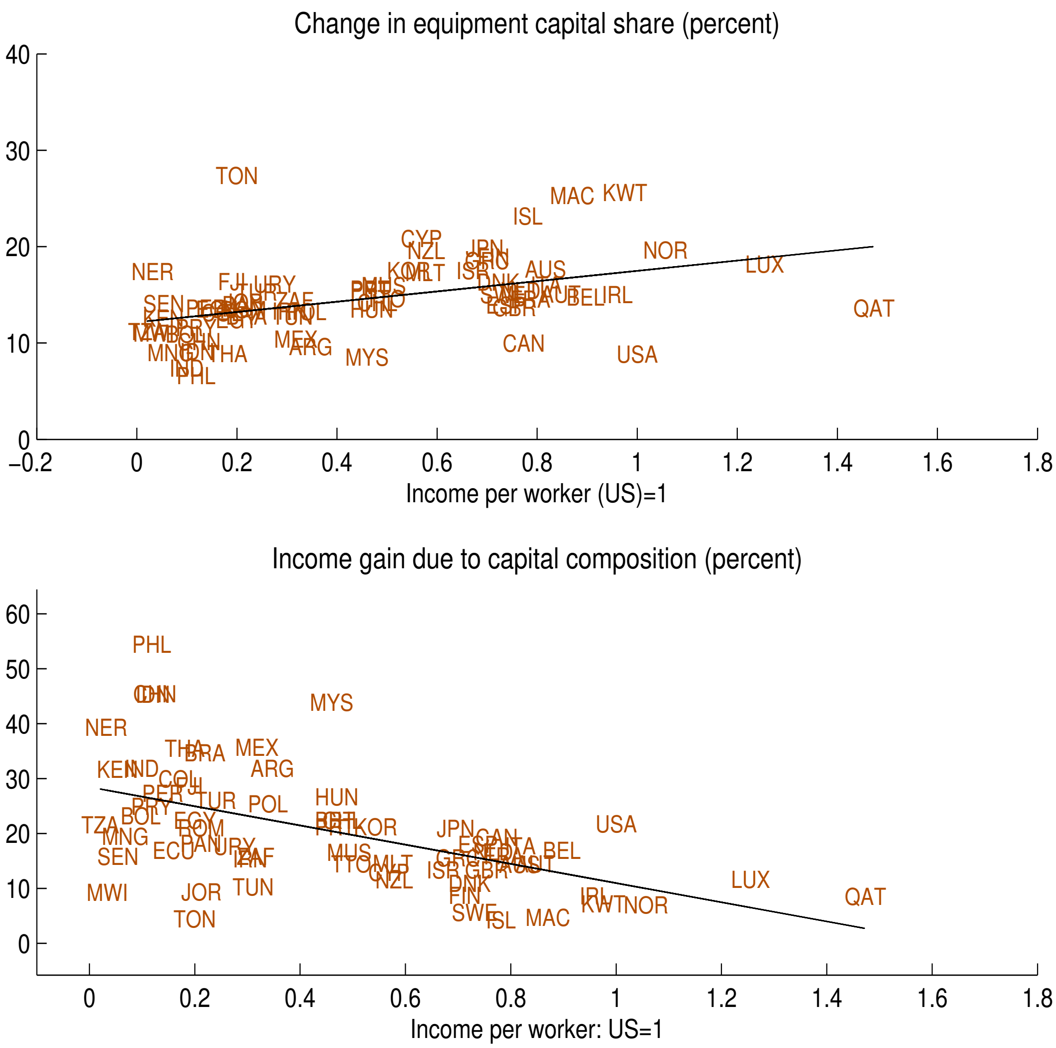
Figure 7: Autarky in equipment



The changes in equipment capital share across countries have implications for incomes. Autarky is costly for all countries. Income per worker decreases by 20 percent in the rich and 15 percent in the poor. A bulk of these losses are because of the capital composition channel. It accounts for 47 percent of the income loss in the rich and 71 percent in the poor. The contribution of the capital composition term to income change for all countries is presented in figure 7.

Zero gravity in equipment: In this experiment, I eliminate restrictions to equipment trade by setting τ_{eij}=1 for all i and j, keep other parameters at their baseline calibrated levels, and re-compute the world general equilibrium. This experiment simulates frictionless equipment trade between countries. Equivalently, since $\pi_{ii} = 1$, in this counterfactual world equipment goods flow across borders as they flow within a country. That is, if there are restrictions to goods flow within countries, similar restrictions apply to cross-border equipment trade as well. Intermediate goods trade is restricted by the calibrated levels of trade costs.

Figure 8: Zero gravity in equipment, $\tau_{eij} = 1$



With zero gravity, equipment goods are not lost in transit, and the quantity of world equipment goods increases. This leads to overall higher equipment investment levels and larger equipment capital stock, compared to the baseline. All countries experience an increase in their equipment capital share, and rich gain more than do poor. The share of equipment increases to 49 percent in the rich from 34 percent in the baseline, and the poor's equipment capital share increases from 8.4 percent to 19.3 percent. Figure 8 plots the increase in the equipment capital share. The correlation between the increase in share of equipment and income per worker is 0.43. Cross-country differences in the equipment capital share also decline. The log variance of the share of equipment reduces by 40 percent to 0.12.

With more equipment capital, income rises in all countries. Overall, income per worker increases by 18 percent in the rich and by 63 percent in the poor. Capital composition is an important channel through which equipment trade determines incomes. The change in the capital composition term accounts for 17 percent of income gain in the rich and 23 percent in the poor. The contribution of the capital composition channel for all countries is presented in figure 8. The correlation in this figure is -0.22. Thus, changes in capital composition have a larger impact on incomes in poor countries.

6.3 Discussion

Clearly, equipment trade is quantitatively important for the composition of capital. Rich benefit by producing more of their comparative advantage good and poor benefit by exchanging intermediate goods for equipment that is inefficiently produced at home. Over the years, declining costs to equipment trade have fueled the rise of equipment capital intensity in the world. If equipment trade costs had remained at their level in 1985, the average world equipment capital share would've been smaller by 4.7 percent. This is about one-fourth of the average equipment capital share in 2005.

Income per worker is highly responsive to adjustments in equipment trade costs. With the decline in equipment trade barriers, incomes rise by 8.5 percent, on average. Countries gain income either because of changes in TFP, increase in the level of capital stock or because of changes in the composition of their capital. A bulk of the income gains are channelled through changes in capital composition, especially for poor countries. The proportion of income changes stemming from changes in capital composition is 33 percent in rich and 73 percent in poor, on average. Thus, the capital composition channel is quantitatively more important for poor countries (see also, the bottom panel of figures 6, 7, and 8).

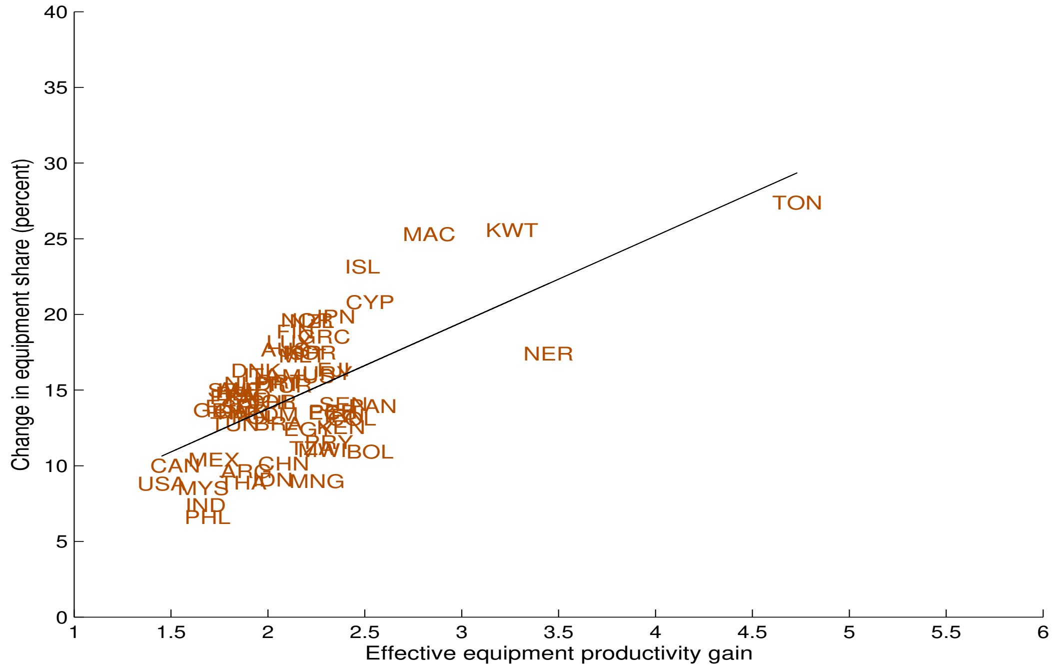
The decline in equipment trade costs also has implications for TFP levels (see equation 4). The intermediate goods export barriers faced by poor countries have a bearing on the volume of their exports and, through balanced trade, on the volume of their equipment imports. Reductions in equipment trade costs facilitate equipment investment in poor by reducing the price of equipment and easing the pressure on intermediate goods exports to finance equipment imports. With the 1985-2005 decline in τ_{eij}, poor no longer need to export as much to finance their equipment imports. Rich countries, on the other hand, increase their equipment exports and, through balanced trade, intermediate goods imports. As a result, intermediate goods home expenditure shares, π_{mii}, reduce in rich and increase in poor. This affects their TFP levels, $\left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(1-\gamma_c)}{\gamma_m}}$: TFP increases in rich countries and declines in poor countries.

The roots of income gains from equipment trade lie in what happens to *effective* equipment productivity, $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$, as the trade costs are adjusted. Equipment trade affects the composition of capital, and therefore, income through a country's equipment home expenditure share. Rich countries have higher average equipment productivity, ${\lambda_i}^{\theta}$, than poor countries. The size of a country's equipment sector is determined by its relative sectoral productivity levels. Accordingly, rich have a larger equipment sector than poor even when there is autarky in equipment. With trade, rich countries specialize in the production of equipment goods for which they have the highest idiosyncratic productivity draws, resulting in higher effective equipment productivity levels. The fall in equipment trade costs from 1985 to 2005 increases the relative size of the equipment sector, leading to lower equipment home expenditure shares and higher effective equipment productivity. This translates into larger equipment capital stocks and higher equipment capital shares in rich countries.

Poor countries, on the other hand, have less equipment in their capital stock because they are inefficient at producing equipment. In autarky, factor mobility across sectors ensures a relatively small equipment sector and, so, little equipment is produced at home. This leads to smaller equipment capital stock and lower equipment capital shares in autarky. The decline in equipment trade barriers from 1985 to 2005 reallocates resources to the production of intermediate goods that are exported to finance imported equipment. This reduces the size of the equipment sector in poor countries and their equipment home expenditure shares decline. As a result, their effective equipment productivity, equipment capital stocks, and so, equipment capital shares increase.

Figure 9 plots the 1985-2005 increases in equipment capital share along with the gains in effective equipment productivity. The baseline level of US effective equipment productivity is normalized to unity. The correlation in this figure is 0.72. That is, countries that experience larger gains in their effective equipment productivity are the ones that also witness bigger increases in their equipment capital share. From 1985 to 2005, the effective equipment

Figure 9: Equipment capital share and effective equipment productivity: 1985-2005



Note: US effective equipment productivity in baseline is normalized to one.

productivity increases by a factor of 1.7 in rich and by a factor of 1.5 in poor. The rich-poor gap in effective equipment productivity increases marginally. The analogous figures under autarky and zero gravity in equipment, figures D.5 and D.6, are in appendix D.

Overall, a reduction in equipment trade costs reallocates world resources towards more efficient outcomes and increases effective equipment productivity in all countries. The gains in effective productivity have significant implications for incomes: (i) the income gains are large for all countries, and (ii) capital composition is an important channel through which reduced equipment trade costs result in higher incomes for all countries.

Economic growth is accompanied by an equipment intensification of physical capital. Trade speeds up this process. Textbooks on economic growth and development characterize the process of economic growth by rapid capital accumulation. One key feature of rapid capital accumulation has been the rise of equipment capital intensity. Countries that gain the most from equipment trade do so not only because they accumulate more capital but also because they accumulate equipment capital at a faster rate than structures. All countries gain from reductions in equipment trade costs; poor countries gain more through the capital composition channel.

7 Conclusion

In this paper, I first examine the role of equipment trade in determining capital composition across countries. Although productivity levels are quantitatively the most important, I also unearth a non-trivial role for trade. I have argued that rich countries have a higher share of equipment in capital because they are more productive in equipment, and through equipment trade they reap efficiency gains that accompany specialization in the goods of comparative advantage. Poor countries, on the other hand, have a lower share of equipment because they are inefficient at producing equipment and face large costs to export their comparative advantage good in exchange for imported equipment. I also unearth a new quantitatively important channel through which trade affects incomes: composition of capital. Reductions in equipment trade costs alter capital composition across countries and result in income gains for all.

While my model explains capital composition and measures the impact of trade on capital composition and incomes reasonably, obviously I have not told the whole story. As noted previously, capital composition is affected by the abundance of complementary factors, a channel that is absent in my framework. Also, my framework abstracts from investment-specific technological change and cross-country differences in the quality of equipment and structures capital. Much remains to be said about implications of these for capital composition, and the role of trade in these mechanisms.

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Appendix

A Derivations

Price indices and trade shares: In this section, I derive the expressions for the price index and trade share of equipment. The expressions for the price index and trade share of intermediate goods can be derived in a similar manner. The derivations below follow the ones in Alvarez and Lucas (2007).

To derive an expression for the aggregate equipment price index, I use following properties of an exponential distribution:

1) $u \sim \exp(\psi)$ and $\kappa > 0 \Rightarrow \kappa u \sim \exp(\psi/\kappa)$.

2) $u_1 \sim \exp(\psi_1)$ and $u_2 \sim \exp(\psi_2) \Rightarrow \min\{u_1, u_2\} \sim \exp(\psi_1 + \psi_2)$.

The producers in the equipment sector minimize their costs of production. This implies the following price for each equipment good $e \in [0,1]$ that has idiosyncratic productivity of z_{ei} in country i and is produced domestically:

$$p_{eii}(e) = V_e \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha} \right)^{\gamma_e} P_{mi}^{1-\gamma_e} z_{ei}^{\theta},$$

where $V_e = (\alpha\gamma_e)^{-\alpha\gamma_e}((1-\alpha)\gamma_e)^{(\alpha-1)\gamma_e}(1-\gamma_e)^{\gamma_e - 1}$ is a collection of constant terms. Perfect competition implies that price of good e in country i, when purchased from country j, is given by:

$$p_{eij}(e) = V_e \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} z_{ej}^{\theta}.$$

Country i purchases each individual equipment good from the least cost supplier. So, the price of good e is

$$p_{ei}(e)^{1/\theta} = (V_e)^{1/\theta} \min_j \left[\left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{1/\theta} z_{ej}^{\theta} \right].$$

Since $z_{ej} \sim \exp(\lambda_{ej})$, it follows from property 1 that

$$\left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{1/\theta} z_{ej} \sim \exp\left(\left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej} \right).$$

Then, property 2 implies that

$$\min_j \left[\left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{1/\theta} z_{ej} \right] \sim \exp\left(\sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej} \right).$$

Another application of property 1 leads to:

$$p_{ei}(e)^{1/\theta} \sim \exp(\phi_{ei})$$
$$\phi_{ei} = (V_e)^{-1/\theta} \sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej} \tag{7}$$

This implies

$$P_{ei}^{1-\eta} = \phi_{ei} \int p_{ei}{}^{\theta(1-\eta)} \exp\left(-\phi_{ei} p_{ei}\right) dp_{ei}.$$

Letting $\omega_i = \phi_{ei} p_{ei}$, the above expression modifies to:

$$P_{ei}^{1-\eta} = (\phi_{ei})^{\theta(\eta-1)} \int \omega_i^{\theta(1-\eta)} \exp(-\omega_i) d\omega_i.$$

Let $U = \Gamma(1+\theta(1-\eta))^{1/(1-\eta)}$, where $\Gamma(\cdot)$ is the Gamma function. Therefore,

$$P_{ei} = UV_e \left[\sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej} \right]^{-\theta} \tag{8}$$

To derive the trade share, π_{eij}, note that π_{eij} is the fraction of country i's total spending on equipment goods that are sourced from country j. Because of the distributional assumption and the law of large numbers, this fraction is also the probability that j is a least cost supplier of equipment to i:

$$\begin{aligned} \pi_{eij} &= \Pr\left\{ p_{eij}(e) \leq \min_v \left[p_{eiv}(e) \right] \right\} \\ &= \frac{\left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej}}{\sum_v \left\{ \left(r_{ev}^{\alpha\mu} r_{sv}^{\alpha(1-\mu)} w_v^{1-\alpha} \right)^{\gamma_e} P_{mv}^{1-\gamma_e} \tau_{eiv} \right\}^{-1/\theta} \lambda_{ev}}, \end{aligned} \tag{9}$$

where I use property 2 and the following property of exponential distribution: $u_1 \sim \exp(\psi_1)$ and $u_2 \sim \exp(\psi_2) \Rightarrow \Pr(u_1 \leq u_2) = \frac{\psi_1}{\psi_1+\psi_2}$.

Equilibrium relative prices: Here, I derive the equilibrium expression for relative prices that are used in the calibration of the model: P_{ei}/P_{mi}, P_{ei}/P_{ci}, and P_{si}/P_{ci}. These derivations follow the ones in Mutreja, Ravikumar, and Sposi (2016). In equilibrium, aggregate price indices are given by:

$$P_{ei} = UV_e \left[\sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej} \right]^{-\theta}$$

$$P_{mi} = UV_m \left[\sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_m} P_{mj}^{1-\gamma_m} \tau_{mij} \right\}^{-1/\theta} \lambda_{mj} \right]^{-\theta}$$

$$P_{si} = V_s \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha} \right)^{\gamma_s} P_{mi}^{1-\gamma_s}$$

$$P_{ci} = V_c \frac{1}{A_{ci}} \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha} \right)^{\gamma_c} P_{mi}^{1-\gamma_c}$$

Using equations (8) and (9):

$$\pi_{eii} = \frac{\left\{ \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha} \right)^{\gamma_e} P_{mi}^{1-\gamma_e} \right\}^{-1/\theta} \lambda_{ei}}{(UV_e)^{1/\theta} P_{ei}^{-1/\theta}}$$

$$\Rightarrow \frac{P_{ei}}{P_{mi}} = UV_e \left(\frac{r_{ei}^{\mu} r_{si}^{1-\mu}}{w_i} \right)^{\alpha\gamma_e} \left(\frac{w_i}{P_{mi}} \right)^{\gamma_e} \left(\frac{\lambda_{ei}}{\pi_{eii}} \right)^{-\theta} \tag{10}$$

Using aggregate price of structures and final good,

$$\frac{P_{ei}}{P_{ci}} = \frac{UV_e}{V_c} A_{ci} \left(\frac{r_{ei}^{\mu} r_{si}^{1-\mu}}{w_i} \right)^{\alpha(\gamma_e - \gamma_c)} \left(\frac{w_i}{P_{mi}} \right)^{\gamma_e - \gamma_c} \left(\frac{\lambda_{ei}}{\pi_{eii}} \right)^{-\theta}$$

$$\frac{P_{si}}{P_{ci}} = \frac{V_s}{V_c} A_{ci} \left(\frac{r_{ei}^{\mu} r_{si}^{1-\mu}}{w_i} \right)^{\alpha(\gamma_s - \gamma_c)} \left(\frac{w_i}{P_{mi}} \right)^{\gamma_s - \gamma_c} \tag{11}$$

Using trade share and price index of intermediate goods,

$$\pi_{mii} = \frac{\left\{ \left(r_{ei}^{\alpha\mu} r_{si}^{\alpha(1-\mu)} w_i^{1-\alpha} \right)^{\gamma_m} P_{mi}^{1-\gamma_m} \right\}^{-1/\theta} \lambda_{mi}}{(UV_m)^{1/\theta} P_{mi}^{-1/\theta}}$$

$$\Rightarrow \frac{w_i}{P_{mi}} = (UV_m)^{-\frac{1}{\gamma_m}} \left(\frac{r_{ei}^{\mu} r_{si}^{1-\mu}}{w_i} \right)^{-\alpha} \left(\frac{\lambda_{mi}}{\pi_{mii}} \right)^{\frac{\theta}{\gamma_m}}$$

Using this in expressions (10) and (11) leads to the equations in (6).

Composition of capital: The equilibrium capital-output ratios are a function of the respective relative prices:

$$\frac{k_{ei}}{y_i} = \frac{\alpha\mu}{\frac{1}{\beta} - (1 - \delta_e)} \frac{1}{P_{ei}/P_{ci}}$$

$$\frac{k_{si}}{y_i} = \frac{\alpha(1-\mu)}{\frac{1}{\beta} - (1 - \delta_s)} \frac{1}{P_{si}/P_{ci}}$$

Using the expressions for relative prices derived above leads to the expression for capital-output ratios and equipment capital share in (3).

Income per worker: The income per worker is defined as

$$y_i = \frac{w_i}{P_{ci}} + \frac{r_{ei}}{P_{ci}} + \frac{r_{si}}{P_{ci}}$$

Using the first order conditions from firm optimization,

$$y_i = \frac{1}{1-\alpha}\frac{w_i}{P_{ci}}$$

Using the expression for price of final good, derived above, along with first order conditions from firm optimization leads to the following expression:

$$y_i = (1-\alpha)^{(1-\alpha)\gamma_c}\alpha\mu^{\alpha\mu\gamma_c}\alpha(1-\mu)^{\alpha(1-\mu)\gamma_c}V_c\ k_{ei}^{\alpha\mu\gamma_c}\ k_{si}^{\alpha(1-\mu)\gamma_c}\ \left(\frac{w_i}{P_{mi}}\right)^{1-\gamma_c}$$

Combining this with the following expression of intermediate goods home expenditure share and firm optimization first order conditions,

$$\pi_{eii} = UV_m \frac{\left(r_{ei}^{\alpha\mu\gamma_m} r_{si}^{\alpha(1-\mu)\gamma_m} w_i^{(1-\alpha)\gamma_m} P_{mi}^{1-\gamma_m}\right)^{-\frac{1}{\theta}} \lambda_{mi}}{P_{mi}^{-\frac{1}{\theta}}}$$

results in the following expression for income per worker:

$$y_i = \Lambda\, A_{ci}\left(\frac{\lambda_m}{\pi_{mii}}\right)^{\frac{\theta(1-\gamma_c)}{\gamma_m}}\ \left(k_{ei}^{\mu}k_{si}^{1-\mu}\right)^{\alpha}$$

where $\Lambda = (1-\alpha)^{-(1-\alpha)}\alpha\mu^{-\alpha\mu}\alpha(1-\mu)^{-\alpha(1-\mu)}\frac{1}{V_c}UV_m^{\theta-\frac{(1-\gamma_c)}{\gamma_m}}$ is a collection of constants.

B Data

The data set comprises prices, national accounts, production, trade, and capital stocks for a cross-section of 65 countries in 2005. The list of countries is in table C.1. This sample includes both rich and poor countries and accounts for 78 percent of world GDP in 2005.[16]

Goods categories: The goods categories here are consistent with the definitions in the System of National Accounts 1993.[17] Equipment corresponds to ISIC revision 2 categories 381-385, i.e., fabricated metal products, electrical and non-electrical machinery, transport equipment, communication equipment, office machinery, and professional and scientific equipment. ICP also identifies these as "machinery & equipment".[18] Structures include residential and non-residential buildings.[19]

Prices: Data on the price of equipment and structures are from the International Comparison Program.[20] The price of equipment corresponds to the purchasing power parity (PPP) price of "Machinery & equipment", world price equal to 1. The price of structures is the PPP price of "Construction"; world price equal to 1. For the price of final good, I use data on variable "PC" from the Penn World Tables version 6.3. The price of intermediate goods uses prices from the benchmark ICP data. It is constructed by aggregating PPP prices across all goods except durable goods and services.

The equipment and structures capital stocks employed in this paper are based on PPP data from Penn World Tables version 6.3 (see Mutreja, 2014, for details). Thus, to maintain consistency with the data on capital stocks, prices and other PPP data have been taken from Penn World Tables version 6.3.

National Accounts: Income per worker is from Penn World Tables version 6.3 (Heston, Summers, and Aten, 2009) as the variable RGDPWOK. Using real GDP per capita (RGDPL), real income per worker (RGDPWOK), and population (POP) from the Penn World Table version 6.3 (Heston, Summers, and Aten, 2009), I calculate $\frac{\text{RGDPL*POP}}{\text{RGDPWOK}}$ to arrive at data on the labor force.

[16]World GDP is computed from the Penn World Tables version 6.3 (Heston, Summers, and Aten, 2009)

[17]SNA 1993 is available at http://unstats.un.org/unsd/nationalaccount/sna1993.asp.

[18]The ICP documentation is available at http://siteresources.worldbank.org/ICPINT/Resources/270056-1255977254560/6483625-1291755426408/7604122-1363984715044/15_Chapter_14.pdf.

[19]In SNA, residential buildings but not consumer durables are considered as as part of the production boundary.

[20]ICP is available at http://siteresources.worldbank.org/ICPEXT/Resources/ICP_2011.html

Production: Data on manufacturing production is from INDSTAT4 2013, a database maintained by UNIDO (2013). This database is organized according to ISIC revision 3 classification.[21] To extract equipment production data from this database, I identify the categories in 4 digit ISIC revision 3 that correspond to categories 381-385 in ISIC revision 2. The ISIC revision 3 categories are 2811, 2812, 2813, 2893, 2899, 291*, 292*, 30**, 31**, 321*, 322*, 323*, 331*, 332*, 3420, 351*, 352*, 353*, and 3599. Intermediate goods correspond to manufactured goods other than equipment.

To have the largest country coverage possible, I supplement production data with information from more aggregated INDSTAT2 2013, which is organized at 2-digit level. Most countries are taken from the year 2005. In the case of missing data for 2005 in both INDSTAT4 and INDSTAT2, if information is available for any of the years 2000-04 and 2006 in INDSTAT4, I take data from the year closest to 2005 and convert into 2005 values by using growth rates of total manufacturing output over the same period.

Trade Flows: Bilateral trade data for 2005 is from UN Comtrade (http://comtrade.un.org). UN Comtrade data are organized according to SITC revision 2 level. In order to identify SITC revision 2 categories for equipment goods, I employ the SITC revision 2 - ISIC revision 3 correspondence in Affendy, Sim Yee, and Satoru (2010). Trade in intermediate goods corresponds to manufactured goods trade other than the trade equipment.

Trade Shares: Following Bernard, Eaton, Jensen and Kortum (2003), I construct bilateral trade shares as follows:

$$\pi_{eij} = \frac{\text{Country } i\text{'s equipment imports from country } j}{\text{Home equipment production + equipment imports from sample - equipment exports to world}}$$

Trade shares for the intermediate goods sector are constructed similarly.

Capital composition: The data on capital composition, and equipment and structures capital stocks are from Mutreja (2014).

Countries in 1985 sample: Australia, Austria, Canada, Denmark, Finland, France, Greece, Hungary, India, Iran, (Islamic Republic of), Ireland, Italy, Japan, Kenya, Luxembourg, Malawi, Mauritius, Netherlands, New Zealand, Norway, Philippines, Portugal, Republic of Korea, Spain, Sweden, Trinidad and Tobago, Turkey, United Kingdom, United Republic of Tanzania, United States of America, Portugal and Egypt.

[21] Available at http://unstats.un.org/unsd/cr/registry/regcst.asp?cl=2

C Tables

Table C.1: Productivity parameters

Country	Isocode	$\frac{\lambda_{eUS}^{\theta}}{\lambda_{ei}^{\theta}}$	$\frac{\lambda_{mUS}^{\theta}}{\lambda_{mi}^{\theta}}$	$\frac{A_{cUS}}{A_{ci}}$
Argentina	ARG	1.17	5.71	3.35
Australia	AUS	1.17	1.22	1.13
Austria	AUT	0.86	1.60	1.05
Belgium	BEL	1.16	2.55	2.24
Bolivia	BOL	2.41	9.05	1.94
Brazil	BRA	1.30	2.48	1.32
Canada	CAN	1.30	4.03	1.39
Chile	CHL	1.62	2.92	1.51
China	CHN	2.75	3.46	2.19
China (Macao SAR)	MAC	1.67	2.14	2.39
Colombia	COL	1.96	4.45	1.74
Cyprus	CYP	1.99	2.95	1.68
Denmark	DNK	0.97	1.64	1.10
Ecuador	ECU	3.77	4.67	1.95
Fiji	FJI	1.46	6.83	1.71
Finland	FIN	1.43	1.07	1.20
France	FRA	0.94	1.07	1.00
Greece	GRC	1.64	1.79	1.36
Hungary	HUN	0.96	2.69	1.12
Iceland	ISL	1.96	1.54	1.71
India	IND	1.88	3.02	1.66
Indonesia	IDN	1.97	7.00	1.88
Iran (Islamic Republic of)	IRN	2.57	3.59	1.98
Ireland	IRL	0.95	1.79	1.14
Israel	ISR	2.16	1.96	1.63
Italy	ITA	1.68	1.19	1.28
Japan	JPN	1.93	1.16	1.37
Jordan	JOR	3.26	3.92	1.99
Kenya	KEN	0.95	5.29	1.61
Luxembourg	LUX	1.02	2.14	1.90
Malawi	MWI	5.06	8.09	7.22
Malaysia	MYS	3.99	6.38	2.37
Malta	MLT	1.90	3.94	1.88
Mauritius	MUS	0.84	4.40	1.74
Mexico	MEX	0.98	4.18	1.08
Mongolia	MNG	5.88	16.76	9.06
Netherlands	NLD	0.63	2.07	1.27
New Zealand	NZL	0.89	1.38	1.07
Norway	NOR	1.33	1.02	1.34
Panama	PAN	4.86	7.03	2.48
Paraguay	PRY	1.22	7.45	1.64
Peru	PER	3.36	4.14	1.78
Philippines	PHL	2.30	7.95	2.13
Poland	POL	1.52	2.34	1.31

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Table C.1 – Continued

Country	Isocode	$\frac{\lambda_{eUS}^{\theta}}{\lambda_{ei}^{\theta}}$	$\frac{\lambda_{mUS}^{\theta}}{\lambda_{mi}^{\theta}}$	$\frac{A_{cUS}}{A_{ci}}$
Portugal	PRT	2.04	2.39	1.44
Qatar	QAT	2.47	4.01	2.43
Republic of Korea	KOR	2.94	1.64	1.84
Romania	ROM	1.62	2.79	1.52
Senegal	SEN	1.89	5.01	2.32
South Africa	ZAF	0.92	1.44	1.21
Spain	ESP	0.97	1.28	1.02
Sweden	SWE	0.59	0.89	0.88
Thailand	THA	3.69	5.55	2.24
Tonga	TON	2.29	6.66	3.05
Trinidad and Tobago	TTO	1.52	3.21	1.40
Turkey	TUR	1.69	2.05	1.40
United Kingdom	GBR	0.84	1.01	1.02
United Republic of Tanzania	TZA	2.83	5.15	2.12
United States of America	USA	1.00	1.00	1.00
Uruguay	URY	1.45	3.71	1.52
Puerto Rico	PRT	2.04	2.29	1.49
Niger	NER	1.69	7.14	1.73
Egypt	EGY	1.36	3.88	1.96
Kuwait	KWT	5.07	2.07	2.20
Tunisia	TUN	1.47	3.07	1.96

D Figures

Figure D.1: Share in world equipment production

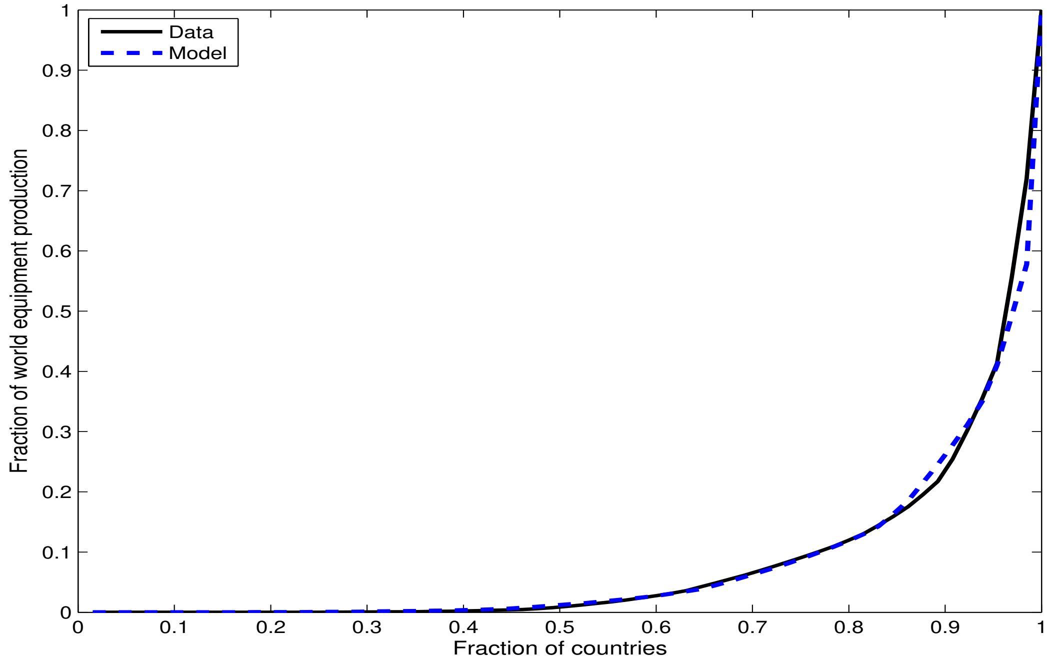


Figure D.2: Capital-output ratios (model versus data)

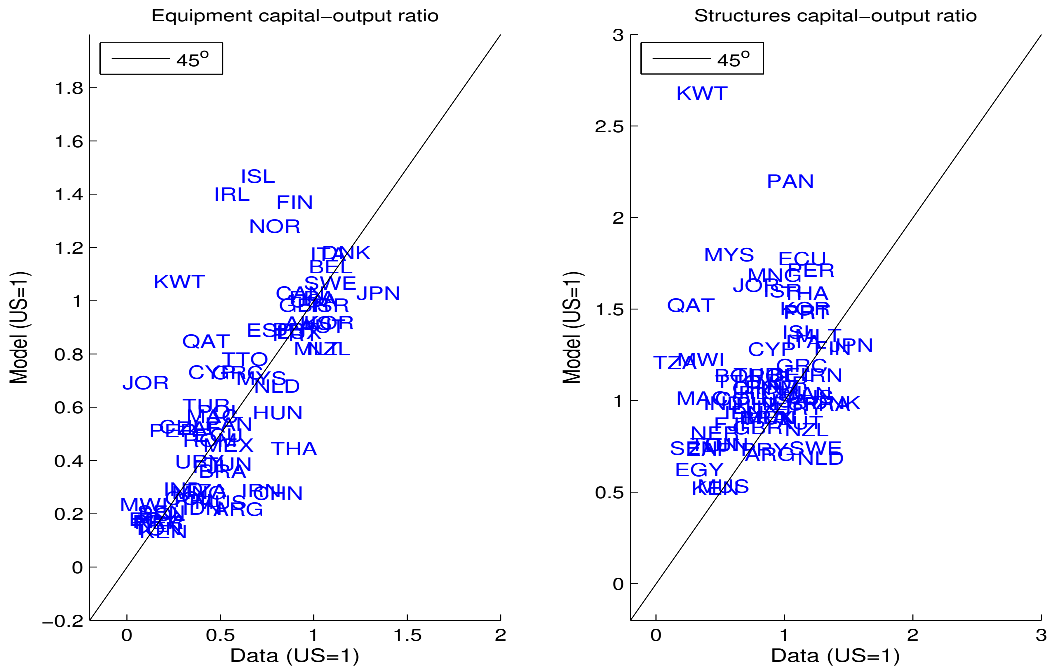


Figure D.3: Capital per worker (model versus data)

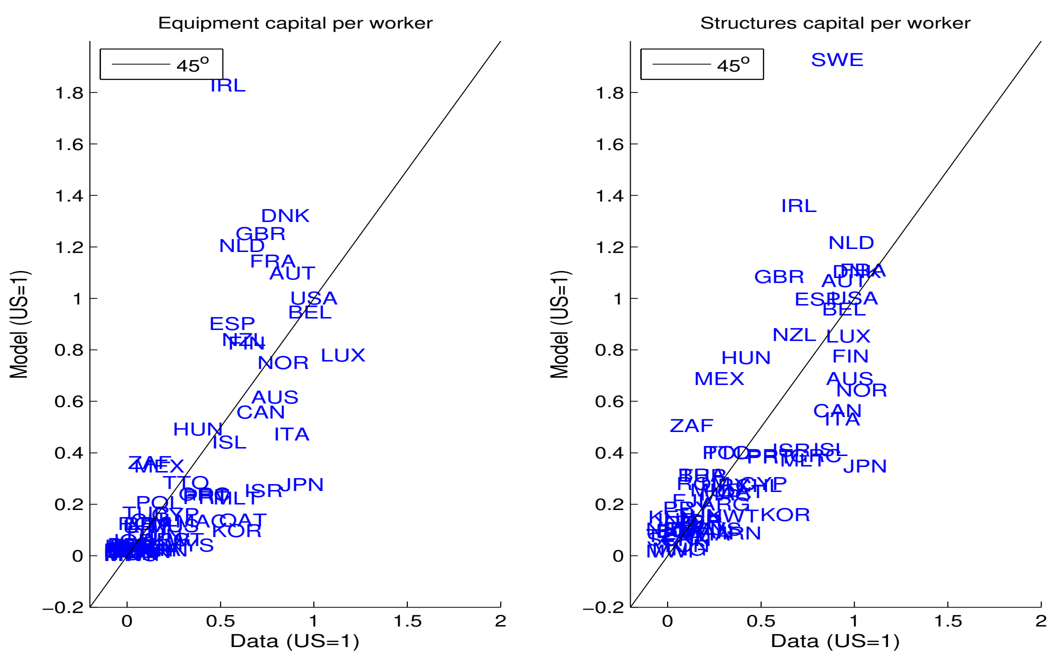


Figure D.4: World income distribution

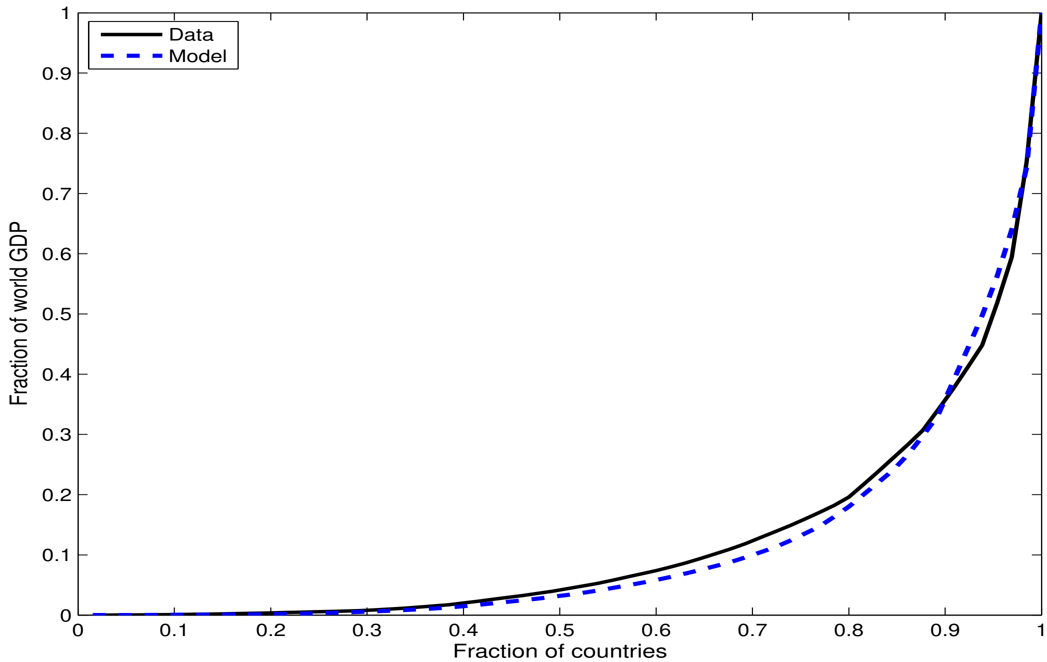
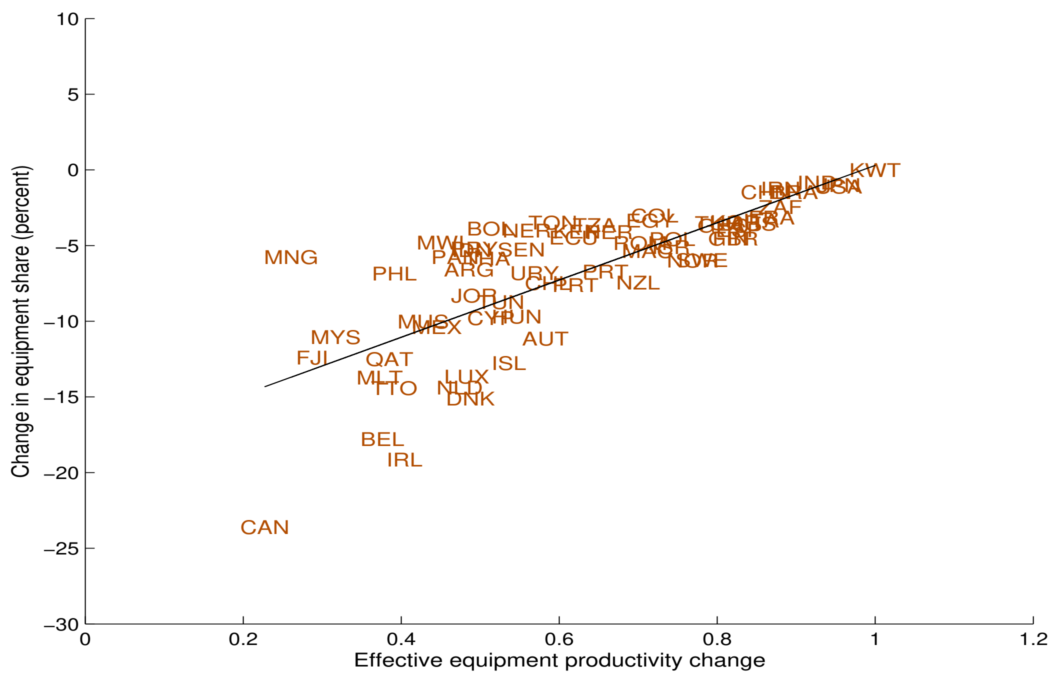
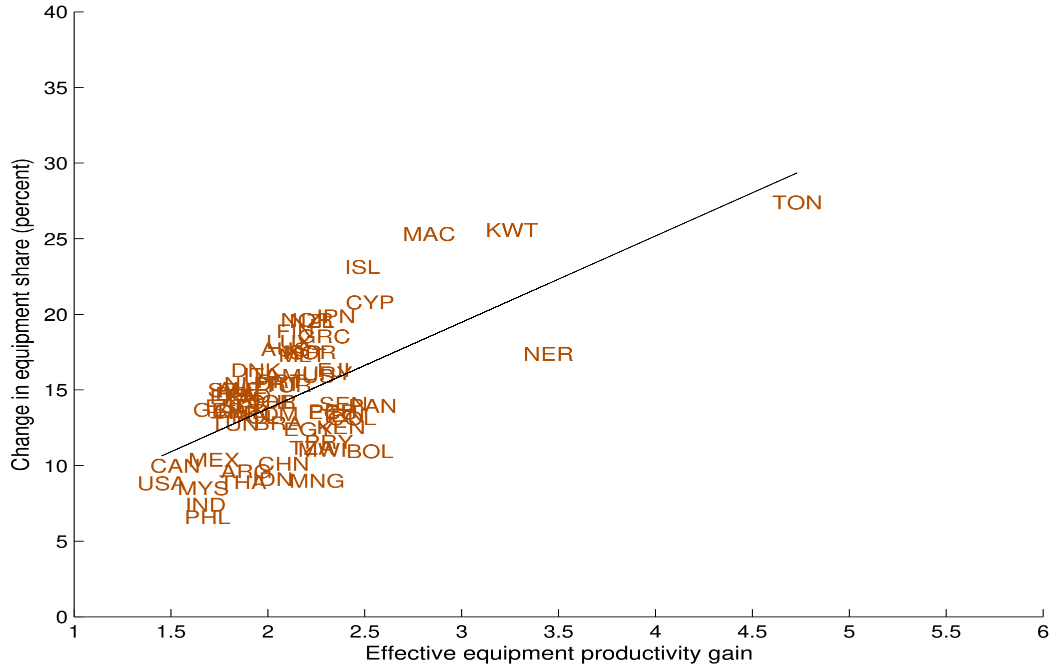


Figure D.5: Equipment capital share and effective equipment productivity: autarky in equipment



Note: US effective equipment productivity in baseline is normalized to one.

Figure D.6: Equipment capital share and effective equipment productivity: zero gravity in equipment



Note: US effective equipment productivity in baseline is normalized to one.