Composition of Capital and Gains from Trade in Equipment

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Abstract

Income differences across countries are enormous. In this paper, I quantify a novel channel through which countries gain from equipment trade: composition of capital. Over time, while the rich-poor gap in the aggregate capital-output ratio has been relatively stable, composition of capital has evolved considerably: the share of equipment has increased in rich countries and declined in many poor countries. Using a multi-country Ricardian trade model, I quantify the impact of the 1985-2005 fall in equipment trade barriers on capital composition and incomes. The decline in trade barriers accounts for approximately one-third of the changes in equipment capital shares. All countries gain income, and nearly one-half of these gains are transmitted via the capital composition channel. Poor countries benefit predominantly through the capital composition channel, and rich countries gain mostly through increases in their total factor productivity.

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1 Introduction

Income disparity across countries is enormous. One of the most robust relationships in the economic growth literature is that differences in physical capital intensity are systematically related to differences in income. This has led economists to examine the determinants of capital formation and the resulting implications for cross-country incomes. The broad consensus is that low productivity levels in poor countries are mainly responsible for low capital-output ratios and, thus, low incomes.[1] Another stylized fact is that the world equipment production is highly concentrated, and most countries import their equipment (see Eaton and Kortum, 2001). Accordingly, researchers have examined the role of equipment trade in incomes, finding that reductions in barriers to equipment trade result in large income gains.[2]

The mechanism through which lower equipment trade barriers translate into income gains is largely a black box. I dig into this black box and focus on composition of capital. Rich countries have higher equipment capital intensity than poor countries. In 2005, 21 percent of the capital in rich is in equipment, and the remainder is in structures.[3] The equipment capital share in poor is only seven percent (I use the 90th and 10th percentiles of the world income per worker distribution to represent rich and poor, respectively). Over time, while the rich-poor gap in the aggregate capital-output ratio has been relatively unchanged at approximately a factor of three, the composition of capital has changed significantly. The share of equipment has increased in rich countries, but it has declined in many poor countries. In this paper, I assess the role of equipment trade in the evolution of the composition of capital and how it affects incomes through capital composition.

Quantitatively, equipment trade is important for capital composition. The fall in equipment trade barriers during the period 1985-2005 accounts for 30 percent of the increase in the equipment capital share in rich and 32 percent in poor. This is the first contribution of this paper. With lower trade barriers, rich countries specialize in equipment and reap efficiency gains. Poor countries benefit by trading their comparative advantage good for equipment, which is inefficiently produced at home. Second, I examine the channels through which equipment trade affects incomes. The 1985-2005 fall in equipment trade costs resulted in higher incomes in all countries. I quantify a novel channel, namely capital composition, through which income gains are transmitted. The capital composition channel accounts for 35 percent of the income gain in rich and 64 percent in poor. This channel is quantitatively more important for poor countries and rich countries gain mainly through increases in total factor productivity (henceforth, TFP). To the best of my knowledge, this is the first paper that studies the role of equipment trade in the cross-country composition of capital and quantifies channels through which countries gain from trade.

[1] Restuccia and Urrutia (2001), Hsieh and Klenow (2007) and Greenwood, Sanchez, and Wang (2013) are examples.

[2] See, for instance, Eaton and Kortum (2001) and Mutreja, Ravikumar, and Sposi (2016).

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

One might argue that the *level* of capital stock, as compared to its *composition*, is more important for determining income. As noted previously, the cross-country gap in the level of the aggregate capital-output ratio exhibits little change over time, while the composition of capital has changed significantly across countries. In a standard income accounting exercise, this implies that the importance of capital composition for income has more than quadrupled over time. 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 in 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 and 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 home produced goods).

To quantify the multi-country model, I calibrate productivity levels and trade costs to match the data on relative prices and bilateral trade flows in a sample of 65 countries in 2005. The quantitative model fits calibration targets well and is also consistent with the observed cross-country differences in equipment capital share, equipment and structures capital stocks, and income. 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. Similar to Waugh (2010), poor countries face higher trade costs than rich countries to export to all destinations.

In the structural framework, the equipment capital share in a country is a function of its equipment productivity, intermediate goods productivity, and trade flows. A variance decomposition exercise implies that equipment trade flows account for 23 percent of the cross-country dispersion in the equipment capital share in 2005. Equipment productivity differences account for 50 percent, and the 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 counterfactual experiments by adjusting equipment trade costs. In the main experiment, I assess the impact of the 1985-2005 decline in equipment trade barriers. For this, I calibrate equipment trade costs in 1985 for all bilateral country pairings among the 65 countries in the 2005 sample. The average fall in equipment trade costs during the period 1985-2005 is 71 percent, with rich exporters experiencing a slightly larger decline. In the counterfactual experiment, I adjust equipment trade barriers to their level in 1985, and set other parameters at their calibrated levels in 2005. The results imply that the 1985-2005 decline in equipment trade costs increased the equipment capital share by 10 percentage points in rich and 3 percentage points in poor. Incomes, on average, increased by 8.4 percent, with poor gaining slightly more. These gains are attributable only to the 1985-2005 fall in equipment trade costs, as other parameters are set at their 2005 level.

How are the income gains from reduced trade costs transmitted? Income in my model is determined by a country's TFP, level of capital stock, and a term that captures the effect of capital composition. Capital composition is a quantitatively significant channel through which income gains are transmitted: changes in the capital composition term account for 35 percent of the income gain in rich and 64 percent in poor. While all countries gain from the reductions in trade costs, poor gain mostly through changes in the composition of capital and not per se the level. Rich countries gain via changes in their TFP and level of capital stock.[4]

The mechanics of the above income gains lie in how *effective* equipment productivity responds to adjustments in equipment trade costs via prices. The equipment sector has a continuum of goods. Intuitively, effective equipment productivity captures a country's average productivity over the subset of continuum that is produced at home. Reductions in equipment trade costs affect the relative price of equipment and lead to specialization according to comparative advantage in all countries. Rich countries specialize more in the production of those equipment goods that have the highest idiosyncratic productivity draws, and poor countries reduce the production of equipment goods with low idiosyncratic productivity draws. Owing to the declining equipment trade costs between 1985 and 2005, effective equipment productivity across countries increased by a factor of 1.4, on average. Countries that experience larger gains in effective equipment productivity benefit most via the capital composition channel.

The importance of equipment capital for economic growth is well known. A growing body of research quantifies the role of equipment trade in economic growth and related outcomes.[5] Technological improvements are often embodied in improved equipment (see, for instance, Greenwood, Hercowitz, and Krusell, 1997), they tend to be skill-biased and so, exhibit capital-skill complementarity (see, for instance, Krusell et al., 2000). 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 the trade costs lead to large gains in economic well-being, but the literature is relatively silent on the transmission mechanisms

[4]TFP is partially endogenous and depends on the trade flows.

[5]See, for example, Eaton and Kortum (2001), Burstein, Cravino, and Vogel (2013), Parro (2013), and Raveh and Reshef (2016).

for these gains. I assess the channels through which these gains are transmitted.

The literature on the 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. Bems (2008) presents facts on investment in tradable and non-tradable goods but does not shed light on the determinants of disaggregate investment levels.

This paper relates to the section of the 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 12.5 percent of the income differences. Contrary to Eaton and Kortum (2001), capital stocks and capital composition are endogenous in my model. I find that from 1985 to 2005, on average, approximately one-half of the income gains from reduced equipment trade costs were transmitted through the capital composition channel.

My paper is related to parallel research in Mutreja, Ravikumar, and Sposi (2016): the main distinctions are the question and the quantitative results. Mutreja, Ravikumar, and Sposi (2016) construct a multi-country Ricardian model of trade in which equipment trade affects incomes through capital formation and TFP. While the theoretical setup is similar in both the papers, this paper builds on Mutreja, Ravikumar, and Sposi (2016). Using recent data on capital composition, I separate the effect of composition of capital from its level and quantify a novel channel for the transmission of gains from equipment trade. Poor countries gain mostly through the capital composition channel, while rich reap income gains via increases in their TFP and level of capital stock.

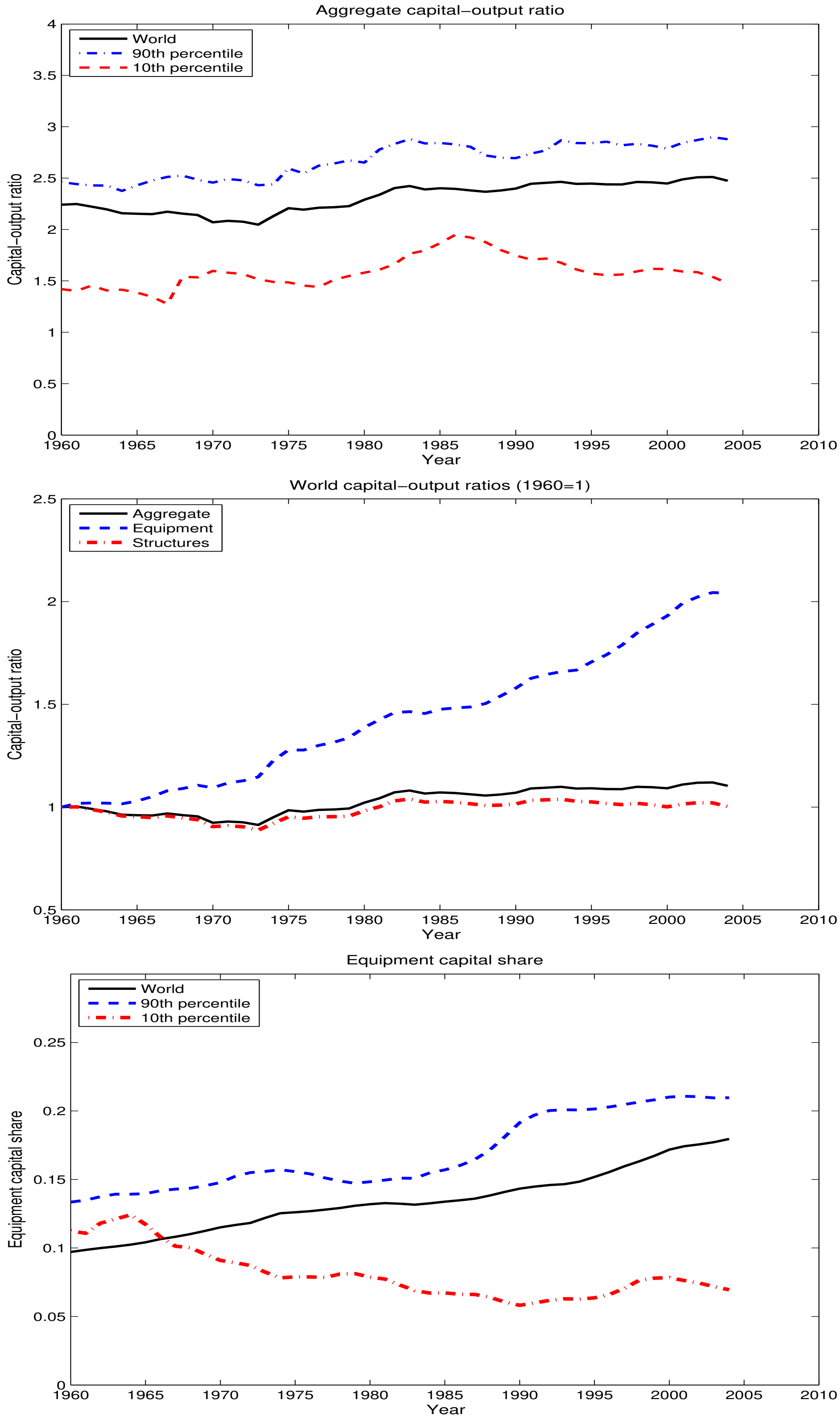
2 Motivating facts

Why should we focus on the composition of capital? In this section, I present the 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, for details).

The top panel in figure 1 plots the aggregate capital-output ratios over time for the world, the 90th percentile country (representative rich) and the 10th percentile country (representative poor).[6] The facts presented in this figure are already well known. Over time the aggregate capital-output ratios show little upward movement and have been essentially flat. As a result, the gap in capital-output ratios between rich and poor has been relatively stable: the 90th to 10th percentile ratio falls in the range 3-4, though this gap has slightly widened in the recent years.

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

Figure 1: Capital and its composition



The picture looks different when we decompose the 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 have experienced a decline instead of an increase in their equipment capital shares. The bottom panel of figure 1 plots the equipment capital shares in the world, the representative rich country and the representative poor country. From 1960 to 2005, the equipment capital share increased by 84 percent in rich and declined by 36 percent in poor. A majority of rich and poor countries exhibit this pattern. For instance, during this time period the equipment capital share more than tripled in the US and it nearly doubled in Luxembourg. In Niger, equipment capital share decreased by 65 percent and in Gambia, it decreased by 44 percent. Countries growing at high rates experience episodes of steep rise in their equipment capital shares. Between 1960 and 1990, Korea's structural transformation coincided with a growth of its equipment capital share by 264 percent and since 1980, China's manufacturing growth has accompanied a near doubling of its equipment capital share.

Thus, while cross-country gap in the level of aggregate capital-output ratio has been stable over the years, the composition of capital has changed substantially. Are these changes in composition important for income 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 cross-country log variance in income per worker in 2005. The remaining 77.5 percent of the log variance is due to differences in h_i and residual TFP.

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 income 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.[7] 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 to income by 25 percent. Thus, composition differences are responsible for one-quarter 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 the 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. That is, differences in capital composition matter, much more now than they used to 30 or so years ago.

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 the observed capital-output ratios but it fails to produce the observed differences in capital composition.[8] 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. 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. In the next section, I describe a multi-country trade model that I use to study the role of equipment trade in determining capital composition and assess the 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.

[7] k_{ei} and k_{si} are measured in PPP with US GDP as numeraire.

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

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 later):

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

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.[9]

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.

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 $t = 0, 1, ..., \infty$:

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

[9] 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.

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

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

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):

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

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:

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

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.

Equipment trade affects equipment capital share (and capital composition) through the equipment home expenditure share, π_{eii}. Reductions in the equipment trade barriers change the relative price of equipment faced by various countries and alter the cross-country pattern of specialization. To see this, recall that the equipment sector has a continuum of goods along the unit interval. A fraction of the continuum for which a country has the highest productivity draws, π_{eii}, is produced at home and the remainder, 1-π_{eii}, is imported. Reductions in the equipment trade costs increase specialization and decrease the home expenditure share. $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$ can be interpreted as a country i's effective productivity in the equipment sector: it measures the average productivity over the subset of continuum that is produced at home. Increases in specialization increase this effective equipment productivity.

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. This paper focusses on the capital composition term. 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.[10] 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 than the equipment. The final good sector corresponds to all non-traded goods other than investment structures.

Common Parameters: 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).[11] They calibrate a model of investment-specific technological change to data on the

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

[11] 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.

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).[12]

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.[13] 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.

[12] 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 $\theta_m = 0.25$.

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

Equipped with all the calibrated parameters, when I compute the 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:[14]

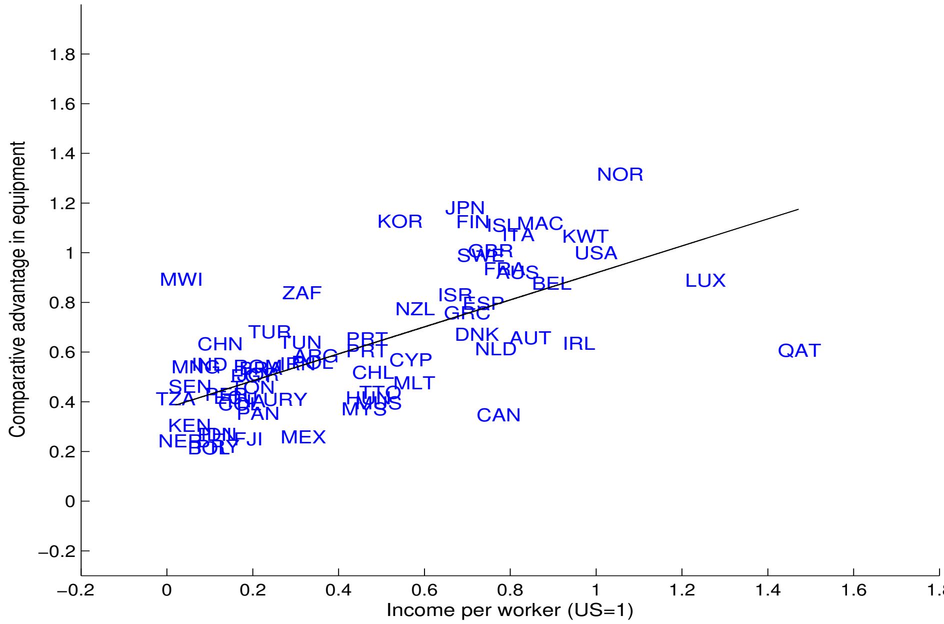
$$
\begin{aligned}
\frac{P_{ei}}{P_{mi}} &= W_m \left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{-\theta} \left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta\gamma_e}{\gamma_m}} \\
\frac{P_{ei}}{P_{ci}} &= W_e \, A_{ci} \left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{-\theta} \left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(\gamma_e-\gamma_c)}{\gamma_m}}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

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 productivity. The 90-10th percentile ratio of λ_e^θ is 3.54 and that of λ_m^θ is 0.87. That is, 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.

[14] 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.

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 shares from the model against those in the data, and table 1 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 countries. The observed share of equipment in the 90th percentile country is 21 percent. 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 1: Equipment share in capital

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

Equipment and structures capital stocks: The quantitative model matches the 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 the model and data distribution for both kinds of capital is 0.99. That is, 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 5.9 between rich and

Figure 3: Equipment share in capital

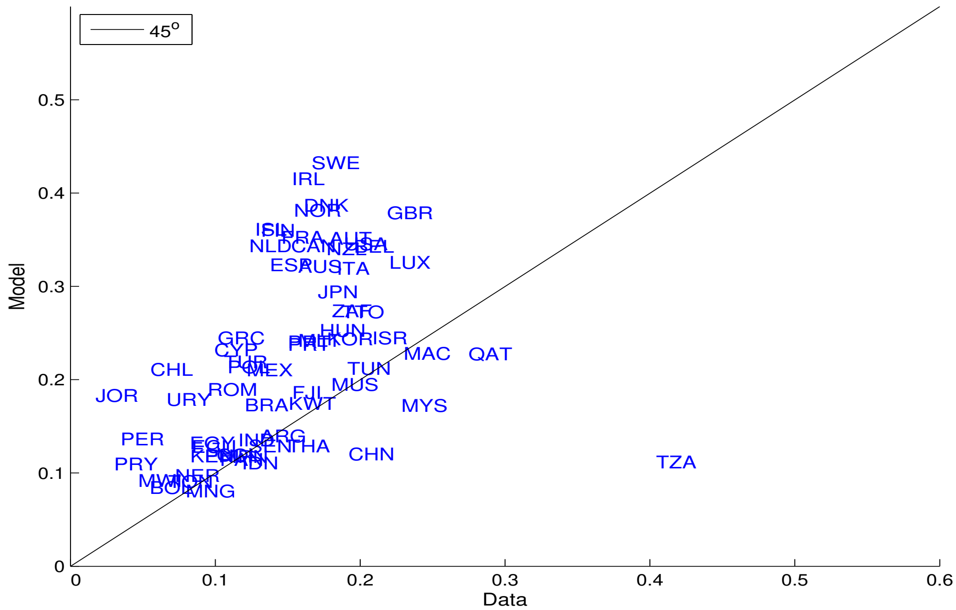
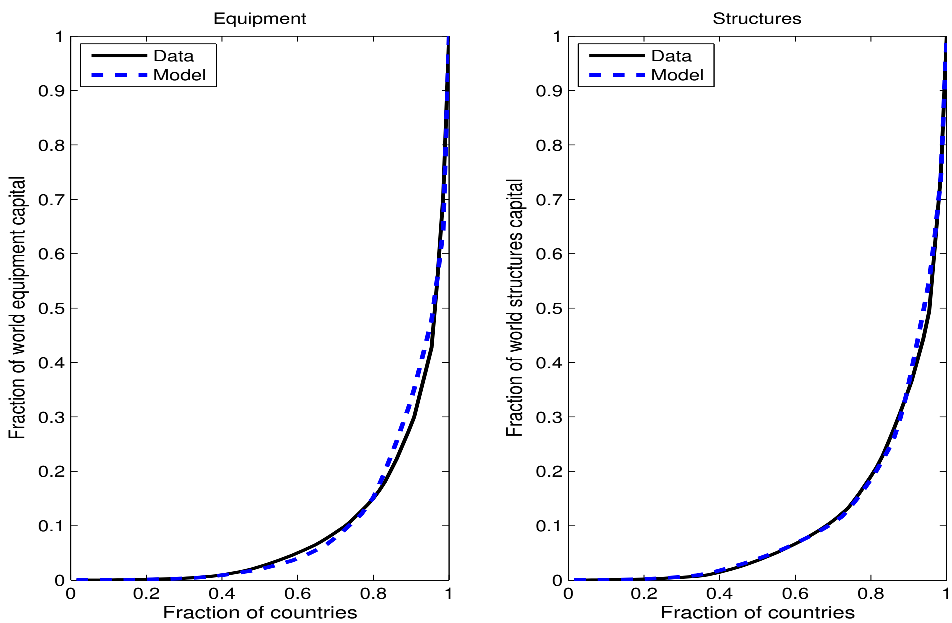


Figure 4: Cross-country distribution of capital



poor in the data and 5.7 in the model. The 90th-10th percentile ratio of structures capital-output ratio is 1.7 in the data and 1 in the model. Figure D.3 in appendix D presents the equipment and structures capital per worker from the model and data. The 90th-10th percentile ratio of equipment capital per worker is 54.1 in the data and 58.6 in the model. The corresponding ratio for structures capital per worker is 15.2 in the data and 10.3 in the model.

Income per worker: The calibrated model is also consistent with the 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 10.3. 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 1.3 in the model and 0.96 in the data.

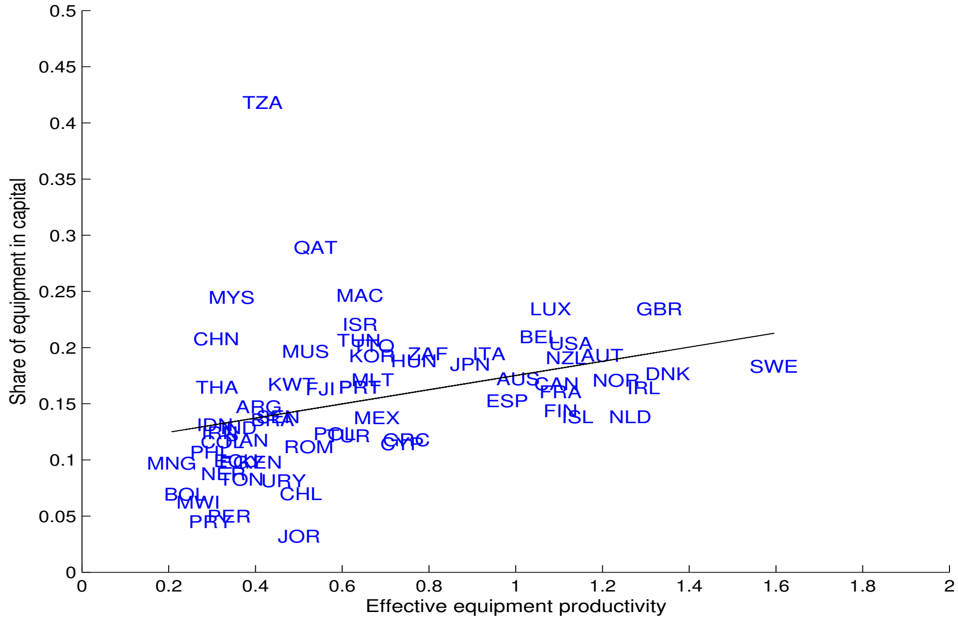
Implications: In the model, the equipment capital share in a country is a function of its productivity levels and trade flows. I use this relationship to evaluate the role of equipment trade in determining the cross-country capital composition. The differences in the equipment capital share are entirely due to the 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 ${\pi_{eii}}^{\theta}$.[15] 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, the variation in equipment productivity accounts for 52.6 percent. The equipment home expenditure share captures the impact of equipment trade flows and accounts for 22.7 percent of the total log variance. In no way, this is small. The remaining 24.7 percent is accounted for by intermediate goods productivity and home expenditure shares.

Another way to interpret this variance decomposition is through the effective equipment productivity, $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$. The effective equipment productivity accounts for over three-fourths of the cross-country variation in the equipment capital share. Figure 5 plots the 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 (lowering π_{eii}) 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 the 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

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

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



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

The concurrent rise in the world equipment capital intensity and equipment trade volumes has been facilitated, in part, by the declining trade costs. Equipment trade costs affect the prices faced by poor countries versus rich countries and, thus, govern the equipment-structures investment tradeoff. What is the role of declining equipment trade costs in the evolution of equipment capital shares and incomes across countries? What are the channels through which reductions in equipment trade costs lead to income gains?

To answer these questions, I conduct counterfactual experiments. In the main experiment, I focus on the fall in equipment trade costs between 1985 and 2005. The choice of 1985 is for three reasons: (i) the income accounting exercise in section 2 indicates that capital composition began to play an important role in income in the 1980s, (ii) during the early 1980s, investment and trade data exhibit after-effects of the 1970s oil price shocks, and (iii) during 1980s, the ICP benchmark data on price of equipment (required for calibrating the equipment trade costs) is available only for 1985. So, I choose 1985 as the starting year of the time period under consideration.

To measure the fall in equipment trade barriers during the period 1985-2005, I require bilateral equipment trade costs, τ_{eij}, for 1985. To calibrated these, I employ the methodology from section

4 (see equation 5).[16] Construction of trade shares for 1985 requires the data on production and bilateral trade volumes. These along with the data on equipment prices are available for a sample of 32 countries only.[17] I calibrate τ_{eij} for all bilateral pairings among 32 countries and calculate the average equipment trade cost for each exporter in 1985.[18] 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. Regressing this average fall in equipment export cost on income per worker for 32 exporters, I impute the average fall in equipment trade cost (denoted by $\widehat{\rho}_{ej}$) for all 65 exporters countries in the 2005 sample. Employing $\widehat{\rho}_{ej}$ 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 and τ_{eij} is the baseline calibrated value of equipment trade cost in 2005. That is, 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 over time the equipment trade costs have declined in all countries, but poor countries continue to face higher costs to export. Between 1985 and 2005, the equipment trade costs fell by 74 percent in rich countries and by 68.6 percent in poor countries, on average. In 1985, the average equipment export cost for poor was 11.6 times the export cost in rich. In 2005, the corresponding ratio was only marginally higher at 11.9.

To conduct the experiment, I set the bilateral equipment trade costs at their 1985 levels, i.e., $\tau_{eij} = \widehat{\tau}_{eij}^{1985}$. Other parameters, viz., common parameters, equipment productivity, λ_{ei}^{θ}, intermediate goods productivity and trade costs, λ_{mi}^{θ} and τ_{mij}, and final good productivity, A_{ci}, are set at their calibrated baseline levels in 2005. 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. While in reality, productivity parameters and intermediate goods trade costs also differ between 1985 and 2005, these differences have been shut down to shed light on the role played by the decline in equipment trade costs only.

The results from the experiment are summarized in tables 2 and 3. First row in table 2 presents percentage points increases in the equipment capital share attributable to the decline in equipment trade barriers between 1985 and 2005. Left panel of table 3 presents the associated income gains. Right panel of this table shows the significance of the capital composition channel: the proportion

[16] The data on average equipment tariffs is not available for most countries, so I estimate equipment trade costs that are consistent with the pattern of trade flows and prices.

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

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

Table 2: Change in equipment capital share relative to the baseline (percentage points)

	Rich	Poor	Overall avg.
1985 – 2005	10.3	2.7	4.7
Equip. autarky	-17.8	-3.9	-6.9
Equip. zero gravity	14.7	10.9	14.7

Table 3: Income gain/loss and contribution of the capital composition channel (percent)

	Change in income per worker			Fraction due to capital composition channel		
	Rich	Poor	Overall avg.	Rich	Poor	Overall avg.
1985 – 2005	12.5	10.2	8.4	35.1	64.2	45.1
Equip. autarky	-20.3	-14.6	12.3	46.9	70.9	49.1
Equip. zero gravity	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.

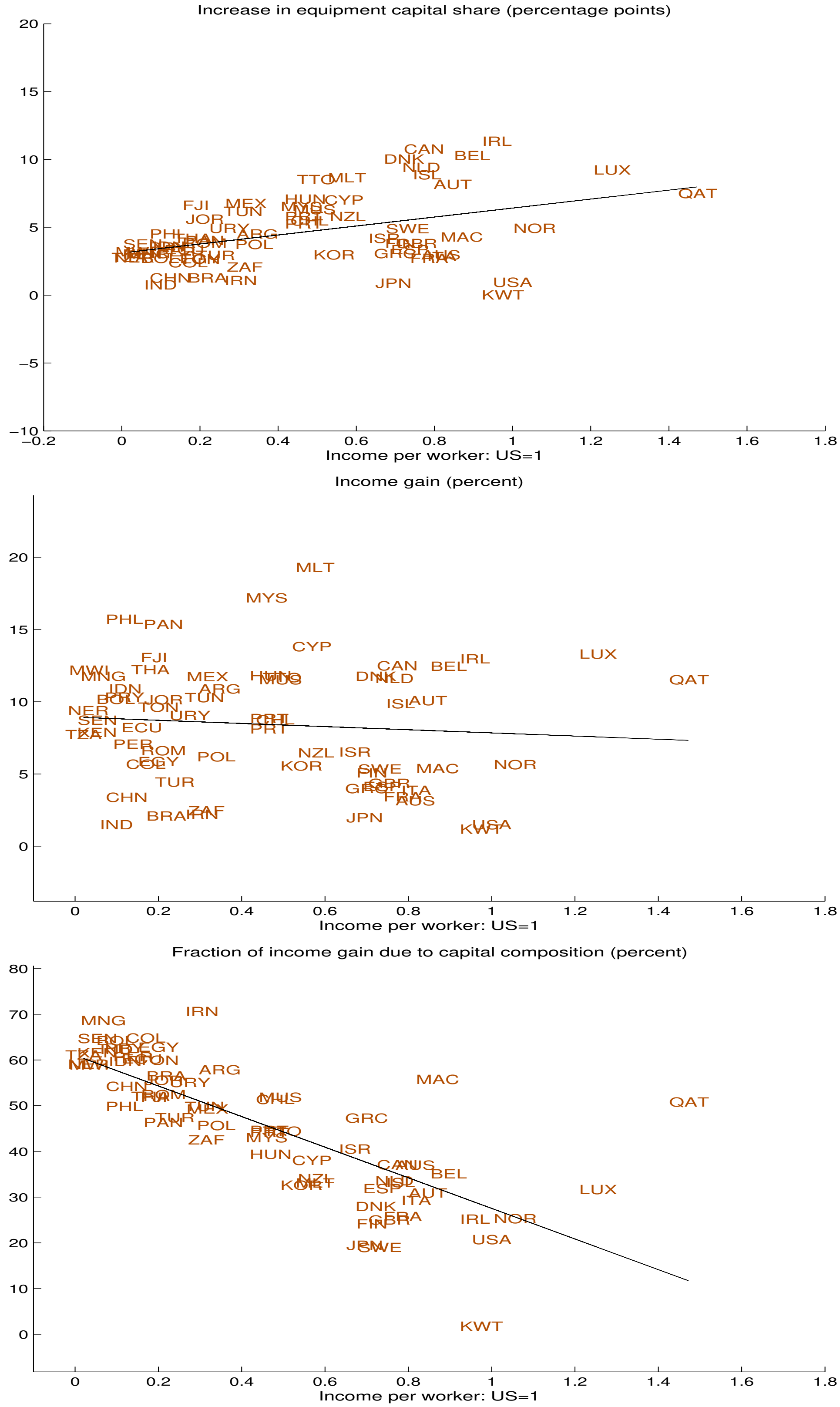
of income gains that accrue to countries due to the changes in capital composition term. These tables also report results from the experiments of autarky and zero gravity in equipment, which are discussed later.[19]

As equipment trade barriers fall, rich countries 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 increases in rich countries. Poor countries also gain. With the fall in barriers to import equipment, equipment becomes relatively less expensive and so, the investment in equipment rises. This increases the equipment capital share in poor countries. The top panel of figure 6 plots the percentage points gain in the equipment capital share associated with the 1985-2005 equipment trade cost decline. Cross-country differences in the equipment capital share also decline with the reductions in equipment trade costs: the log variance of equipment capital share is 0.29 in the counterfactual world and 0.22 in the baseline.

Income per worker is highly responsive to adjustments in the equipment trade costs. Average income per worker gain attributable to the 1985-2005 reduction in equipment trade barriers is 8.4 percent, with poor gaining slightly more (correlation in the middle panel of figure 6 is -0.09). 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 (see equation 4). The decline in equipment trade costs has implications for TFP levels. 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 the equipment trade costs facilitate equipment investment in poor by reducing the price of equipment and easing the pressure on intermediate goods

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

Figure 6: Declining equipment trade costs: 1985 to 2005



exports to finance equipment imports. With lower 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, $\left(\frac{\lambda_{mi}}{\pi_{mii}}\right)^{\frac{\theta(1-\gamma_c)}{\gamma_m}}$. From 1985 to 2005, TFP increased in rich countries and declined in poor countries.[20]

Discussion: Clearly, equipment trade is quantitatively important for the composition of capital and incomes. Rich countries benefit by producing more of their comparative advantage good and poor countries gain 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 the equipment trade costs had remained at their level in 1985, the average world equipment capital share in 2005 would have been smaller by 4.7 percentage points. This is about one-third of the average equipment capital share in 2005. The rise of equipment capital intensity, in turn, has contributed to the increases in income.

What are the channels through which the income gains from reduced rate barriers are transmitted? As equipment trade costs change, so does a country's capital composition term due to the change in its equipment capital share. This changes the income per worker. A large fraction of the income gains stem from changes in the composition of capital (table 3). The capital composition channel accounts for nearly one-half of the average income gains attributable to declining equipment trade costs during the period 1985-2005. Thus, capital composition channel is quantitatively important.

A key finding is that poor countries accrue income gain mostly through the capital composition channel and rich countries gain via increases in TFP and the level of capital. The capital composition channel accounts for 64 percent of the income gain in poor and 35 percent in rich. The remainder of the respective gains are due to changes in TFP and the level of capital. The significance of capital composition channel is systematically related to a country's income level: the contribution from this channel increases by 0.31 percent for every one percent decline in the income level across countries (see table 4). The bottom panel in figure 6 plots the contribution of the capital composition channel (in percentage terms) against income per worker. The correlation in this figure is -0.76.[21]

The roots of the income gains from equipment trade lie in what happens to *effective* equipment

[20] Karabarbounis and Neiman (2013) present evidence that the global labor share has declined by 5 percent since the 1980s. To ascertain the sensitivity of results in this paper to the declining labor share, in an alternative experiment I adjust the share of labor by 5 percent, while setting the equipment trade costs at their 1985 level. Rest of the parameters are set at their 2005 level. The results from this experiment are qualitatively similar to the those in tables 2 and 3.

[21] Deaton and Aten (2017) estimate that the consumption PPPs in 2005 ICP are overpriced by 18-26 percent relative to the US for certain poor countries. In my paper, trade costs affect capital composition (and income) via relative prices. If the extent of over-pricing in case of equipment and structures is similar or more relative to that of consumption, then the significance of capital composition channel would be largely unaffected (and likely strengthened if the latter is true). If over-pricing is less, the quantitative magnitudes would be dampened, though I expect that the capital composition will continue to be a significant channel for the transmission of income gains.

Table 4: Significance of capital composition channel
(dependent variable: percentage of income gain because of capital composition channel)

	1980-2005	Equip. autarky	Equip. zero gravity
Income per worker	-0.31	-0.31	-0.27
	(0.05)	(0.06)	(0.07)
Intercept	3.39	3.46	2.55
	(0.08)	(0.09)	(0.10)
R-square	0.33	0.29	0.21
No. of countries	65	65	65

Note: All variables are in logs. All coefficients are significant at the 1 percent level. Standard errors are shown in parentheses.

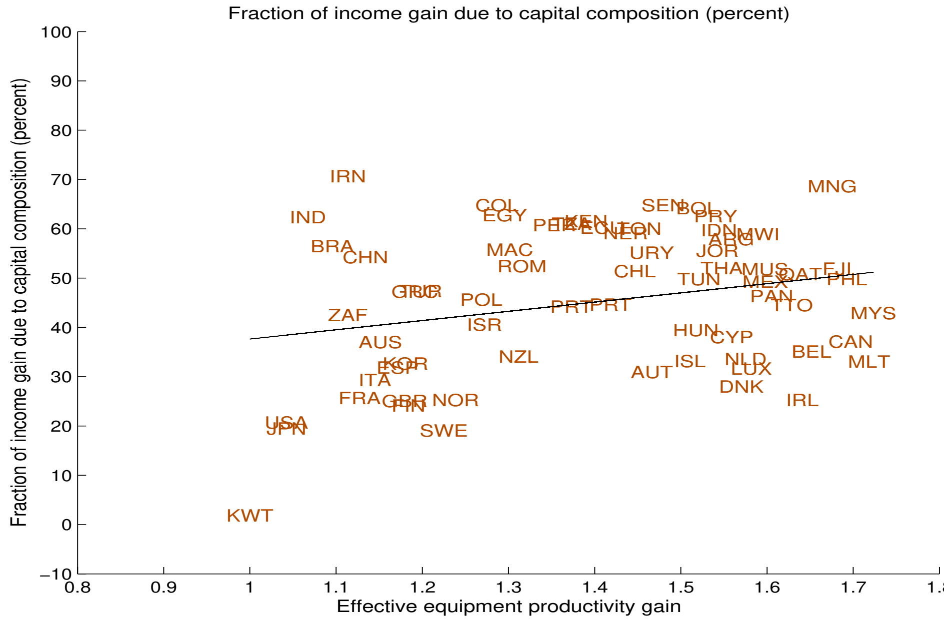
productivity, $\left(\frac{\lambda_{ei}}{\pi_{eii}}\right)^{\theta}$, as the trade costs are adjusted. Rich countries have higher average equipment productivity, λ_i^{θ}, than poor countries. The size of a country's equipment sector is determined by its relative sectoral productivity levels. Equipment trade affects the composition of capital, and therefore, income through a country's equipment home expenditure share. With reductions in the equipment trade costs, rich countries specialize in equipment goods with the highest productivity draws. This reduces their equipment home expenditure shares, leading to higher effective equipment productivity levels. This translates into larger equipment capital stocks and higher equipment capital shares in rich countries.

Poor countries, on the other hand, are inefficient at producing equipment. With trade, poor countries can exchange their comparative advantage good to access equipment. A fall in equipment trade barriers from the baseline 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 equipment capital shares increase.

Figure 7 plots the significance of the capital composition channel along with the gains in effective equipment productivity attributable to the 1985-2005 fall in τ_{eij}. The level of US effective equipment productivity in 2005 is normalized to unity. The correlation in this figure is 0.26. That is, countries that experience larger gains in their effective equipment productivity are the ones that also witness bigger income gains through changes in capital composition. From 1985 to 2005, the effective equipment productivity increased by a factor of 1.7 in rich and 1.5 in poor. The rich-poor gap in effective equipment productivity increased marginally.

Overall, a reduction in the equipment trade costs reallocates world resources towards more efficient outcomes and increases effective equipment productivity in all countries. The gains in effective equipment 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.

Figure 7: Capital composition channel and effective equipment productivity gain: 1985-2005



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

Economic growth is accompanied by an equipment intensification of the 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 the rapid capital accumulation has been the rise of the 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 the reductions in equipment trade costs; poor countries gain more through the capital composition channel.

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

In the absence of equipment trade, rich countries reduce specialization in their comparative advantage good as they divert resources to their relatively inefficient intermediate goods sector. Less equipment is produced at home and, so, the investment in equipment capital declines. As a result, the equipment capital share in the rich falls relative to the baseline (table 2). Poor countries are also adversely affected. With equipment autarky, they can no longer access the equipment that is produced in rich countries and the composition of their capital is determined by the domestic equipment productivity levels only. Factor mobility across sectors ensures a relatively small equipment sector and, so, little equipment is produced at home. Consequently, the equipment capital shares reduce to about one-half in both rich and poor countries. Figure D.5 in appendix D plots the fall in equipment shares because of autarky in equipment. The cross-country differences in equipment capital share also increase as the log variance of equipment's share nearly doubles to 0.39.

The changes in equipment capital share have implications for incomes: autarky is costly for all countries (table 3). A bulk of the income losses are because of the capital composition channel and this channel continues to be more important for poor countries. The figures on the significance of the capital composition channel and equipment effective productivity are in appendix D.

Zero gravity in equipment: In this experiment, I eliminate the 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, in this counterfactual world, the equipment goods flow across borders as they flow within a country (since $\pi_{ii} = 1$). That is, if there are restrictions to goods flow within countries, similar restrictions apply to cross-border equipment trade as well. The intermediate goods trade is restricted by the calibrated levels of trade costs.

With zero gravity, equipment goods are not lost in transit, and the quantity of world equipment goods increases. This leads to higher equipment investment levels and equipment capital stocks, compared to the baseline. The equipment capital share rises in all countries, and rich gain more than do poor. Figure D.6 in appendix D plots the increases in the equipment capital share from this experiment. The correlation between the increase in equipment's share 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. Capital composition is an important channel through which equipment trade determines incomes. The contribution of the capital composition channel is presented in figure D.6. This channel is more important for poor countries: the correlation in figure D.6 is -0.22 (see appendix D for the figure on equipment effective productivity gain in this experiment).

7 Conclusion

In this paper, I first examine the role of equipment trade in determining capital composition across countries and 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 quantify a new channel through which trade affects incomes: composition of capital. Reductions in the equipment trade costs alter capital composition across countries and result in income gains for all. Poor countries gain predominantly via the capital composition channel and rich countries gain through increases in their TFP and the level of capital.

While my model 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 the investment-specific technological change and cross-country differences in the quality of equipment and structures capital. Much remains to be said about the 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:

$$p_{ei}(e)^{1/\theta} \sim \exp(\phi_{ei})$$

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

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:

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

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:

$$\begin{aligned} P_{ei} &= UV_e \left[\sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_e} P_{mj}^{1-\gamma_e} \tau_{eij} \right\}^{-1/\theta} \lambda_{ej} \right]^{-\theta} \\ P_{mi} &= UV_m \left[\sum_j \left\{ \left(r_{ej}^{\alpha\mu} r_{sj}^{\alpha(1-\mu)} w_j^{1-\alpha} \right)^{\gamma_m} P_{mj}^{1-\gamma_m} \tau_{mij} \right\}^{-1/\theta} \lambda_{mj} \right]^{-\theta} \end{aligned}$$

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

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.[22]

Goods categories: The goods categories here are consistent with the definitions in the System of National Accounts 1993.[23] 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".[24] Structures include residential and non-residential buildings.[25]

Prices: Data on the price of equipment and structures are from the International Comparison Program.[26] 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.

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.[27] 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

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

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

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

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

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

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

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.

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
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

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Table C.1 – Continued

Country	Isocode	$\frac{\lambda_{eUS}^{\theta}}{\lambda_{ei}^{\theta}}$	$\frac{\lambda_{mUS}^{\theta}}{\lambda_{mi}^{\theta}}$	$\frac{A_{cUS}}{A_{ci}}$
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

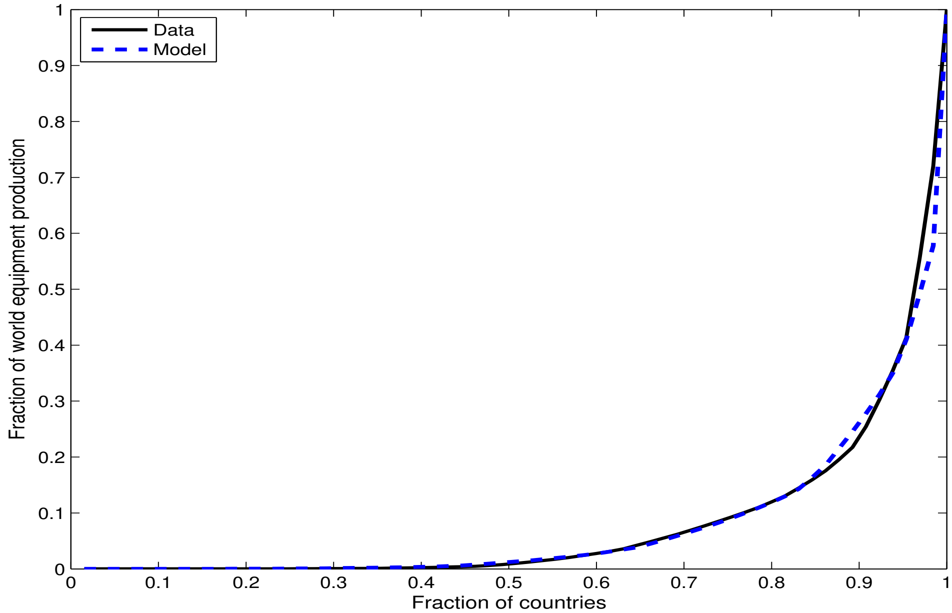


Figure D.2: Capital-output ratios (model versus data)

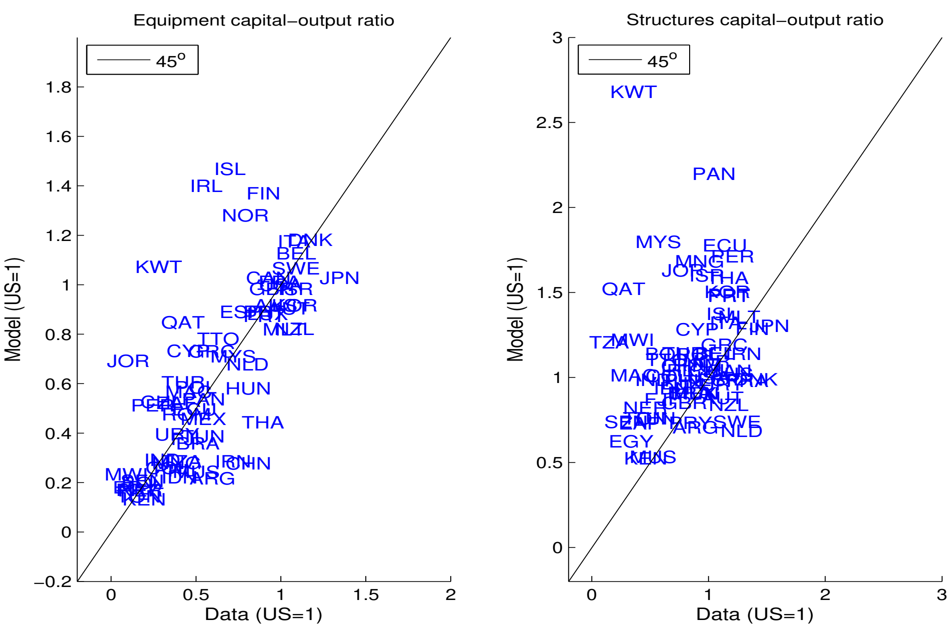


Figure D.3: Capital per worker (model versus data)

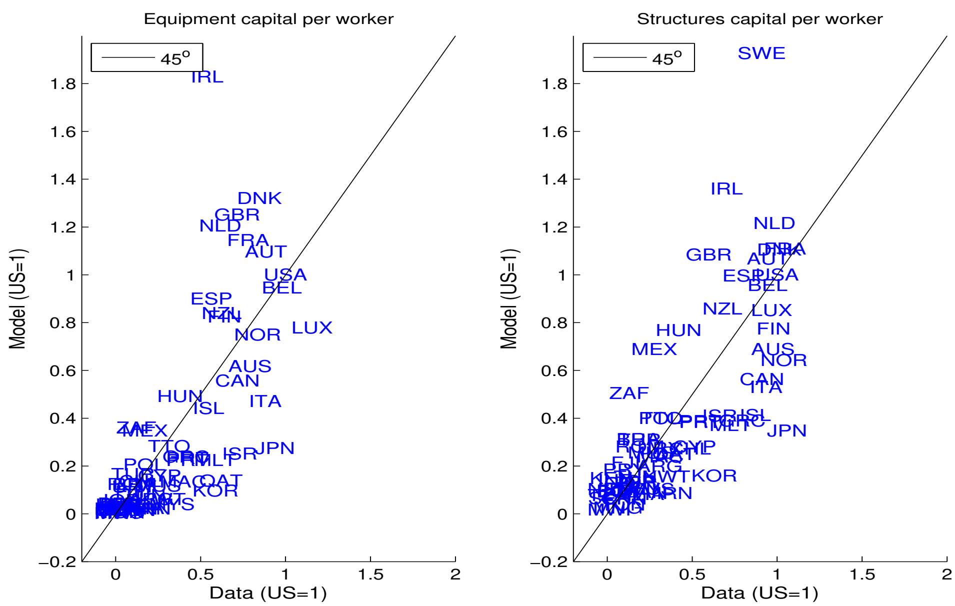


Figure D.4: World income distribution

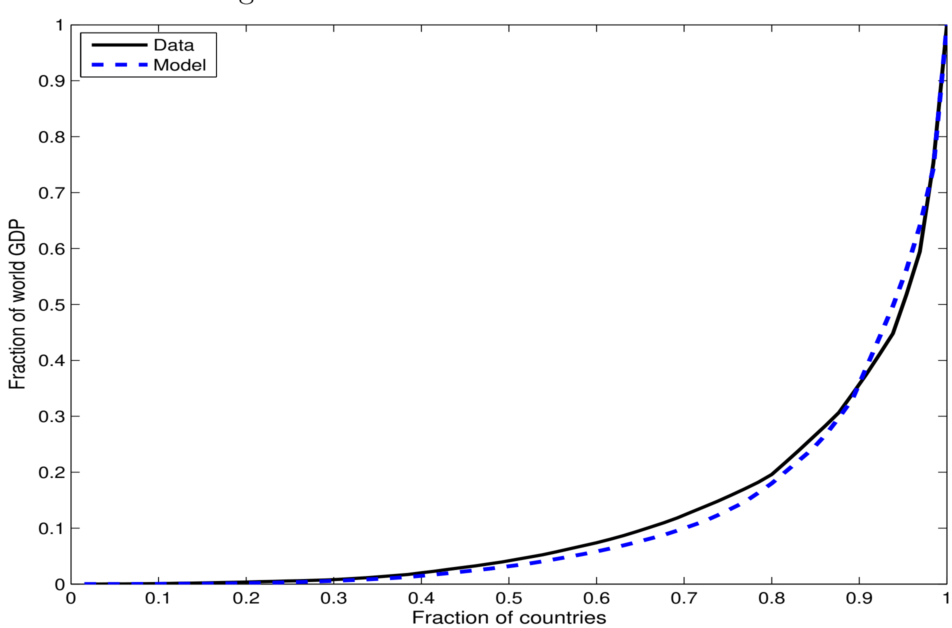


Figure D.5: Autarky in equipment

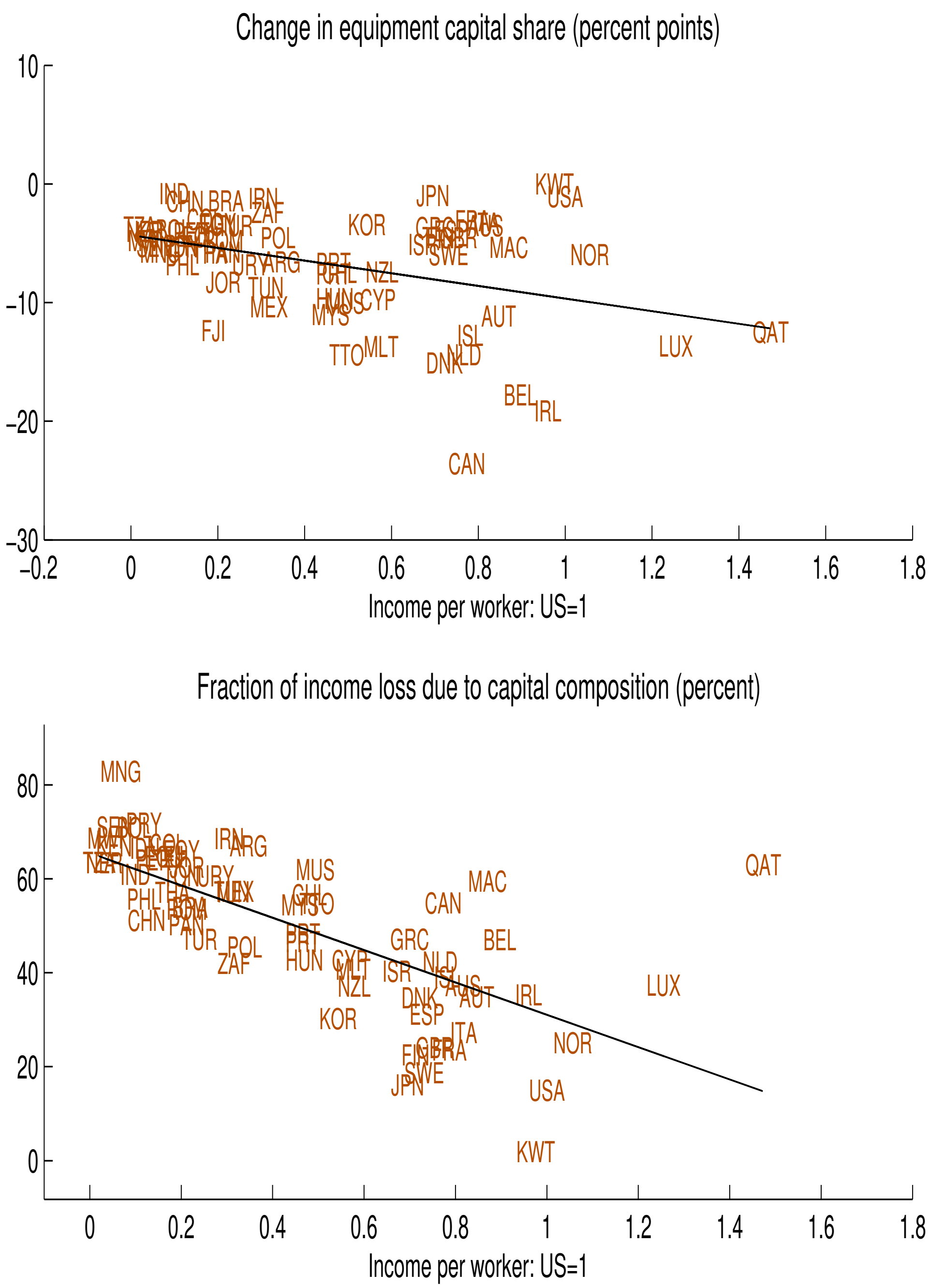


Figure D.6: Zero gravity in equipment, $\tau_{eij} = 1$

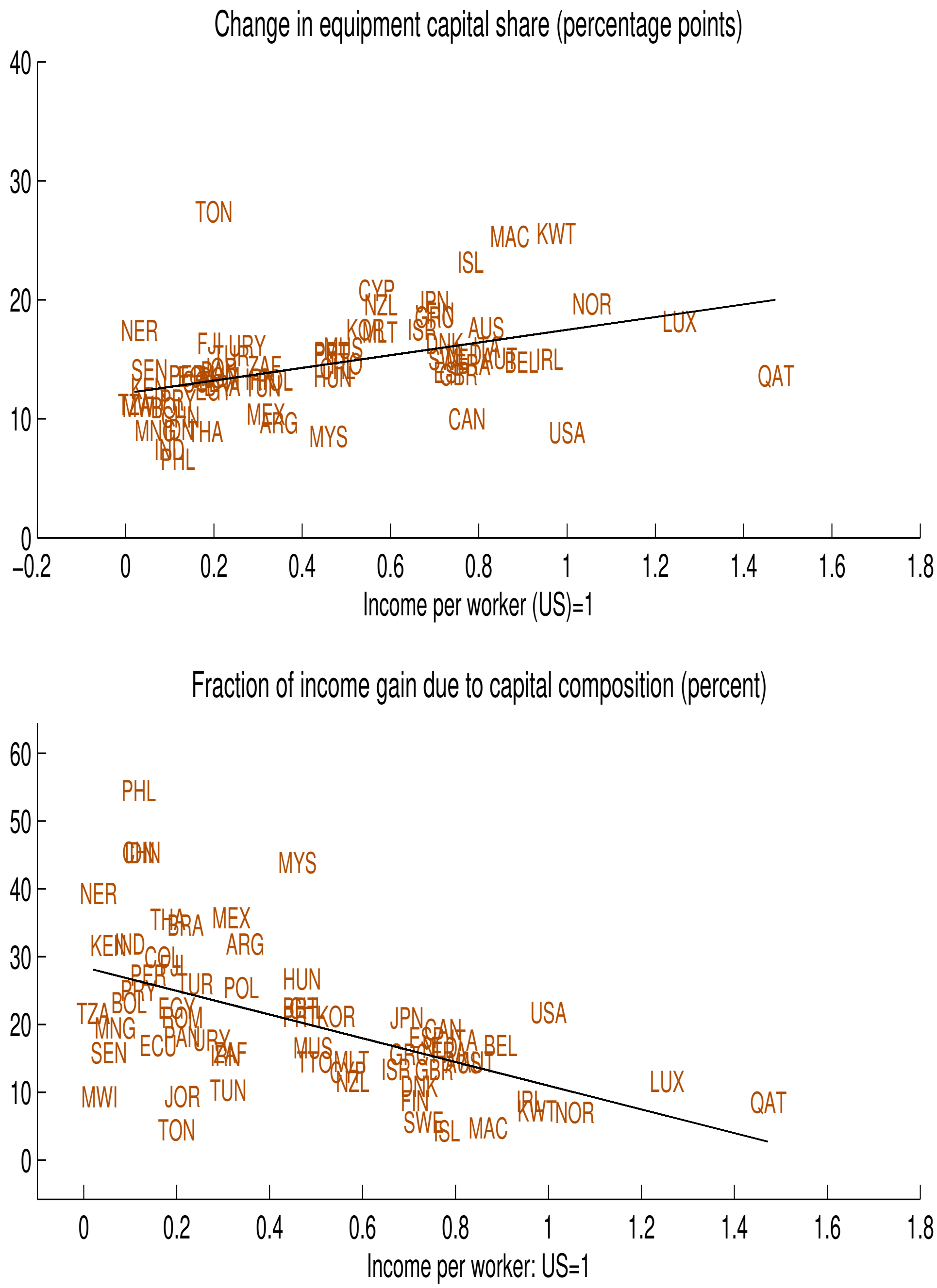
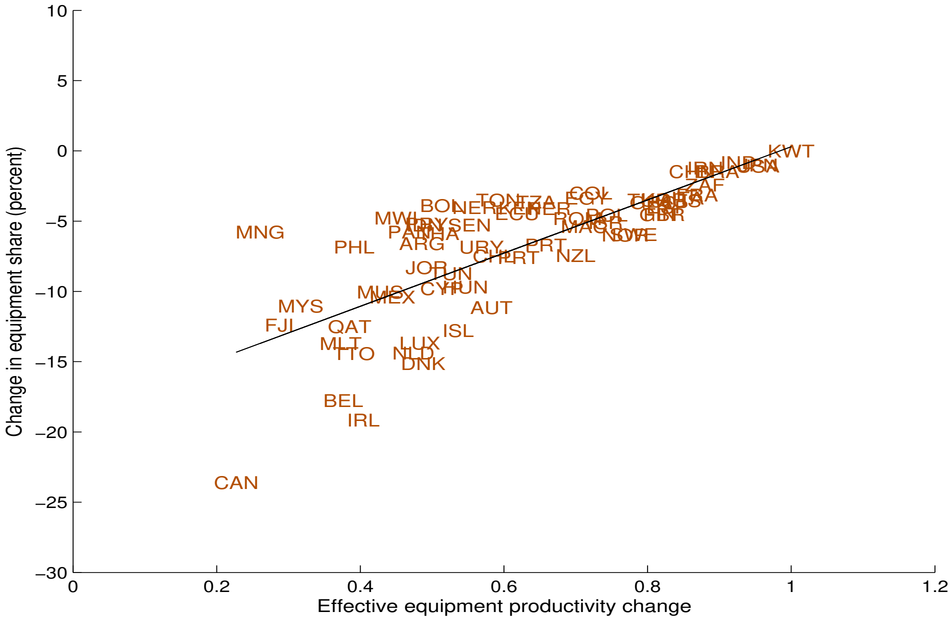
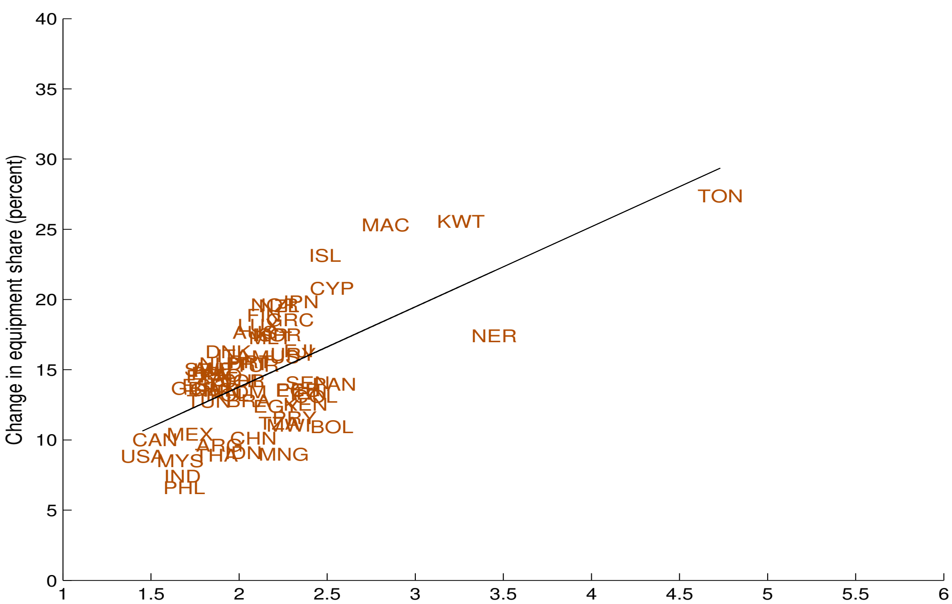


Figure D.7: Equipment capital share and effective equipment productivity: autarky in equipment



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

Figure D.8: Equipment capital share and effective equipment productivity: zero gravity in equipment



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