Equipment and Structures Capital: Accounting for Income Differences

Piyusha Mutreja*

June 2013

Abstract

In this paper, I present comparable measures of equipment capital and structures capital stocks for 119 countries. Cross-country variation in equipment capital-output ratio is over twice the variation in structures capital and aggregate physical capital. The dispersion in equipment capital has also increased overtime. Using development accounting that incorporates equipment and structures capital, I offer evidence relevant to the debate on the importance of productivity versus factors in accounting for income differences. The new measures of heterogeneous capital reduce the burden on TFP by up to five percent.

---

[*] Department of Economics, Syracuse University. Email: pmutreja@syr.edu

1 Introduction

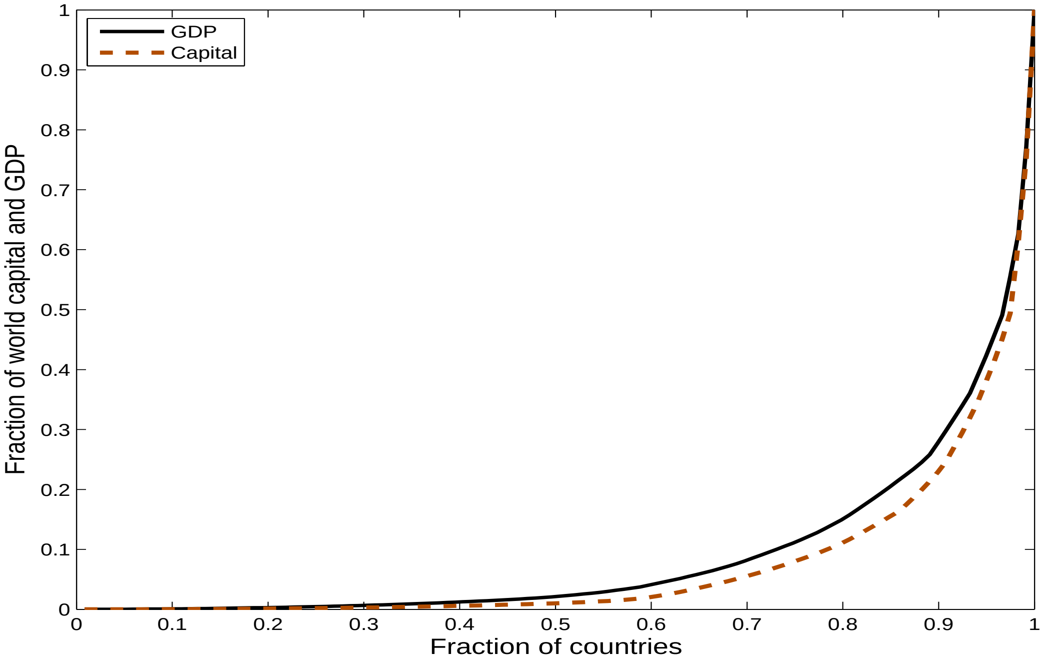
Cross-country differences in income per worker are enormous. The ratio of 90th to 10th percentile in the world income distribution is over 20 (Penn World Tables version 6.3, see Heston et al., 2009). The literature on income differences points to the importance of differences in stocks of physical capital across countries. It is well known that rich countries have much larger stocks of physical capital than poor countries. The capital-output ratio in the country at the 90th percentile of the world income distribution is over three times the capital-output ratio in the 10th percentile country. The 90-10 ratio of capital-per worker is also large, at nearly 75. In fact, the cross-country dispersion in physical capital is more than the dispersion in income per worker (see figure 1).

Little is known about the composition of physical capital across countries. Most of the literature treats physical capital as a homogeneous good. International dollar values of all types of capital goods are summed up to arrive at the aggregate capital stock of a country, with prices acting as weights. Even if the relative valuations of various types of capital are captured by the prices, their relative contributions to output, and hence the contribution of capital composition, are not accounted for by the prices. Such an aggregation also assumes that the various types of capital are perfect substitutes of one another, which is clearly not the case. Using the US data on manufacturing, Sato (1967) estimates the elasticity of substitution between equipment and structures, and finds that the two kinds of capital are far from being perfect substitutes.

In this paper, I present purchasing power parity (PPP) measures of the stocks of equipment capital and structures capital for 119 countries, and demonstrate that the composition of capital is systematically related with the income per worker. To construct the stocks of equipment and structures capital, I use data on the PPP investment levels for equipment and structures during 1950-2004, and employ the perpetual inventory method. Equipment corresponds to fabricated metal products, electrical and non-electrical machinery, transport equipment, communication equipment, office machinery, and professional and scientific equipment. Structures comprise both residential and non-residential buildings.

The cross-country dispersion in equipment capital is much larger than the dispersion in structures capital and aggregate capital. The equipment capital-output ratio is a factor of about 7 between rich and poor countries, while the structures capital-output ratio is a factor of 3, and the aggregate capital-output ratio is a factor of 3.3. The composition of capital is systematically related with the income levels. On average, equipment is 21 percent of the total capital stock in rich countries and 8 percent in poor countries. The dispersion

Figure 1: Cross-country cumulative distribution



in equipment capital has also increased over time, while the dispersion in structures has declined. This systematic variation of heterogeneous capital with incomes is potentially significant for the income differences across countries, as also previously noted by Caselli (2005).

The success of factors in accounting for income differences is determined by the way we model and measure factors across countries. In the absence of measures of heterogeneous capital, standard development accounting exercises have attributed a large fraction of the income differences to unknown total factor productivity (TFP) differences. In this paper, I conduct development accounting with equipment and structures capital to determine the significance of capital composition for the income differences. For development accounting, I consider both Cobb-Douglas and CES specifications to aggregate equipment and structures within a Cobb-Douglas production function.[1]

In my sample of 119 countries for the year 2004, the log variance in income per worker is 1.41, and the 90-10 ratio is 22.24. Relative to the aggregate capital, the measures of heterogeneous capital increase the explanatory power of factors in accounting for the income

---

[1] It is common in the literature to use both an elasticity of one and an elasticity different than one between equipment and structures capital (see, for instance, Krusell, Ohanian, Ríos-Rull, and Violante (2000) and Herrendorf and Valentinyi (2006)).

differences by up to five percent. The implied TFP gap between rich and poor is also smaller, a factor of about 2.8 between rich and poor countries with disaggregate capital and 3.3 with aggregate capital. Thus, the measures of equipment and structures capital make a modest contribution to the debate on the importance of productivity versus factors in accounting for the income differences. However, a large fraction of the income differences remains attributed to the unobserved TFP differences.

The interest in equipment versus structures, both as stocks and flows, and as determinants of incomes across countries, is not new. Caselli and Wilson (2004) study nine capital goods categories and find enormous heterogeneity in investment shares in these categories across countries. However, in the absence of PPP measures of various types of capital, they use imports in each category of capital as a proxy for the overall investment in that type of capital. Bems (2008) presents cross-country facts on tradable and nontradable investment in domestic and PPP prices.[2] He finds that the average investment expenditure share on nontradable goods is approximately 60 percent and it shows no correlation with the incomes. Relative to Caselli and Wilson (2004) and Bems (2008), my paper provides comparable measures of *stocks* of two categories of capital, namely, equipment and structures. The association between equipment and incomes has also been studied previously in the literature. For instance, De Long and Summers (1991) examine the statistical relationship between various components of investment and economic growth. They find that equipment investment plays a much bigger role in economic growth than other components of investment.

This paper relates with the strand of literature that studies the cross-country composition of physical capital. The Groningen Growth and Development Centre maintains data on the disaggregate capital stocks for 15 European Union countries and the United States.[3] Because of the limited country coverage, this database does not shed much light on the cross-country capital composition. A section of the literature also looks at the private versus public composition of capital, and finds large differences across countries (see, for instance, Pritchett (2000) and Dabla-Norris, Brumby, Kyobe, Mills, and Papageorgiou (2012)).

The results presented in this paper also contribute to the vast literature on income differences across countries. Within this literature, Klenow and Rodríguez-Clare (1997), Hall and Jones (1999), and Caselli (2005) through development accounting exercises assess the

---

[2] Equipment, in my paper, roughly corresponds with the tradable investment goods in Bems (2008), while structures can be regarded as largely nontradable.

[3] This database is called the Total Economy Growth Accounting Database, and is available at http://www.rug.nl/research/ggdc/data/total-economy-growth-accounting-database gronigen. It contains information in local currency at constant and current prices for six types of capital: IT equipment, communication equipment, software, non-residential buildings, transport equipment, and other non-ICT equipment.

success of factors in accounting for the income differences. My paper builds on the existing literature by incorporating equipment and structures capital into the development accounting framework. Knowing the measures of heterogenous capital improves our understanding of the physical capital differences across countries. In this respect, my paper also relates with the strand of literature that constructs improved measures of human capital to explain the income differences (see, for example, Hendricks (2002) and Schoellman (2012)).

A strand of the literature on income differences interprets differences in the capital-output ratio as an indicator of the distortions to capital accumulation (see, for instance, Restuccia and Urrutia (2001)). Accordingly, larger cross-country variation in equipment versus aggregate capital implies that, relative to rich countries, poor countries face more distortions in the accumulation of equipment capital than aggregate capital. Within this strand of literature, Eaton and Kortum (2001) employ a structural model of bilateral trade in equipment and construct a trade-based measure of equipment prices. The variation in their trade-based relative price of equipment explains approximately 25 percent of the cross-country income differences, about half of which they attribute to the trade barriers in equipment. Both Eaton and Kortum (2001) and my paper focus on the incomes across countries, but they address two very different aspects of the income differences. While Eaton and Kortum (2001) examine the role of trade distortions (through their impact on the relative price of equipment) in accounting for the income differences, my paper uses cross-country differences in the stocks of equipment and structures capital to account for the income differences.

The rest of the paper is organized as follows. Section 2 describes the procedure for the construction of disaggregate capital stocks from PPP investment levels, and documents the cross-country differences in equipment and structures capital. The development accounting methodology and results are presented in section 3. Section 4 discusses the results, and section 5 concludes.

2 Equipment and structures capital

In this section, I describe the procedure that I employ to construct the stocks of equipment and structures capital from disaggregate investment levels, as well as document the cross-country dispersion in these capital stocks.

2.1 Methodology

To measure capital stocks from the disaggregate PPP investment levels, I use the perpetual inventory method (PIP), as in Hall and Jones (1999) and Caselli (2005). That is, capital stock at time t is measured as sum of the perpetual inventory of previous years' undepreciated investments,

$$K_{eit} = (1 - \delta_e) K_{eit-1} + I_{eit}$$

where K_{eit} is the equipment capital stock of country i in period t, I_{eit} is the investment in equipment in country i in period t, and δ_e is the depreciation rate for equipment capital. Following the standard practice (Hall and Jones (1999) and Caselli (2005)), I compute the initial level of equipment capital stock as

$$K_{ei0} = \frac{I_{ei0}}{g_{ei} + \delta_e}$$

where I_{ei0} is the value of the investment series in the first year it is available, and g_{ei} is the average geometric growth rate for the investment series between the first year with available data and 1980. The rationale for this choice is the following: $I_0/(g + \delta)$ is the expression for the capital stock in the steady state of the Solow model. Similarly, for structures capital

$$K_{sit} = (1 - \delta_s) K_{sit-1} + I_{sit} \quad \text{and} \quad K_{si0} = \frac{I_{si0}}{g_{si} + \delta_s}$$

I also construct the stocks of aggregate capital by employing the PIP. The corresponding aggregate investment levels are computed as the sum of investment in equipment and investment in structures.

$$K_{agg,it} = (1 - \delta_{agg}) K_{agg,it-1} + I_{agg,it} \quad \text{and} \quad K_{agg,i0} = \frac{I_{agg,i0}}{g_{agg,i} + \delta_{agg}}$$

Clearly, $K_{agg,it} \neq K_{eit} + K_{sit}$.

2.2 Data

I employ data on the PPP estimates of equipment and structures investment levels that I obtained from the Center for International Comparisons (CIC).[4] The base year for these measures is 2005. Equipment corresponds to ISIC Rev. 2 categories 381-385, i.e., fabricated

---

[4] CIC published its own estimates of capital stocks for producer durables, residential construction, and non-residential construction in the Penn World Table (PWT) version 5.6, but it discontinued these measures in the later versions of PWT.

metal products, electrical and non-electrical machinery, transport equipment, communication equipment, office machinery, and professional and scientific equipment.[5] Structures include buildings, both residential and non-residential. It is standard in the literature to consider residential buildings but not consumer durables, as part of the production boundary. This is consistent with the System of National Accounts 1993.[6] Also, the aggregate PPP investment rate available in the Penn World Table includes investment in residential buildings. I construct equipment and structures capital stocks for 119 countries. This set includes both rich and poor countries, and accounts for about 89 percent of the world GDP in 2004 (as computed from Penn World Tables version 6.3, see Heston et al., 2009).

In addition to the PPP investment levels, cross-country data on g_{ei}, g_{si}, and $g_{agg,i}$ are required for the measurement of initial levels of capital stocks. I measure these with the average geometric growth rate of the respective PPP investment series between 1950 and 1980.[7] Lastly, I require time series data on the labor force. Using real GDP per capita (RGDPL), real income per worker (RGDPWOK), and population (POP) from the Penn World Table version 6.3 (PWT63, see Heston, Summers, and Aten, 2009), I calculate $\frac{RGDPL^{*}POP}{RGDPWOK}$ to arrive at data on the labor force.

2.3 Parameters

To construct stocks of equipment and structures capital, I set $\delta_e = 0.14$ and $\delta_s = 0.02$. This is analogous to Herrendorf and Valentinyi (2006). Herrendorf and Valentinyi (2006) calculate depreciation rates for the US using data on fixed assets and investment from the Bureau of Economic Analysis. They average $[I_{it} + K_{it-1} - K_{it}]/K_{it-1}$ over the time period 1987-2003 to calculate the depreciation rates for producer durables and buildings. CIC used similar depreciation rates for its construction of the disaggregate capital stocks in PWT version 5.6: 15 percent for machinery, 24 percent for transportation equipment, and 3.5 percent for construction. Greenwood, Hercowitz, and Krusell (1997) use $\delta_e = 0.12$ and $\delta_s = 0.06$.[8] For construction of the aggregate capital stocks, I set $\delta_{agg} = 0.06$, as is commonly used in the literature (see, for instance, Caselli (2005)).

---

[5] ISIC Rev. 2 classification is available at http://unstats.un.org/unsd/cr/registry/regcst.asp?cl=8.

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

[7] A negative g could result in negative or very large initial capital stocks, so it is bounded at zero. This does not alter the cross-country variation in capital stocks significantly.

[8] Setting δ_e at 12 percent and δ_s at 6 percent does not alter the measured cross-country dispersion in equipment and structures capital significantly. See appendix A for the details.

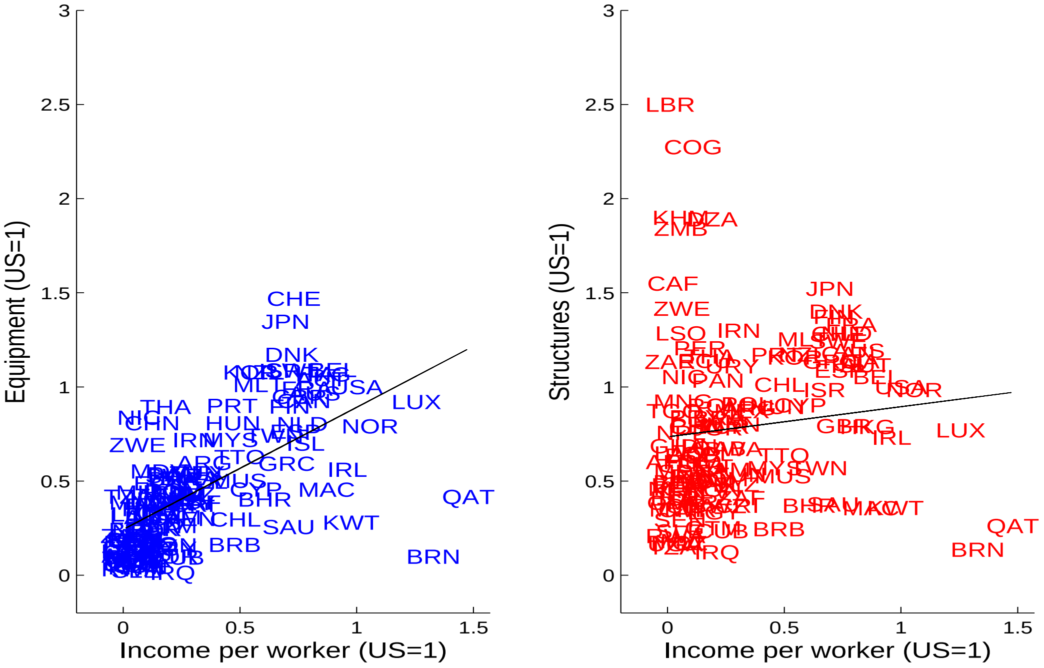
2.4 Capital stocks

The cross-country variation in equipment capital is larger than both structures capital and aggregate capital. The equipment capital-output ratio is a factor of 7.02 between rich and poor countries. The 90-10 ratio of structures capital-output ratio is 2.95, and that for aggregate capital is 3.26 (see table 1). The equipment capital-output ratio varies systematically with the income levels. Figure 2 plots the equipment capital-output ratio with the income per worker relative to the US. The correlation coefficient for this figure is 0.63. The structures capital-output ratio is slightly positively correlated with the incomes; the correlation coefficient is 0.12.

Table 1: Income per worker and capital-output ratio (year = 2004)

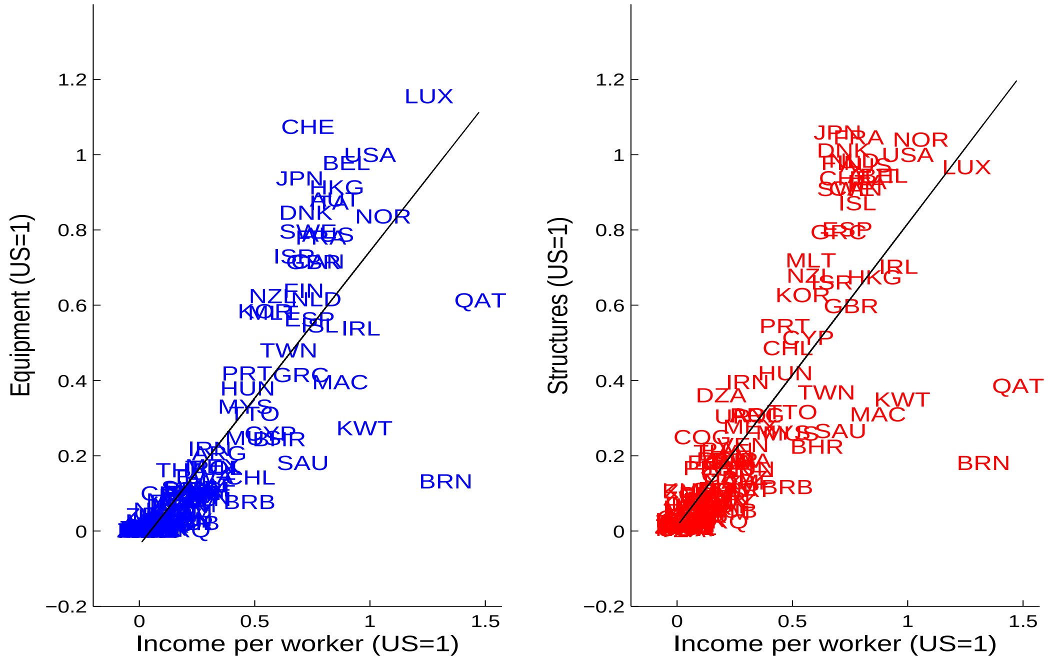
	Income	Aggregate capital	Equipment	Structures
90th percentile	65842.44	2.36	0.59	2.46
10th percentile	2960.20	0.72	0.08	0.83
Ratio	22.24	3.26	7.02	2.95

Figure 2: Capital-output ratio (equipment left, structures right)



The equipment capital per worker is also much higher in the rich countries than in the poor countries. The equipment capital per worker in the 90th percentile country is 156.09

Figure 3: Capital per worker (equipment left, structures right)



times the equipment capital per worker in the 10th percentile country. The 90-10 ratio of structures capital per worker is 65.57, and that for aggregate capital is 72.55. Equipment capital per worker varies positively with income per worker. Figure 3 plots the equipment capital per worker and the structures capital per worker for 2004, along with the income per worker (relative to the US). The correlation between equipment capital per worker and income per worker is 0.85. Structures capital per worker is also positively related to income per worker; the correlation coefficient is 0.81.

To emphasize the dispersion in heterogeneous capital across countries, I plot the world cumulative distribution of GDP, equipment capital, and structures capital in figure 4 (this is analogous to figure 1 in the introduction). The distribution of equipment capital and structures capital is even more unequal across countries than is incomes. In 2004, the 90-10 ratio of aggregate GDP is 780.45, that for structures capital is 2300.85, and that for equipment capital is 5476.98.

Rich and poor countries differ not only in the quantity of equipment and structures capital but also in the share of equipment in total capital stock. I calculate the fraction of equipment capital stock as $\frac{K_e}{K_e+K_s}$. Note that the denominator is not the aggregate capital stock, K_{agg}, as measured above using PIP but rather a sum of the stocks of equipment capital and structures capital. This ratio highlights the cross-country differences in the composition

Figure 4: Cross-country cumulative distribution

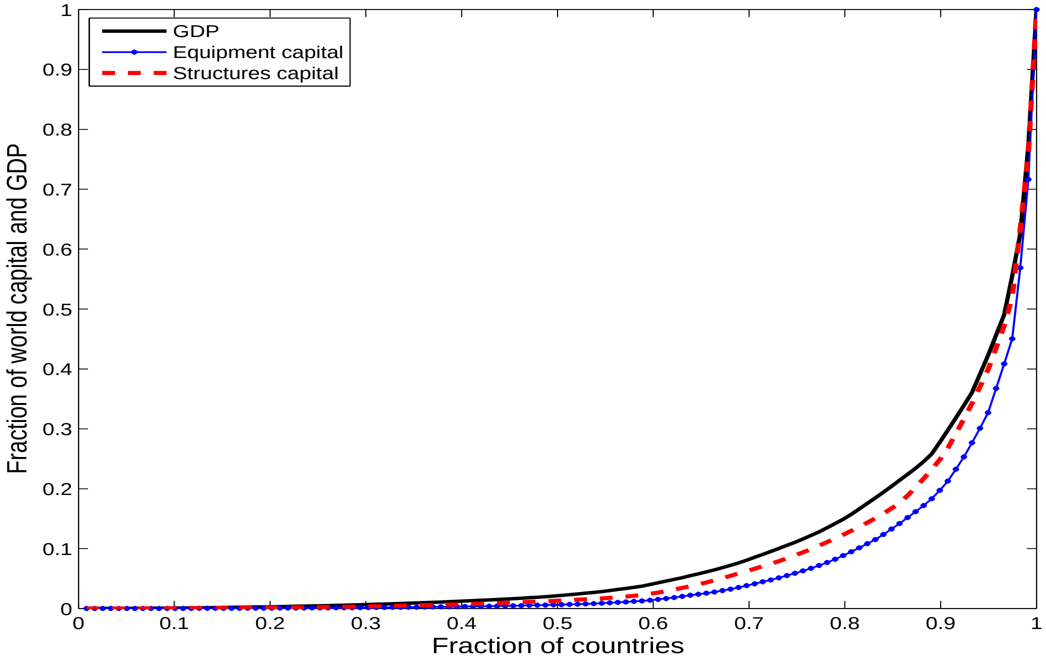


Figure 5: Composition of capital

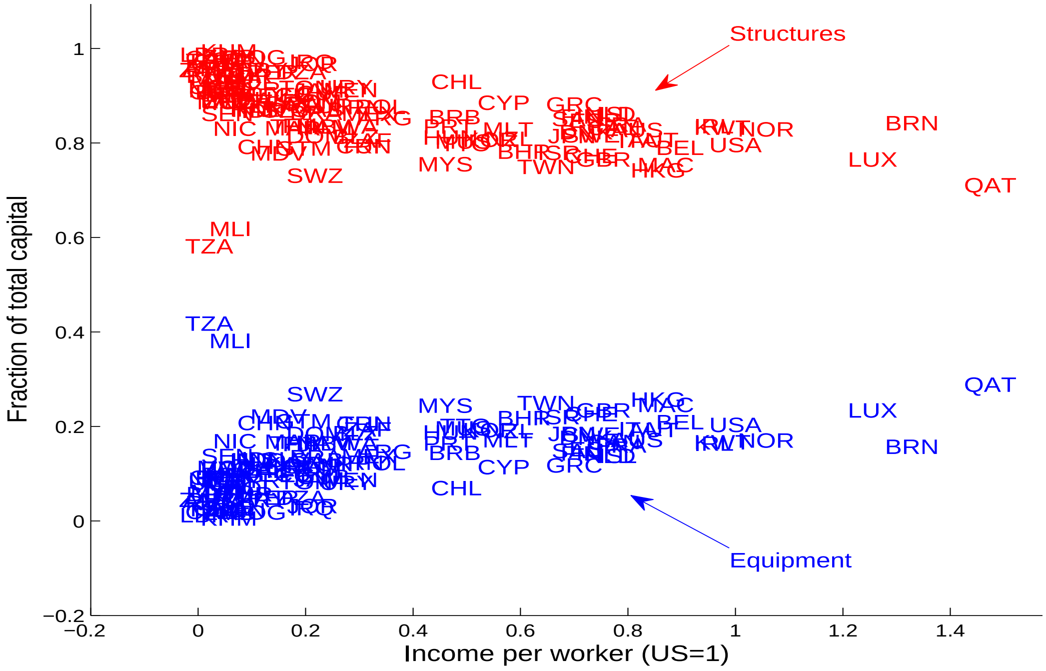
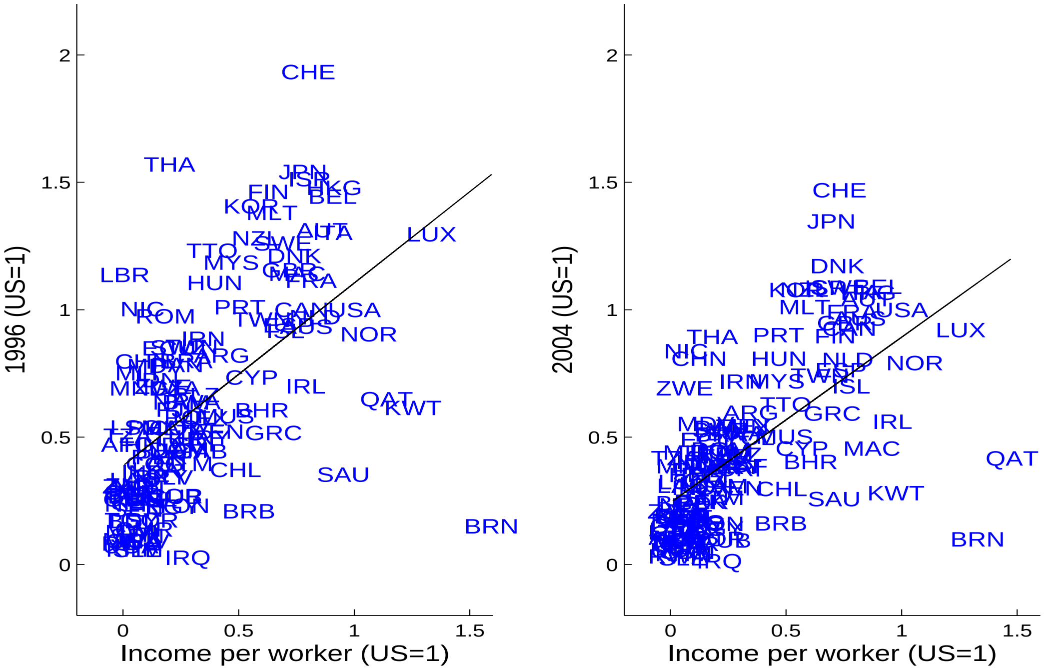


Figure 6: Equipment capital-output ratio (1996 left, 2004 right)



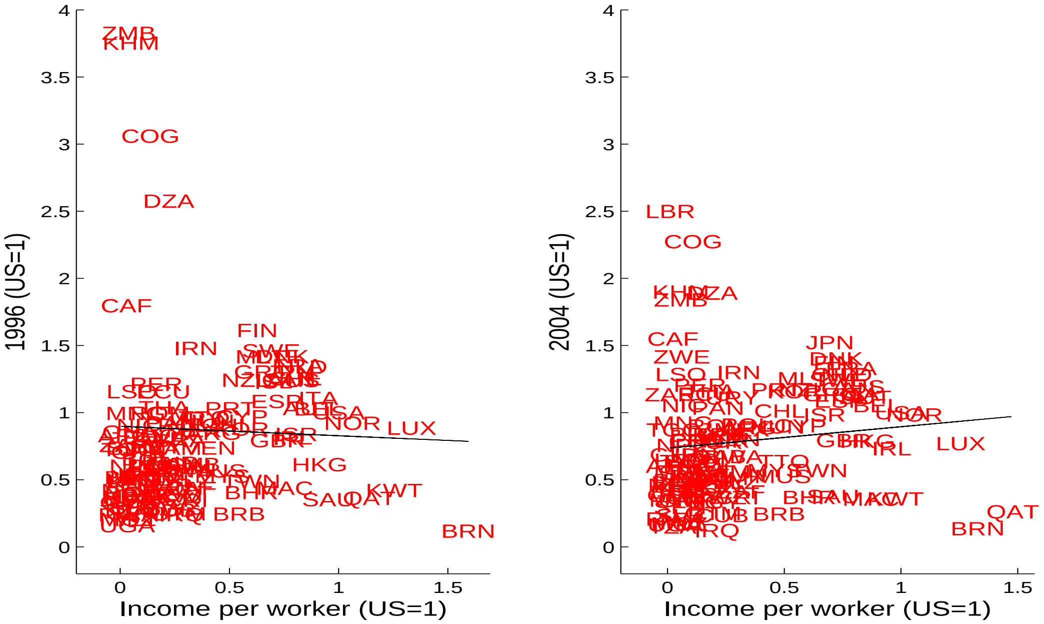
of capital. This ratio for the 90th percentile country is 2.11 times of the ratio for the 10th percentile country. The 90-10 ratio of $\frac{K_s}{K_e+K_s}$ is 0.89. Thus, as a fraction of the total capital stock, rich countries are more abundant in equipment capital than in structures capital. On average, 21 percent of rich countries' capital stock is in equipment versus 8 percent for poor countries.[9] Figure 5 plots the share of equipment and structures in total capital stock, along with income per worker relative to the US. The composition of physical capital is systematically related with income levels. The correlation between the fraction of equipment capital and income per worker is 0.52 (and -0.52 between the fraction of structures capital and income per worker).

A natural question to ask is whether or not the cross-country dispersion in capital stocks has changed over time. Figures 6 and 7 plot the equipment capital-output ratio and the structures capital-output ratio for 1996 and 2004, respectively. The correlation between equipment capital-output ratio and income per worker increased from 0.57 in 1996 to 0.63 in 2004. Structures capital-output ratio exhibits very little correlation with income per worker: the correlation is -0.03 in 1996 and 0.12 in 2004. So, the systematic variation of

---

[9] Rich countries correspond to the 12 countries with income per worker that is greater than the income per worker in the 90th percentile country. Poor countries are the ones that are below the 10th percentile in the world income distribution.

Figure 7: Structures capital-output ratio (1996 left, 2004 right)

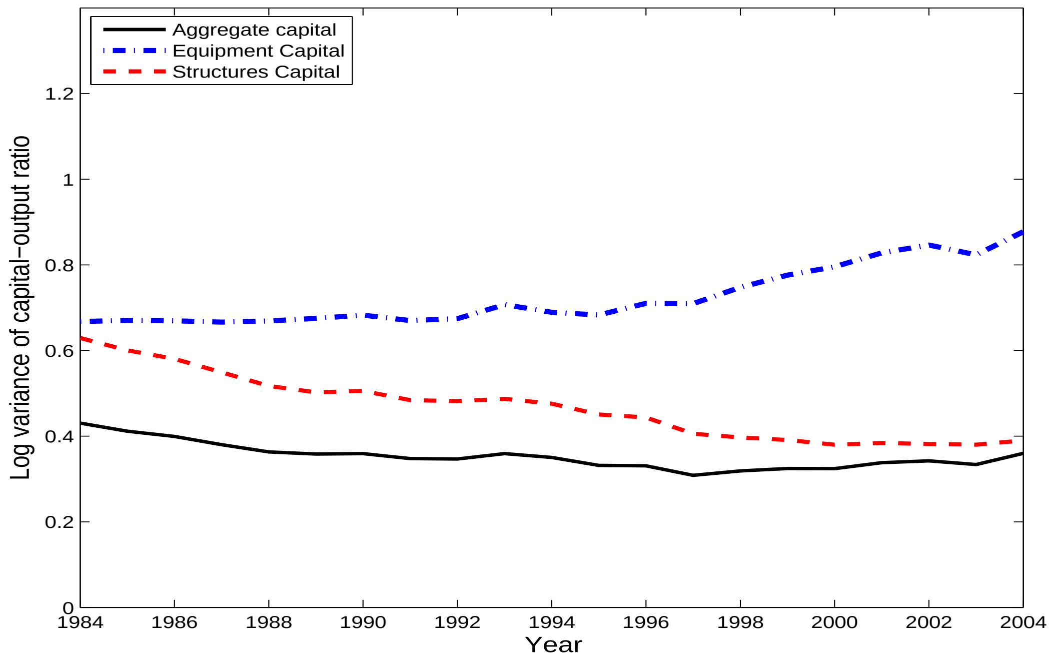


the disaggregate capital-output ratio with the incomes shows little change between 1996 and 2004.

A different picture emerges when we look at log variance of the capital-output ratios. Figure 8 plots the log variance of the capital-output ratio for aggregate capital, equipment capital, and structures capital for the time period 1984-2004. As already established in the literature, the cross-country variation in aggregate capital-output ratio is relatively unchanged over time. The log variance of aggregate capital-output ratio in figure 8 reinforces this fact. Hidden behind this well-documented fact is the evolution of composition of capital across the 119 countries in my sample. The cross-country variation in the structures capital-output ratio declined between 1984 and 2004 as it approached the level of the log variance in the aggregate capital-output ratio. The evolution of equipment capital-output ratio is the most noteworthy. The log variance of equipment-capital ratio experienced a steady rise in the 20-year time period. Thus, on one hand rich countries have a larger fraction of capital in equipment, and on the other, the gap between rich and poor countries has increased overtime.

One remark is in order here. As I mentioned in the introduction, Bems (2008) documents the expenditure shares on tradable and nontradable investment goods. The notable difference between Bems (2008) and my paper is that my paper is concerned with PPP *stocks* of

Figure 8: Log variance of capital-output ratio



heterogeneous capital, and not investment.[10] Bems (2008) finds that the average investment expenditure share on nontradable goods is approximately 60 percent and it shows no correlation with incomes. Is this finding at odds with the finding in my paper that compared to poor countries, rich countries have larger PPP stocks of equipment capital than structures capital? No, for two reasons. One, Bems (2008) finding of similar nontradable expenditure shares across countries corresponds mostly to the investment in domestic prices. In PPP prices, the average investment expenditure share of structures, across the 119 countries in my sample, is 51 percent for 2005 (consistent with table 12 in Bems (2008)). What is noteworthy is that the standard deviation of this PPP expenditure share is 17 percent. Two, relative to consumption goods, poor countries face a higher PPP price for equipment than structures. The correlation between relative PPP price of equipment and income per worker is -0.48, and that for structures is -0.15. This effectively results in smaller real stocks of equipment capital in poor countries.

What determines these large capital composition differences across countries, especially the evolution thereof? And what are the implications of these large differences in the com-

---

[10] The data requirement for these two is very different. I use PPP investment data for all years 1950-2004 for the construction of heterogeneous capital stocks. To document PPP investment shares, Bems (2008) uses data pertaining to the ICP benchmark years only.

position of capital for the income differences? I approach the latter in the next section, and explore possible explanations for the former and the consequent connections with cross-country economic development in section 4.

3 Accounting for income differences

3.1 Methodology

In this section, I develop the development accounting framework. It is a standard practice in the literature to assume a Cobb-Douglas constant returns to scale aggregate production function for each country i,

$$Y_{it} = A_{it} K_{agg,it}^{\alpha} \left(L_{it} h_{it}\right)^{1-\alpha} \tag{1}$$

where Y_{it} is the aggregate output in country i at time t, $K_{agg,it}$ is the aggregate physical capital stock, L_{it} is the size of labor force, h_{it} is the average human capital per worker, and A_{it} represents TFP. α is the factor income share of capital. In per worker terms,

$$y_{it} = A_{it} k_{agg,it}^{\alpha} h_{it}^{1-\alpha} \tag{2}$$

Thus, the variation in y_{it} is explained by unknown TFP, A_{it}, and the measurable contribution from factors of production, $k_{agg,it}^{\alpha} h_{it}^{1-\alpha}$. The magnitude of A_{it} is captured as a residual after measuring the contribution of factors to cross-country incomes. Clearly, the more that is explained by the factors, the less is the burden on TFP. I include equipment capital and structures capital via a nested Cobb-Douglas specification to account for the contribution of heterogeneous capital.

$$Y_{it} = A_{it} \left(K_{eit}^{\mu} K_{sit}^{1-\mu}\right)^{\alpha} \left(L_{it} h_{it}\right)^{1-\alpha}$$

where K_{eit} is the equipment capital stock, K_{sit} is the structures capital stock, and μ is the share of capital income accruing to equipment capital. In per worker terms,

$$y_{it} = A_{it}\, k_{eit}^{\mu\alpha}\, k_{sit}^{(1-\mu)\alpha}\, h_{it}^{1-\alpha}$$

Here, the measurable contribution from factors is $k_{eit}^{\mu\alpha}\, k_{sit}^{(1-\mu)\alpha}\, h_{it}^{1-\alpha}$. Since, the composition of capital is systematically biased in favor of equipment for rich countries, apriori, the inclusion of equipment and structures capital could account for a larger variation in incomes. If β_{it} is the fraction of equipment in the total value of capital stock, i.e. $\beta_{it} = \frac{k_{eit}}{k_{eit}+k_{sit}}$, then income per worker can be written as,

$$y_{it} = A_{it} \left[\beta_{it}^{\mu\alpha} \left(1-\beta_{it}\right)^{(1-\mu)\alpha}\right] k_{it}^{\alpha}\, h_{it}^{1-\alpha} \tag{3}$$

where $k_{it} = k_{eit} + k_{sit}$ is the total value of capital stock. $\beta_{it}^{\mu\alpha}(1-\beta_{it})^{(1-\mu)\alpha}$ is the contribution of capital composition to the income differences. The contribution from factors in this specification is potentially different relative to specification 2, because of (i) the contribution of capital composition, and (ii) the difference between the total value of capital stock, and the aggregate capital stock, i.e., $k_{eit} + k_{sit} - k_{agg,it}$.

Specification 3 assumes an elasticity of one between equipment capital and structures capital. As an alternative, I consider the following nested CES specification,

$$Y_{it} = A_{it}\left[\mu^{\frac{1}{\gamma}}K_{eit}^{\frac{\gamma-1}{\gamma}} + (1-\mu)^{\frac{1}{\gamma}}K_{sit}^{\frac{\gamma-1}{\gamma}}\right]^{\alpha\frac{\gamma}{\gamma-1}}(L_{it}h_{it})^{1-\alpha}$$

where γ is the elasticity of substitution between equipment and structures capital. In per worker terms,

$$y_{it} = A_{it}\left[\mu^{\frac{1}{\gamma}}k_{eit}^{\frac{\gamma-1}{\gamma}} + (1-\mu)^{\frac{1}{\gamma}}k_{sit}^{\frac{\gamma-1}{\gamma}}\right]^{\alpha\frac{\gamma}{\gamma-1}} h_{it}^{1-\alpha}$$

or equivalently,

$$y_{it} = A_{it}\left[\mu^{\frac{1}{\gamma}}\beta_{it}^{\frac{\gamma-1}{\gamma}} + (1-\mu)^{\frac{1}{\gamma}}(1-\beta_{it})^{\frac{\gamma-1}{\gamma}}\right]^{\alpha\frac{\gamma}{\gamma-1}} k_{it}^{\alpha}h_{it}^{1-\alpha} \tag{4}$$

Here, the measurable contribution from factors is $[\mu^{\frac{1}{\gamma}}\beta_{it}^{\frac{\gamma-1}{\gamma}} + (1-\mu)^{\frac{1}{\gamma}}(1-\beta_{it})^{\frac{\gamma-1}{\gamma}}]^{\alpha\frac{\gamma}{\gamma-1}} k_{it}^{\alpha}h_{it}^{1-\alpha}$, of which $[\mu^{\frac{1}{\gamma}}\beta_{it}^{\frac{\gamma-1}{\gamma}} + (1-\mu)^{\frac{1}{\gamma}}(1-\beta_{it})^{\frac{\gamma-1}{\gamma}}]^{\alpha\frac{\gamma}{\gamma-1}}$ is the contribution from the composition of capital.

To measure the success of heterogeneous capital in explaining cross-country income differences, I compare specifications 3 and 4 with the baseline specification 2. Following Caselli (2005), I use two measures of success: log variance and 90-10 ratio.

3.2 Data

Apart from the equipment and structures capital stocks, development accounting requires cross-country data on real income per worker and average human capital per worker. I use RGDPWOK from the Penn World Table version 6.3 (PWT63, see Heston, Summers, and Aten, 2009) as the measure for real income per worker.

As in Hall and Jones (1999) and Caselli (2005), I convert the data on years of schooling from Barro and Lee (2010) into the measures of human capital by using Mincer returns. I take average years of schooling for the population age 25 and up, and convert these into measures of human capital using $h = \exp(\phi(s))$, where $\phi(s)$ is piecewise linear in average years of schooling s. As in Caselli (2005), I use the following estimates of $\phi(s)$ (common across countries): 0.134 for $s \leq 4$, 0.101 for $4 < s \leq 8$, and 0.068 for $s > 8$.

3.3 Parameters

To conduct development accounting, I also require parameter values for the various factor shares and the elasticity of substitution between equipment and structures. A generally accepted value for the share of capital in GDP, α, is 1/3 (see Gollin (2002) for details). Accordingly, I set α at 1/3. In the literature, values for the factor share of equipment capital, μ, range between 0.54-0.65. Using data on the US economy, Valentinyi and Herrendorf (2008) measure the factor share of land, equipment capital, and structures capital at the sectoral level. Their measures for the aggregate economy (and, also, for non-agriculture) imply a μ of 0.54.[11] Greenwood, Hercowitz, and Krusell (1997) calibrate a model of investment-specific technological change to data on the US economy and their estimates imply an equipment factor share of 0.56. Also, Krusell, Ohanian, Ríos-Rull, and Violante (2000) build a quantitative model of capital-skill complementarity and estimate an income share of structures capital of 0.117. This corresponds to $(1-\mu)\alpha$ in my paper, implying a μ of 0.65. Following this literature, I set μ at 0.56.[12]

The elasticity of substitution between equipment and structures has also been estimated previously in the literature. Sato (1967) employs data on US manufacturing to estimate an elasticity of 1.63 between equipment and structures. Using data on the US for the time period 1927-1968, Boddy and Gort (1971) estimate an elasticity of 1.72. More recently, Herrendorf and Valentinyi (2006) measure sectoral TFP across countries, and their estimates imply an elasticity of 1.58 between producer durables and buildings (see table 3 in their paper). Following the literature, I set γ at 1.72.[13]

3.4 Results

In this section, I present the results from development accounting with equipment and structures capital. As I demonstrated in section 2, not only are equipment and structures capital stocks larger for rich countries than for poor countries, equipment capital is even more systematically related with the incomes than aggregate capital. The separation between equipment capital and structures capital has important implications, as evident from the development accounting results in table 2.

In my sample of 119 countries for the year 2004, the log variance in income per worker is

---

[11] This is computed as 0.15/0.28; see table 3 in Valentinyi and Herrendorf (2008).

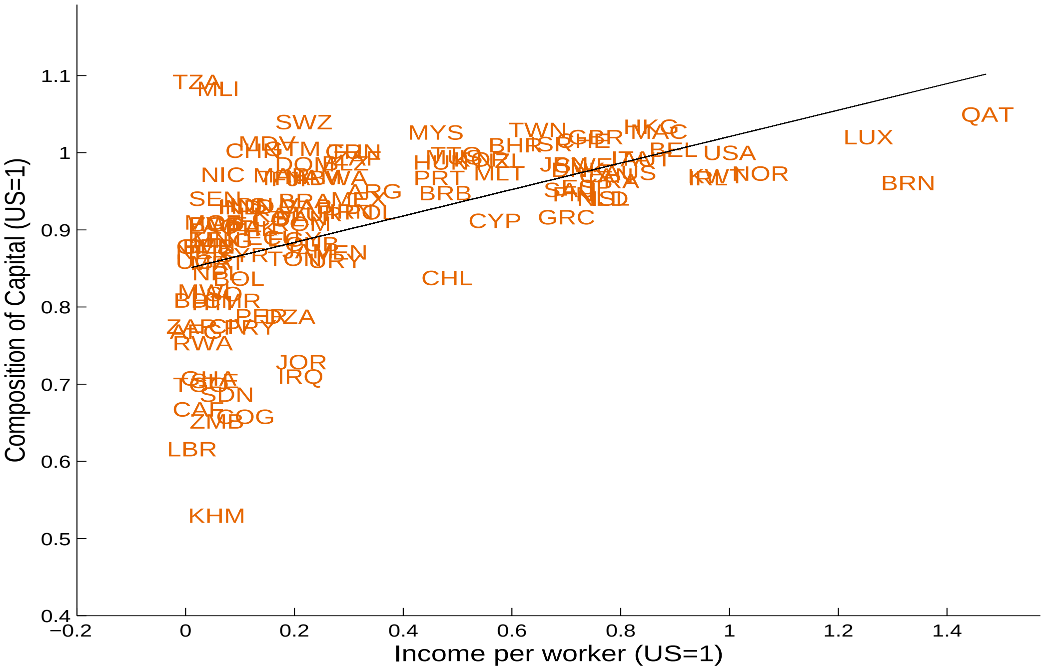
[12] As discussed in appendix B, the development accounting results are robust to values of μ in the range 0.5-0.7.

[13] Setting the elasticity, instead, at either 1.58 or 1.63 does not significantly alter the development accounting results from specification 4.

Table 2: Development Accounting

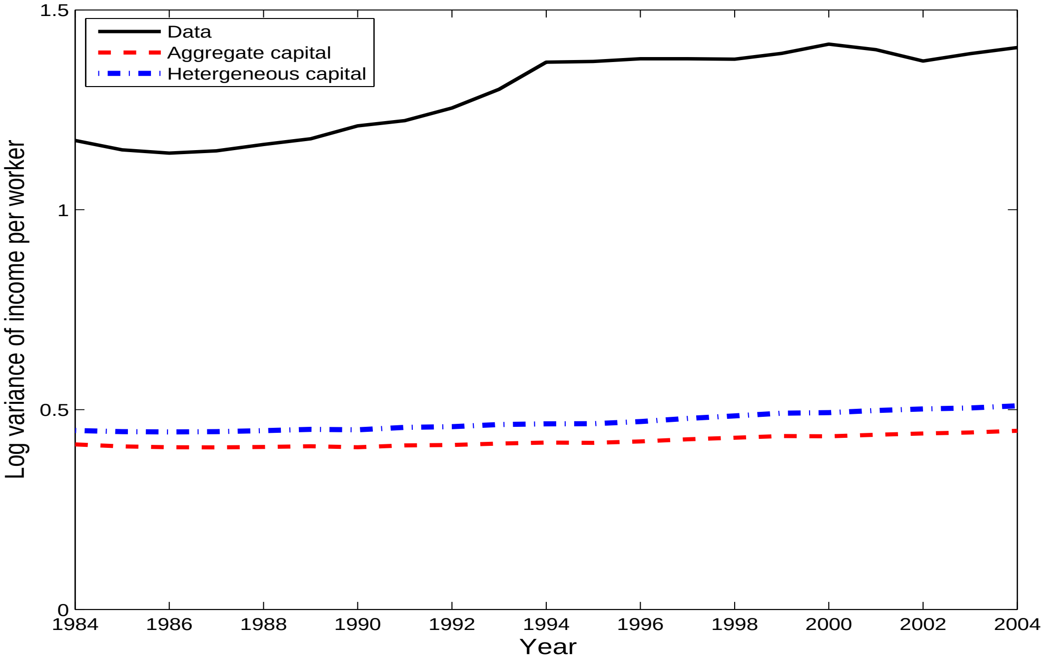
	Log variance	90-10 ratio
Data	1.41	22.24
$k^{\alpha} h^{1-\alpha}$	0.45	6.71
$k_e^{\mu\alpha}\, k_s^{(1-\mu)\alpha}\, h^{1-\alpha}$	0.51	7.63
$[\mu k_e^{\gamma} + (1-\mu) k_s^{\gamma}]^{\alpha/\gamma}\, h^{1-\alpha}$	0.49	7.57

Figure 9: Contribution from composition of capital, $\beta_{it}^{\mu\alpha}(1-\beta_{it})^{(1-\mu)\alpha}$



1.41, and the 90-10 ratio is 22.24. I consider two specifications for the aggregate production function to assess the explanatory power of heterogeneous capital. The first specification assumes that the output is a nested Cobb-Douglas aggregate of equipment and structures capital, as well as human capital (equation 3). The log variance of income per worker in this specification is 0.51, and the 90-10 ratio is 7.63. The second specification assumes a CES aggregate of the two kinds of capital that is nested into a Cobb-Douglas aggregate production function (equation 4). This specification produces a log variance in income per worker of 0.49, and a 90-10 ratio of 7.55. In contrast, the development accounting with aggregate physical capital and human capital (specification 2) produces a log variance of 0.45 and a 90-10 ratio of 6.71. Thus, heterogeneous capital increases our understanding of the income differences by up to five percent.

Figure 10: Log variance of income per worker from factors



Relative to the specification with aggregate capital (equation 2), specification 3 produces a larger variation in incomes because of (i) the capital composition term, $\beta_{it}^{\mu\alpha}(1-\beta_{it})^{(1-\mu)\alpha}$, and (ii) the difference between the total value of capital stock (specification 3) and aggregate capital stock, $k_{eit}+k_{sit}-k_{agg,it}$. Figure 9 plots the contribution of capital composition against income levels; the correlation coefficient is 0.54. The capital composition term results in a log variance in income per worker of 0.02, which accounts for approximately 1.4 percent of log variance in the income per worker. The remainder of the contribution comes from the improved measures of physical capital stocks.

Next, I assess if the explanatory power of factors in accounting for the income differences has changed over time. Figure 10 plots the inter-temporal evolution of the log variance reproduced by factors (specification 2 and 3) between 1984 and 2004. Note that the heterogeneous capital (along with human capital) accounts for a larger fraction of the cross-country variation in the incomes, relative to the aggregate capital for all the years 1984-2004. In the data, the log variance and the 90-10 ratio of income per worker have steadily increased over time. The log variance of income per worker accounted for by the factors shows a much smaller increase relative to the increase in log variance in the data. Thus, the contribution of factors has in effect declined over time.

4 Discussion

Hall and Jones (1999) use an alternative specification to account for the income differences. Starting with the aggregate production function in equation 1, income per worker can alternatively be written as

$$y_{it} = A_{it} \left(\frac{K_{agg,it}}{Y_{it}} \right)^{\frac{\alpha}{1-\alpha}} h_{it}$$

As Hall and Jones (1999) point out, this specification is potentially superior to the one based on capital per worker. In the Solow model, the capital-output ratio is proportional to the investment rate along a balanced growth path; thus, this decomposition links income per worker with the investment rates across countries. Also, exogenous increases in A_{it} over time will typically lead to increases in capital per worker. A decomposition based on the capital per worker will tend to attribute these increases in income to the increases in capital accumulation, even if the capital-output ratio is relatively unchanged with the increase in A_{it}. In fact, this is true, as evident in figure 8: the log variance of the aggregate capital-output ratio has changed little over time.

Introducing equipment and structures capital into this specification we get,

$$y_{it} = A_{it} \left(\frac{K_{eit}}{Y_{it}} \right)^{\mu\frac{\alpha}{1-\alpha}} \left(\frac{K_{sit}}{Y_{it}} \right)^{(1-\mu)\frac{\alpha}{1-\alpha}} h_{it} \tag{5}$$

Development accounting results from this alternative specification are presented in table 3. Equipment, structures, and human capital reproduce a log variance in income per worker of 0.6, i.e., the factors account for a log variance of 42.39 percent. This is considerably larger than the log variance from a decomposition based on the capital per worker (see, table 2). The 90-10 ratio from this specification is 8.84, implying a TFP gap of 2.51. Figure 11 plots the TFP levels implied by this specification, along with income per worker (see, also, table 5). The correlation coefficient between these TFP measures and the income per worker is 0.7.

Table 3: Hall and Jones (1999) Income Accounting

	Log variance	90-10 ratio
Data	1.41	22.24
$\left(\frac{K_{it}}{Y_{it}}\right)^{\frac{\alpha}{1-\alpha}} h_{it}$	0.25	3.69
$\left(\frac{K_{eit}}{Y_{it}}\right)^{\mu\frac{\alpha}{1-\alpha}} \left(\frac{K_{sit}}{Y_{it}}\right)^{(1-\mu)\frac{\alpha}{1-\alpha}} h_{it}$	0.60	8.84

Figure 11: Measured TFP, $\frac{y_{it}}{\left(\frac{K_{eit}}{Y_{it}}\right)^{\mu\frac{\alpha}{1-\alpha}}\left(\frac{K_{sit}}{Y_{it}}\right)^{(1-\mu)\frac{\alpha}{1-\alpha}}h_{it}}$, and income per worker

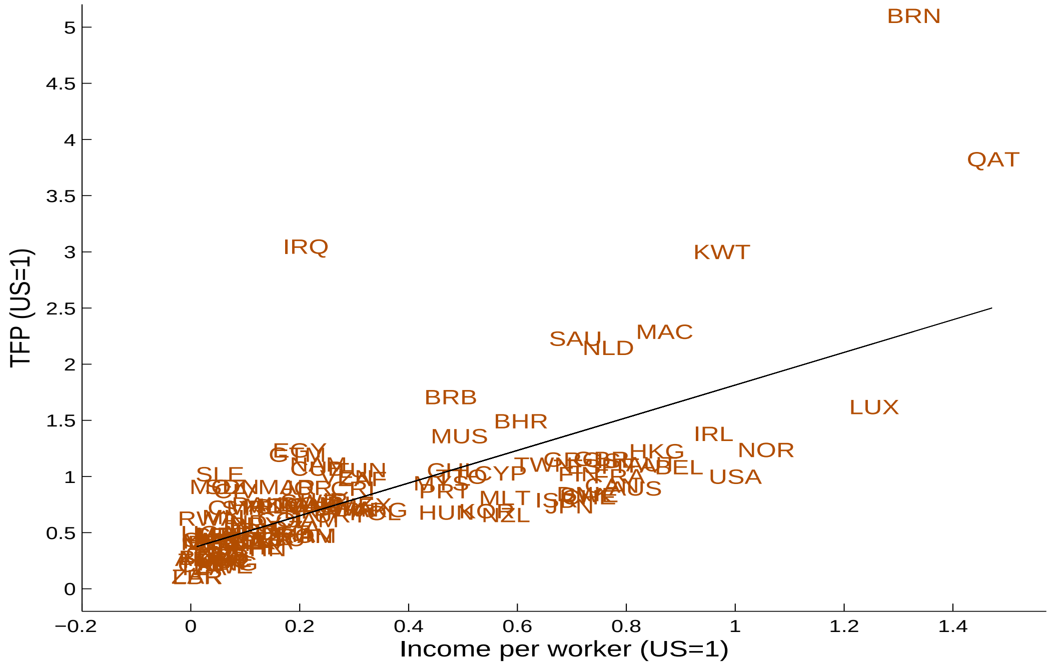
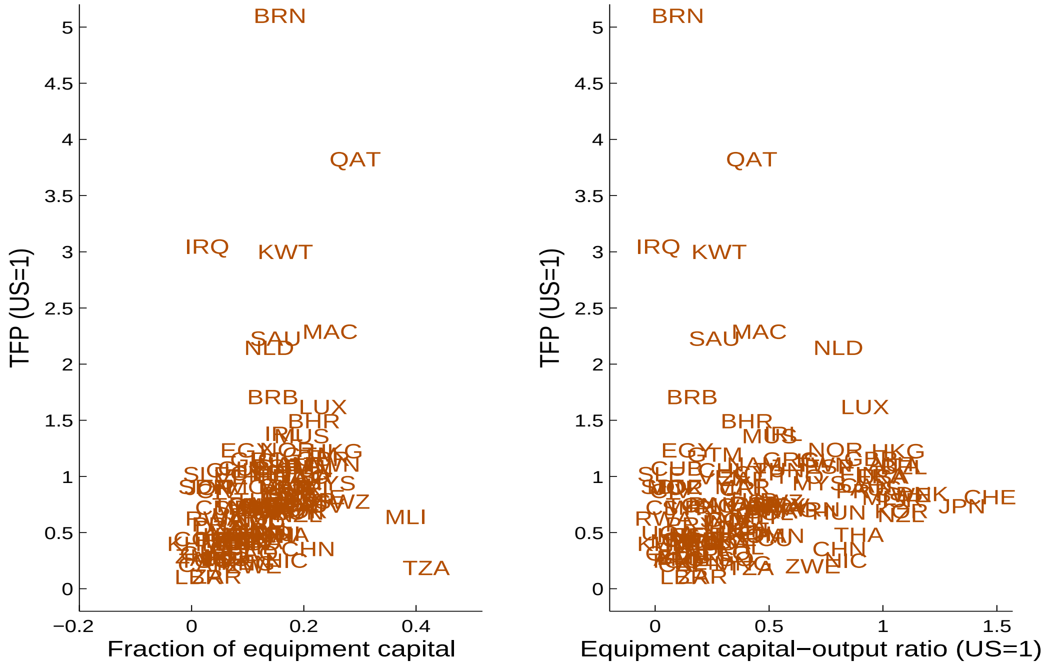


Figure 12: Measured TFP, $\frac{y_{it}}{\left(\frac{K_{eit}}{Y_{it}}\right)^{\mu\frac{\alpha}{1-\alpha}}\left(\frac{K_{sit}}{Y_{it}}\right)^{(1-\mu)\frac{\alpha}{1-\alpha}}h_{it}}$, and equipment capital



In development accounting, the differences in income per worker are due to the differences in factors (equipment capital, structures capital, and human capital per worker), and TFP. A related question is why factors and TFP differ so much across countries. Also, factors are not necessarily orthogonal to productivity. Factors and TFP are likely complementary to each other. This can be seen in figure 12, which plots the TFP levels with the fraction of equipment in capital, and with the equipment capital-output ratio.

What determines the accumulation of equipment and structures capital across countries, especially the evolution of the composition of capital over time? Herrendorf and Valentinyi (2012) examine the sectoral TFPs across countries, and find that the cross-country TFP differences in the production of equipment are larger than those for structures. Countries with high TFP are likely to have high returns to capital accumulation. Put differently, countries characterized by significant distortions to the accumulation of capital are also most likely to have low levels of TFP. This observation relates with the strand of literature on income differences that studies the role of distortions in economic development, and interprets differences in the capital-output ratio as an indicator of distortions to capital accumulation (see, for instance, Restuccia and Urrutia (2001)). That is, poor countries face larger distortions for the accumulation of equipment capital than do rich countries.

The distortions faced by poor countries can be both domestic and international. Restuccia and Rogerson (2008) show that policies that result in heterogeneous plants' facing different prices for capital can lead to sizeable decreases in the output and measured TFP. Buera, Kaboski, and Shin (2010) and Greenwood, Sanchez, and Wang (2010) show that domestic financial frictions lead to a suboptimal firm size distribution, and, hence, cross-country differences in capital-output ratios and economic development. Prices are an important channel through which these distortions affect the capital accumulation and incomes.

In the literature, relative prices have been used to infer the distortions faced by countries in the accumulation of capital. Within this context, international trade potentially plays an important role in determining capital accumulation across countries. Eaton and Kortum (2001) document that equipment production is concentrated in a few countries, and poor countries depend on international trade in capital goods for their equipment. In fact, equipment imports are systematically related with the income levels. Thus, trade in equipment is likely an important determinant of the composition of capital across countries. This points to a need for future research on determinants of the composition of capital and, hence, of economic development.

5 Conclusion

In this paper, I present new information on the composition of physical capital for 119 countries. The cross-country differences in equipment capital are much larger than the differences in structures capital. The equipment capital-output ratio is a factor of approximately 7 between rich and poor, while the structures capital-output ratio is a factor of only 3. The cross-country dispersion in the equipment capital-output ratio has also increased over time, while the dispersion in the structures capital-output ratio has declined. Through development accounting that incorporates equipment and structures capital, I found that the new measures of heterogeneous capital increase our understanding of the cross-country income differences by up to five percent. The contribution of capital composition to income differences is systematically related with the income levels.

I then explored possible explanations for the composition of capital differences across countries. Complementarity between technology (and its growth) and the return to accumulation of equipment capital is potentially an important determinant of the composition of capital across countries. The larger cross-country differences in equipment capital versus structures capital also imply that the poor countries face much larger distortions for the accumulation of equipment capital than do rich countries. Poor countries have poorly developed financial markets and, also, depend on international trade for their supply of equipment. Thus, future research on the determinants of the composition of capital is imperative for an understanding of the cross-country economic development.

References

Barro, R. J. and J.-W. Lee (2010, April). A new data set of educational attainment in the world, 19502010. Working Paper 15902, National Bureau of Economic Research.

Bems, R. (2008). Aggregate investment expenditures on tradable and nontradable goods. *Review of Economic Dynamics 11*, 852883.

Boddy, R. and M. Gort (1971). The substitution of capital for capital. *The Review of Economics and Statistics 53*(2), 179–188.

Buera, F. J., J. P. Kaboski, and Y. Shin (2010). Finance and development: A tale of two sectors. forthcoming: American Economic Review.

Caselli, F. (2005). Accounting for cross-country income differences. In P. Aghion and S. Durlauf (Eds.), *Handbook of Economic Growth*, Handbook of Economic Growth, Chapter 9, pp. 679–741. Elsevier.

Caselli, F. and D. J. Wilson (2004). Importing technology. *Journal of Monetary Economics 51*, 1–32.

Dabla-Norris, E., J. Brumby, A. Kyobe, Z. Mills, and C. Papageorgiou (2012). Investing in public investment: an index of public investment efficiency. *Journal of Economic Growth 17*, 235–266.

De Long, J. B. and L. H. Summers (1991). Equipment investment and economic growth. *The Quarterly Journal of Economics 106*(2), 445–502.

Eaton, J. and S. Kortum (2001). Trade in capital goods. *European Economic Review 45*, 1195–1235.

Gollin, D. (2002). Getting income shares right. *Journal of Political Economy 110*(2), 458–474.

Greenwood, J., Z. Hercowitz, and P. Krusell (1997). Long-run implications of investment-specific technological change. *American Economic Review 87*(3), 342–362.

Greenwood, J., J. M. Sanchez, and C. Wang (2010). Quantifying the impact of financial development on economic development. Working Paper 10-05, Federal Reserve Bank of Richmond.

Hall, R. E. and C. I. Jones (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics 114*(1), 83–116.

Hendricks, L. (2002). How important is human capital for development? evidence from immigrant earnings. *The American Economic Review 92*(1), 198–219.

Herrendorf, B. and Á. Valentinyi (2006). Which sectors make poor countries so unproductive? Working paper.

Herrendorf, B. and Á. Valentinyi (2012). Which sectors make poor countries so unproductive? *Journal of the European Economic Association 10*(2), 323341.

Heston, A., R. Summers, and B. Aten (2009, August). Penn World Table version 6.3. Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.

Klenow, P. and A. Rodríguez-Clare (1997, September). The neoclassical revival in growth economics: Has it gone too far? In *NBER Macroeconomics Annual 1997, Volume 12*, NBER Chapters, pp. 73–114. National Bureau of Economic Research, Inc.

Krusell, P., L. E. Ohanian, J.-V. Ríos-Rull, and G. L. Violante (2000). Capital-skill complementarity and inequality: A macroeconomic analysis. *Econometrica 68*(5), 1029–1053.

Pritchett, L. (2000). The tyranny of concepts: Cudie (cumulated, depreciated, investment effort) is not capital. *Journal of Economic Growth 5*, 361–384.

Restuccia, D. and R. Rogerson (2008, October). Policy distortions and aggregate productivity with heterogeneous plants. *Review of Economic Dynamics 11*(4), 707–720.

Restuccia, D. and C. Urrutia (2001). Relative prices and investment rates. *Journal of Monetary Economics 47*(1), 93–121.

Sato, K. (1967). A two-level constant-elasticity-of-substitution production function. *The Review of Economic Studies 34*(2), 201–218.

Schoellman, T. (2012). Education quality and development accounting. *Review of Economic Studies 79*(1), 388–417.

Valentinyi, Á. and B. Herrendorf (2008). Measuring factor income shares at the sectoral level. *Review of Economics and Statistics 11*(4), 820–835.

APPENDIX

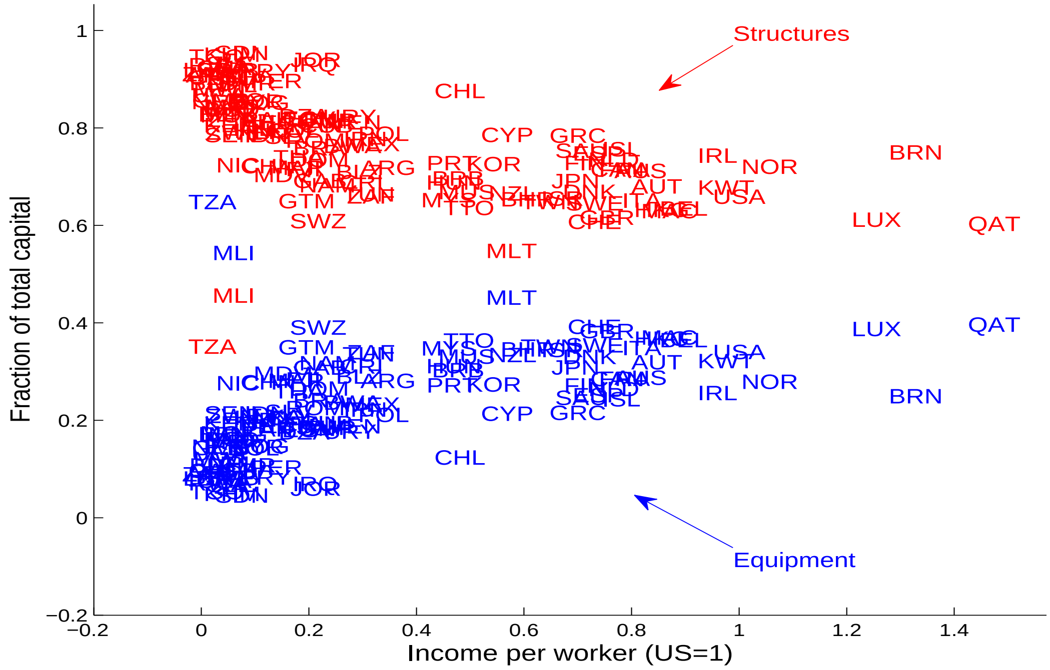
A Robustness

The capital stocks measured with the perpetual inventory method rely on estimates of depreciation rates. In this section, I reconstruct equipment and structures capital stocks for alternative values of depreciation rates that have been used previously in the literature. I use 12 percent for the depreciation rate of equipment and 6 percent for structures, as in Greenwood, Hercowitz, and Krusell (1997). δ_{agg} is unchanged at 6 percent. The corresponding capital-output ratios are presented in table 4.

Table 4: Income per worker and capital-output ratio, $\delta_e = 0.12$ and $\delta_s = 0.06$

	Income	Aggregate capital	Equipment	Structures
90th percentile	65842.44	2.36	0.67	1.26
10th percentile	2960.20	0.72	0.10	0.57
Ratio	22.24	3.26	7.00	2.19

Figure 13: Composition of capital, $\delta_e = 0.12$ and $\delta_s = 0.06$

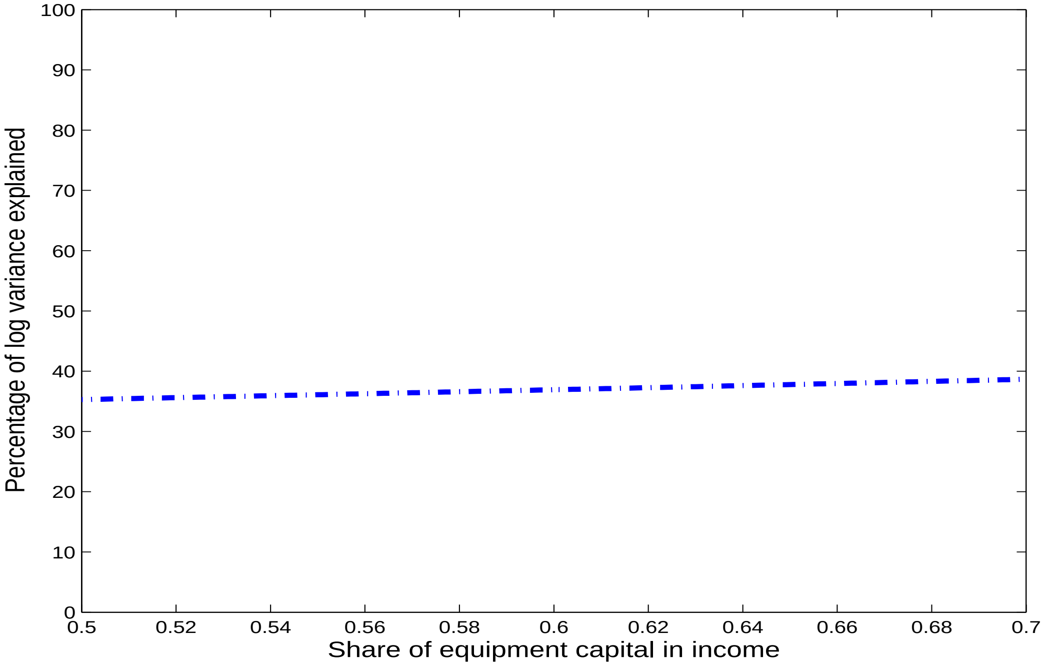


The gap between rich and poor countries in the structures capital-output ratio falls from 2.95 to 2.19 with the increase in the depreciation rate for structures. The equipment capital-output ratio in rich and poor countries shows little response to the change in the depreciation rate. The fraction of equipment and structures capital in the total value of capital is presented in figure 13. Relative to figure 5, with the higher δ_s and lower δ_e, the fraction of equipment in total capital is larger for all countries. The systematic variation with income levels changes by a small magnitude. The correlation coefficient between the equipment capital-output ratio and income per worker is 0.63, which is the same as the correlation in baseline case. The correlation between the structures capital-output ratio and income per worker increases to 0.26 from 0.12 in the baseline case.

B Sensitivity analysis

One might argue that the development accounting results presented in section 3.4 are possibly sensitive to the particular value of the factor share of equipment, μ, that was chosen. In the literature, values for the factor share of equipment capital range between 0.54-0.65. To determine the sensitivity of development accounting results to μ, I conduct the development accounting with values of μ in the range 0.5-0.7. The corresponding fraction of explained variation from the development accounting with the Cobb-Douglas specification (equation 3) are presented in figure 14. Clearly, the results are not very sensitive to the factor share of equipment capital in the neighborhood of the baseline value that is used in this paper. The log variance of income per worker from factors is 0.50 with μ =0.5 and 0.54 with μ =0.7. The fraction of log variance explained by factors ranges from 35.3 percent to 38.7 percent.

Figure 14: Sensitivity of development accounting results w.r.t. μ



C Tables

Table 5: TFP, $\frac{y_{it}}{\left(\frac{K_{eit}}{Y_{it}}\right)^{\mu\frac{\alpha}{1-\alpha}}\left(\frac{K_{sit}}{Y_{it}}\right)^{(1-\mu)\frac{\alpha}{1-\alpha}}h_{it}}$, and income per worker

Country	**Isocode**	y (US=1)	**TFP** (US=1)
Afghanistan	AFG	0.02	0.27
Algeria	DZA	0.19	0.54
Argentina	ARG	0.35	0.70
Australia	AUS	0.82	0.90
Austria	AUT	0.85	1.11
Bahrain	BHR	0.61	1.49
Bangladesh	BGD	0.06	0.41
Barbados	BRB	0.48	1.71
Belgium	BEL	0.90	1.08
Belize	BLZ	0.29	0.76
Benin	BEN	0.04	0.41
Bolivia	BOL	0.10	0.43
Botswana	BWA	0.28	0.72
Brazil	BRA	0.22	0.69
Brunei	BRN	1.33	5.10
Burundi	BDI	0.02	0.28
Cambodia	KHM	0.06	0.40
Cameroon	CMR	0.09	0.72
Canada	CAN	0.77	0.92
Central African Republic	CAF	0.02	0.21
Chile	CHL	0.48	1.06
China	CHN	0.12	0.36
Colombia	COL	0.17	0.62
Congo, Dem. Rep.	ZAR	0.01	0.11
Congo, Republic of	COG	0.11	0.44

Continued on Next Page…

Table 5 – Continued

Country	**Isocode**	y (US=1)	**TFP** (US=1)
Costa Rica	CRI	0.30	0.89
Cote d‘Ivoire	CIV	0.08	0.87
Cuba	CUB	0.23	1.07
Cyprus	CYP	0.57	1.03
Denmark	DNK	0.72	0.85
Dominica	DMA	0.22	0.75
Ecuador	ECU	0.16	0.44
Egypt	EGY	0.20	1.23
El Salvador	SLV	0.16	0.74
Fiji	FJI	0.19	0.49
Finland	FIN	0.71	1.02
France	FRA	0.79	1.00
Gabon	GAB	0.22	0.74
Gambia, The	GMB	0.04	0.44
Ghana	GHA	0.04	0.32
Greece	GRC	0.70	1.15
Guatemala	GTM	0.20	1.20
Haiti	HTI	0.05	0.48
Honduras	HND	0.11	0.50
Hong Kong	HKG	0.86	1.23
Hungary	HUN	0.47	0.68
Iceland	ISL	0.78	1.14
India	IND	0.10	0.59
Indonesia	IDN	0.12	0.52
Iran	IRN	0.30	0.71
Iraq	IRQ	0.21	3.05
Ireland	IRL	0.96	1.38
Israel	ISR	0.67	0.79
Italy	ITA	0.82	1.10
Jamaica	JAM	0.22	0.61
Japan	JPN	0.70	0.74
Jordan	JOR	0.21	0.90
Kenya	KEN	0.05	0.23
Korea, Republic of	KOR	0.54	0.69
Kuwait	KWT	0.98	3.00
Laos	LAO	0.05	0.32
Lesotho	LSO	0.06	0.27
Liberia	LBR	0.01	0.11
Luxembourg	LUX	1.26	1.62
Macao	MAC	0.87	2.29
Malawi	MWI	0.03	0.42
Malaysia	MYS	0.46	0.94
Maldives	MDV	0.15	0.74
Mali	MLI	0.06	0.64
Malta	MLT	0.57	0.81
Mauritania	MRT	0.06	0.48
Mauritius	MUS	0.49	1.36
Mexico	MEX	0.32	0.74
Mongolia	MNG	0.07	0.23
Morocco	MAR	0.18	0.91
Mozambique	MOZ	0.05	0.91
Namibia	NAM	0.23	1.11
Nepal	NPL	0.06	0.31
Netherlands	NLD	0.77	2.15
New Zealand	NZL	0.58	0.66
Nicaragua	NIC	0.07	0.25
Niger	NER	0.03	0.41
Norway	NOR	1.06	1.24
Pakistan	PAK	0.12	0.75
Panama	PAN	0.21	0.47
Paraguay	PRY	0.12	0.57
Peru	PER	0.14	0.44

Continued on Next Page…

Table 5 – Continued

Country	**Isocode**	y (US=1)	**TFP** (US=1)
Philippines	PHL	0.12	0.37
Poland	POL	0.34	0.68
Portugal	PRT	0.47	0.87
Qatar	QAT	1.47	3.82
Romania	ROM	0.21	0.47
Rwanda	RWA	0.03	0.63
Saudi Arabia	SAU	0.71	2.23
Senegal	SEN	0.05	0.48
Sierra Leone	SLE	0.05	1.02
South Africa	ZAF	0.32	0.98
Spain	ESP	0.74	1.09
Sri Lanka	LKA	0.14	0.42
Sudan	SDN	0.08	0.91
Swaziland	SWZ	0.22	0.78
Sweden	SWE	0.73	0.84
Switzerland	CHE	0.73	0.82
Syria	SYR	0.10	0.72
Taiwan	TWN	0.65	1.11
Tanzania	TZA	0.02	0.19
Thailand	THA	0.18	0.48
Togo	TGO	0.03	0.25
Tonga	TON	0.20	0.75
Trinidad &Tobago	TTO	0.50	1.00
Tunisia	TUN	0.31	1.06
Turkey	TUR	0.24	0.79
Uganda	UGA	0.03	0.50
United Kingdom	GBR	0.75	1.16
United States	USA	1.00	1.00
Uruguay	URY	0.27	0.66
Venezuela	VEN	0.29	0.99
Zambia	ZMB	0.06	0.29
Zimbabwe	ZWE	0.06	0.20