The Marginal Product of Capital

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Abstract

Whether or not the marginal product of capital (MPK) differs across countries is a question that keeps coming up in discussions of comparative economic development and patterns of capital flows. Attempts to provide an empirical answer to this question have so far been mostly indirect and based on heroic assumptions. The first contribution of this paper is to present new estimates of the cross-country dispersion of marginal products. We find that the MPK is much higher on average in poor countries. However, the financial rate of return from investing in physical capital is *not* much higher in poor countries, so heterogeneity in MPKs is not principally due to financial market frictions. Instead, the main culprit is the relatively high cost of investment goods in developing countries. One implication of our findings is that increased aid flows to developing countries will not significantly increase these countries' incomes. (*JEL codes:* E22, O11, O16, O41. *Keywords:* investment, capital flows).

1 Introduction

Is the world's capital stock efficiently allocated across countries? If so, then all countries have roughly the same aggregate marginal product of capital (MPK). If not, MPK will vary substantially from country to country. In the latter case, the world foregoes an opportunity to increase global GDP by reallocating capital from low to high MPK countries. The policy implications are far reaching.

Given the enormous cross-country differences in observed capital-labor ratios (they vary by a factor of 100 in the data used in this paper) it may seem obvious that the MPK must vary dramatically as well. However, as Lucas (1990) pointed out in his celebrated article, poor countries also have lower endowments of factors complementary with physical capital, such as human capital, and lower total factor productivity (TFP). Hence, large differences in capital-labor ratios may coexist with MPK equalization.[1]

It is not surprising then that considerable effort and ingenuity have been devoted to the attempt to generate cross-country estimates of the MPK. Banerjee and Duflo (2004) present an exhaustive review of existing methods and results. Briefly, the literature has followed three approaches. The first is the cross-country comparison of interest rates. This is problematic because in financially repressed/distorted economies interest rates on financial assets may be very poor proxies for the cost of capital actually born by firms.[2] The second is some variant of regressing ΔY on ΔK for different sets of counties and comparing the coefficient on ΔK. Unfortunately, this approach typically relies on unrealistic identification assumptions. The third strategy is calibration, which involves choosing a functional form for the relationship between physical capital and output, as well as accurately measuring the additional complementary factors – such as human capital and TFP – that affect the MPK. Since giving a full account of the complementary factors is overly ambitious, this method is also highly suspect. Both within and between these three broad approaches results vary widely. In sum, the effort to generate reliable comparisons of cross-country MPK differences has not

[1] See also Mankiw (1995), and the literature on development-accounting [surveyed in Caselli (2004)], which documents these large differences in human capital and TFP.

[2] Another issue is default. In particular, it is not uncommon for promised yields on "emerging market" bond instruments to exceed yields on US bonds by a factor of 2 or 3, but given the much higher risk these bonds carry it is possible that the *expected* cost of capital from the perspective of the borrower is considerably less. Finally, each country offers a whole menu of ionterest rates to choose from, and it is far from easy to choose the appropriate pairs of assets for cross-country comparisons of rates.

yet paid off.

The first contribution of this paper is to present new estimates of the aggregate MPK for a large cross-section of countries, representing a broad sample of developing and developed economies. Relative to existing alternative measures, ours is extremely direct, imposes extremely little structure on the data, and is extremely simple. Essentially, we notice that under conditions approximating perfect competition on the capital market the MPK equals the rate of return to capital, and that the latter multiplied by the capital stock equals capital income. Hence, the aggregate marginal product of capital can be easily recovered from data on total income, the size of the capital stock, and the capital share in income. We then combine standard data on output and capital with recently developed data on the capital share to back out the MPK.

We find substantial differences in the MPK between rich and poor countries. The average MPK in the developing economies in our sample is more than twice as large as in the developed economies. We also find that within the developing-country sample the MPK is three times as variable as within the developed-country sample. When we quantify the efficiency implications of these MPK differentials we find that they are large: a reallocation of capital that equalized the MPK across the countries in our sample would generate a roughly 3 percent increase in global GDP (or 25 percent of the aggregate GDP of the developing countries in our sample).[3]

Capital, then, clearly fails to flow from rich to poor countries to equalize MPKs. So why doesn't it? Our result that MPKs differ implies that different endowments of complementary factors or of TFP are not the only cause of differences in capital intensity. Lucas (1990) also considered a second set of explanations: that world financial markets are segmented. Because of frictions affecting international credit relations, poor countries are unable to fully tap into the capital endowment of the rich world. While Lucas himself is lukewarm about this explanation, the credit-friction view has many vocal supporters. Reinhart and Rogoff (2004), for example, build a strong case based on developing countries' histories of serial default, as well as evidence by Alfaro, Kalemli-Ozcam and Volosovych (2003) and Lane (2003) linking institutional factors to capital flows to poorer economies. Another forceful exposition of the credit-friction view is in Stulz (2005). Our evidence that MPKs differ substantially may seem at first glance supportive of the credit friction camp. However, we present an alternative

[3] Our counter-factual calculations of the consequences of full capital moblity for world GDP are analogous to those of Klein and Ventura (2004) for labor mobility.

explanation that is better supported by the data.

Our second main contribution is indeed to show that MPK differences can be sustained even in a world completely unencumbered by any form of segmentation, discrimination, and agency cost. In particular, even if poor-country agents have access to unlimited borrowing and lending at the same conditions offered to rich-country agents, the MPK will be higher in poor countries if the relative price of capital goods is higher there. Intuitively, poor-country investors in physical capital need to be compensated by a higher MPK for the fact that capital is more expensive there (relative to output).

Using cross-country data on the relative price of investment goods we can rationalize much of the cross-country variation in MPKs without appealing to capital-market frictions. Differences in the rate of return on investing in physical capital are only slightly higher in the developing sample, and the cost of these differences in terms of foregone world GDP drops to about one third of the cost implied by MPK differences. Consistent with the view that financial markets have become more integrated worldwide, however, we also find some evidence that the cost of credit frictions has declined over time.[4]

In sum, we conclude that neither of the popular explanations for the failure of capital to flow across borders is really consistent with the data. MPKs do differ substantially, so we can't only blame differences in human capital, TFP, or other complementary factors. Put another way, the world allocation of physical capital is inefficient. But the rate of return of investing in physical capital *does not* vary dramatically – not nearly as much as the MPK – so it is hard to argue that financial frictions are a big part of the story either. Instead, the reason why poor countries have a higher MPK, even in the presence of fairly free capital flows, is that they face higher costs of installing capital in terms of foregone consumption.[5]

Our results have implications for the recently-revived policy debate on financial aid to developing countries. The existence of large MPK differentials between poor and

[4] Cohen and Soto (2002) also observe that the data are consistent with rate of return equalization, but stop short of a systematic exploration of this issue.

[5] Producing an explanation for the cross-country pattern of the relative price of investment goods is beyond the scope of this paper. The two main explanations that have been proposed are (i) that poor countries tax sales of machinery relatively more than sales of final goods [e.g. Chari, Kehoe and McGrattan (1996)]; and that (ii) poor countries have relatively lower TFP in producing capital goods than in producing final goods [e.g. Hsieh and Klenow (2003)]. It may also reflect differences in the composition of output or in unmeasured quality.

rich countries would usually be interpreted as *prima facie* support to the view that increased aid flows may be beneficial. But such an interpretation hinges on a credit-friction explanation for such differentials. Our result that financial rates of return are fairly similar in rich and poor countries, instead, implies that any additional flow of resources to developing countries is likely to be offset by private flows in the opposite direction seeking to restore rate-of-return equalization.[6]

2 MPK Differentials

Consider the standard neoclassical model featuring a constant-return production function and perfectly competitive (domestic) capital markets. Under these (minimal) conditions the rental rate of capital equals the marginal product of capital, so that aggregate capital income is $MPK\text{x}K$, where K is the capital stock. If α is the capital share in GDP, and Y is GDP, we then have $\alpha = MPK\text{x}K/Y$, or

$$MPK = \alpha\frac{Y}{K}.$$

We obtain cross-country data on Y, K, and α from the dataset developed by Caselli (2004), where more details can be found. Briefly, Y is GDP in purchasing power parity (PPP) from Version 6.1 of the Penn World Tables [PWT, by Heston, Summers and Aten (2004)]; K is constructed with the perpetual inventory method from time series data on real investment, also from the PWT; and α is 1 minus the labor share in GDP (essentially, employee compensation plus an adjustment for the labor income of the self-employed), as constructed by Bernanke and Gurkaynak (2001). It is the latter data that puts the heaviest constraints on the sample size, so that we end up with 53 countries. These data are reported in Appendix Table 7. Capital per worker, k, and the capital share are also plotted against output per worker, y, in Appendix Figures 8 and 9.

[6] Our conclusion that a more integrated world financial market would not lead to major changes in world output is in a sense stronger than Gourinchas and Jeanne (2003)'s conclusion that the welfare effects of capital-account openness are small. Gourinchas and Jeanne (2003) find large (calibrated) MPK differentials, and consequently predict large capital inflows following capital-account liberalization. However, they point out that in welfare terms this merely accelerates a process of convergence to a steady state that is independent of whether the capital-account is open or closed. Hence, the discounted welfare gains are modest. Our point is that, even though differences in MPKs are large, differences in financial rates of return are small, so we should not even expect much of a reallocation of capital in the first place.

It is important to observe that, relative to alternative estimates in the literature, our estimates of the MPK require no functional form assumptions (other than linear homogeneity), much less that we come up with estimates of human capital, TFP, or other factors that affect a country's MPK. Furthermore, the assumptions we do make are typically shared by the other approaches to MPK estimation, so the set of restrictions we impose is a strict subset of those imposed elsewhere.[7]

The implied MPKs are reported in Appendix Table 7, and plotted against GDP per worker, y, in Figure 1. The overall relationship between the MPK and income is clearly negative. However, the non-linearity in the data cannot be ignored: there is a remarkably neat split whereby the MPK is highly variable and high on average in developing countries (up to Malaysia), and fairly constant and low on average among developed countries (up from Portugal). The average MPK among the 29 lower income countries is 27 percent, with a standard deviation of 9 percent. Among the 24 high income countries the average MPK is 11 percent, with a standard deviation of 3 percent. Neither within the subsample of countries to the left of Portugal, nor in the one to the right, there is a statistically significant relationship between the MPK and y [nor with $\log(y)$].

2.1 Quantifying the deadweight loss

To provide a quantitative assessment of the importance of the variation in MPK uncovered by the previous section we compute counter-factual incomes under a reallocation of capital from low- to high-MPK countries. The difference between the resulting counterfactual world GDP and observed world output is a measure of the cost borne by the world for not equalizing MPKs.

While our MPK estimates are free of functional form assumptions, in order to perform our counterfactual calculations me must now choose a specific production function. We thus fall back on the standard Cobb-Douglas workhorse:

$$y = k^{\alpha} X^{1-\alpha}, \tag{1}$$

where $X^{1-\alpha}$ is a summary of the factors complementary to capital. A popular version of $X^{1-\alpha}$ is $(Ah)^{1-\alpha}$, where A is TFP and h is human capital per worker, but for our

[7] This is not to say that these restrictions are innocuous, of course. For example, we rule out adjustment costs to the stock of capital – which in certain models could drive a wedge between the rental rate on capital and the MPK.

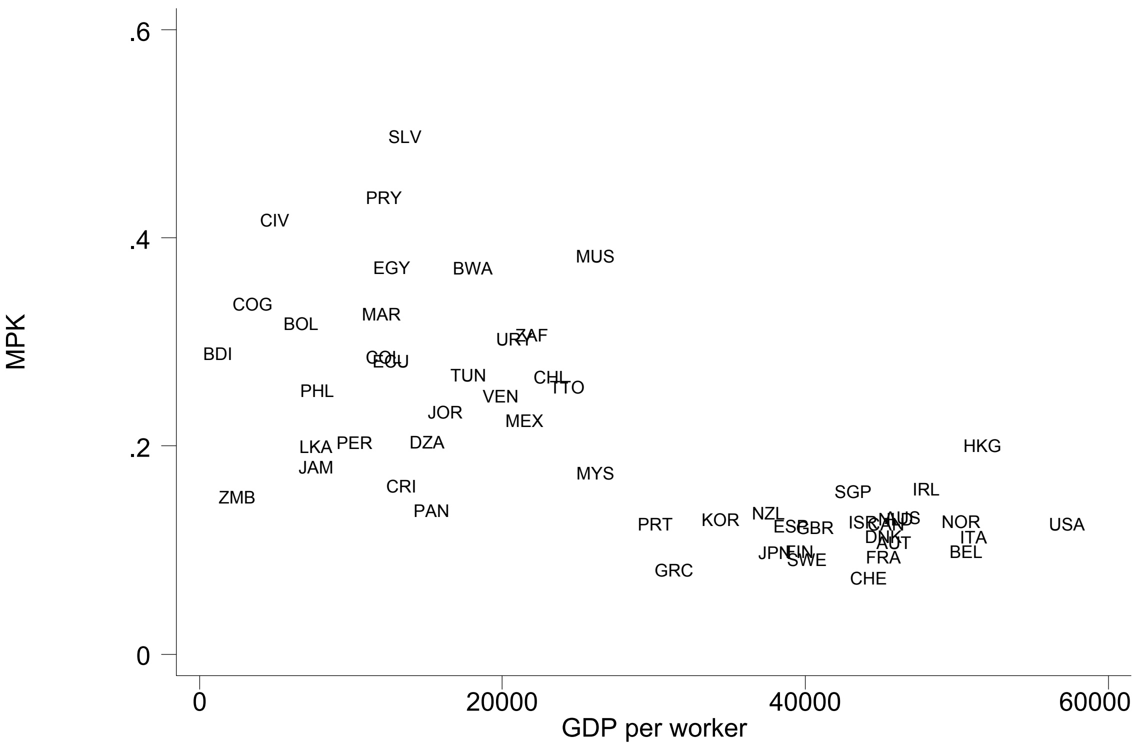

Figure 1: Implied MPKs

purposes we can leave the interpretation of this term entirely unspecified. Of course α continues to be the capital share.

Under (1) the marginal product of capital is

$$MPK = \alpha k^{\alpha-1} X^{1-\alpha}.$$

Suppose now that capital was reallocated across countries in such a way that the MPK took the same value, MPK^*, everywhere. Then the counter-factual level of capital in a generic country would be (inverting the last expression):

$$k^* = \left(\frac{\alpha}{MPK^*}\right)^{\frac{1}{1-\alpha}} X. \tag{2}$$

Countries with a greater stock of complementary characteristics, and a larger capital share, would be assigned a larger capital stock.

The resource constraint is obviously that the counter-factual capital stocks do not exceed the world endowment, or

$$\sum k^* L = \sum kL,$$

where L is the labor force. Hence, summing over (2) and substituting we get:

$$\sum kL = \sum \left(\frac{\alpha}{MPK^*}\right)^{\frac{1}{1-\alpha}} XL. \tag{3}$$

Now notice that the quantity X can be backed out for each country as $(y/k^{\alpha})^{1/(1-\alpha)}$, from the data at hand. The only unknown in (3) is thus MPK^*, which can be solved for with a simple non-linear numerical routine (the solution is 0.1274).

With the counterfactual world MPK at hand we can use equation (2) to back out each country's assigned capital stock when MPKs are equalized.[8] Figure 2 plots the resulting counter-factual distribution of capital-labor ratios against the actual distribution. The solid line is a 45-degree line. Not surprisingly, most developing countries would be recipient of capital under the MPK-equalization scheme, and the developed economies would be senders (the exceptions are high-income countries with very high X/k). The magnitude of the changes in capital-labor ratios is fairly spectacular, with the average developing country experiencing a 300 percent increase. In the average rich country the capital-labor ratio falls by 12 percent. These figures remain in the same ball park when weighted by population. The average developing country worker experiences a still sizable 235 percent increase in his capital endowment. The average rich-country worker loses 18 percent of his capital allotment. In order to achieve this reshuffling, 18 percent of the world's capital stock would have to be shipped across borders.

Despite this substantial amount of reallocation, many developing countries would still have less physical-capital per worker, reflecting their lower X. Hence, some fraction of the overall difference in capital-labor ratios between rich and poor countries can be attributed to differences in complementary factors (more on this below).

We can plug the k^*s in the production function (1) (together with the observed values of α and X) to further back out the counterfactual values of each country's GDP under MPK equalization, or y^*.[9] These counter-factual GDPs are plotted in Figure 3, again together with a 45-degree line. Consistent with their increased counter-factual capital-labor ratios, developing countries tend to experience increases in GDP, and rich countries declines. But the differences in MPK are such that while the average developing country experiences a 75 percent gain, the average developed country only "loses" 3 percent. When weighted by population, the average gain in the developing

[8] Note that, from (2), $k^*/k = (MPK/MPK^*)^{1/(1-\alpha)}$.

[9] In fact, we can simply compute $y^*/y = (k^*/k)^{\alpha}$.

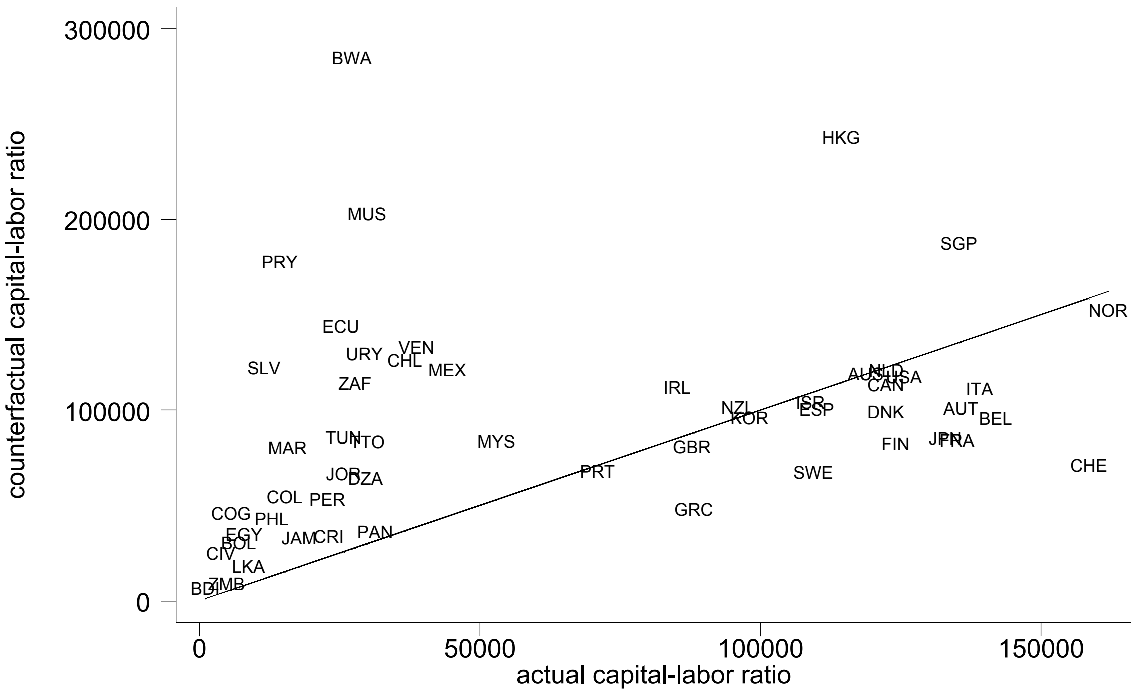

Figure 2: Effects of MPK Equalization on Capital

world is 58 percent, and the average loss in the developed world is 8 percent.

To provide a comprehensive summary measure of the deadweight loss from the failure of MPKs to equalize across countries we compute the percentage difference between world output in the counterfactual case and actual world output, or

$$\frac{\sum (y^* - y)L}{\sum yL}.$$

The result is in the order of 0.03, or world output would increase by 3 percent if we redistributed physical capital so as to equalize the MPK. This number is large. To put it in perspective, consider that the 28 developing countries in our sample account for 12 percent of the aggregate GDP of the sample. Hence, the deadweight loss from inefficient allocation of capital is in the order of one quarter of the aggregate (and hence also per capita) income of developing countries.

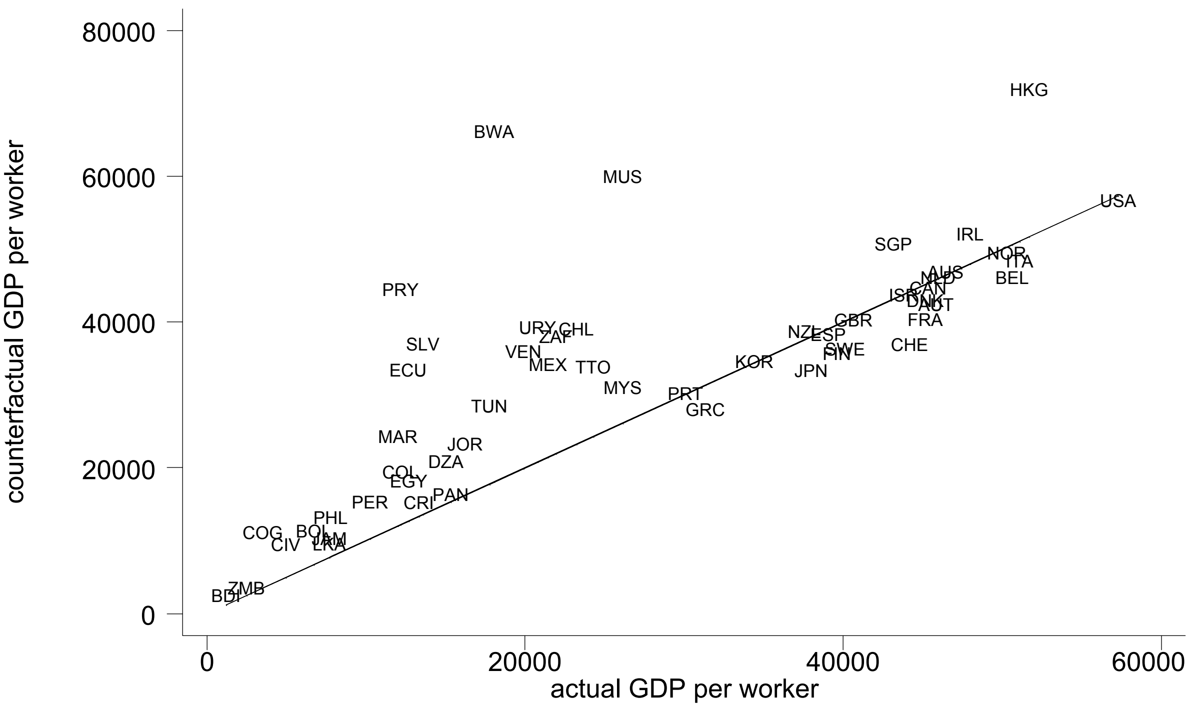

Figure 3: Effects of MPK Equalization on Output

3 MPK Differentials and the Mobility of Capital

Since the aggregate marginal product of capital is high and highly variable in poor countries, and low and fairly uniform in rich countries, it is tempting to conclude that capital flows fairly freely among the latter group, but not towards and among the former. In other words, Figure 1 (as well as 2 and 3) looks like a big win for the credit friction answer to the Lucas question. We now argue, however, for a different interpretation.

If one defines free capital mobility as a situation in which firms in all countries can rent a physical unit of capital at a *common* world rental rate R^*, then clearly we have found that there is no freedom of capital movements. However, the idea of a world rental market for machinery is clearly unrealistic. We therefore explore a narrower but much more realistic sense in which capital may be said to “flow” across countries.

Consider the decision by a firm or a household in one country to purchase a piece of equipment. The return from this transaction is

$$\frac{P_y(t)MPK(t) + P_k(t+1)(1-\delta)}{P_k(t)},$$

where $P_y(t)$ is the domestic price of output at time t, $P_k(t)$ is the domestic price of capital goods, and δ is the depreciation rate. A more realistic definition of "free" capital flows may be that these firms and households also have access to an alternative investment opportunity, that yields a common world interest rate R^*. Abstracting for simplicity from capital gains, then, according to this broader definition of capital mobility we would expect

$$PMPK \equiv \frac{P_y MPK}{P_k} = R^* - (1-\delta).$$

Hence, what would be constant is not the MPK, but the MPK augmented by the (inverse) relative price of capital goods. Countries where capital goods are relatively expensive would have high MPKs. In the appendix we make these heuristic observations more rigorous with the help of two simple illustrative multi-sector models.

We report PWT data on P_y/P_k in Appendix Table 7, and we plot these data against y in Appendix Figure 10. P_y is essentially a weighted average of final-good prices, while P_k is a weighted average of equipment prices. The list of final and equipment goods to be included in the measure is constant across countries. Hence, P_y/P_k is a summary measure of the price of final goods relative to equipment goods. As many authors have already pointed out, capital goods are relatively more expensive in poor countries, so the modified "free capital flows" condition should fit the data better than the unmodified condition.[10]

The resulting cross-country data on $PMPK$ are reported in Appendix Table (7), and plotted in Figure 4. For ease of comparison Figure 4 also retains the plot of MPK. However, the country codes are now used to identify the values of $PMPK$, while the "old" MPKs are identified by the triangles. Broadly speaking, $PMPK$ is much less variable both between and within the low income and the high income groups. The mean of $PMPK$ within the low-income set of countries is 16 percent, and the standard deviation is 6 percent. The mean in the high-income group is 13 percent, with a standard deviation of 2 percent. The "modified free flows" view of the world, therefore, looks like a pretty good approximation.

[10] See, e.g., Hsieh and Klenow (2003) for a further discussion of these data.

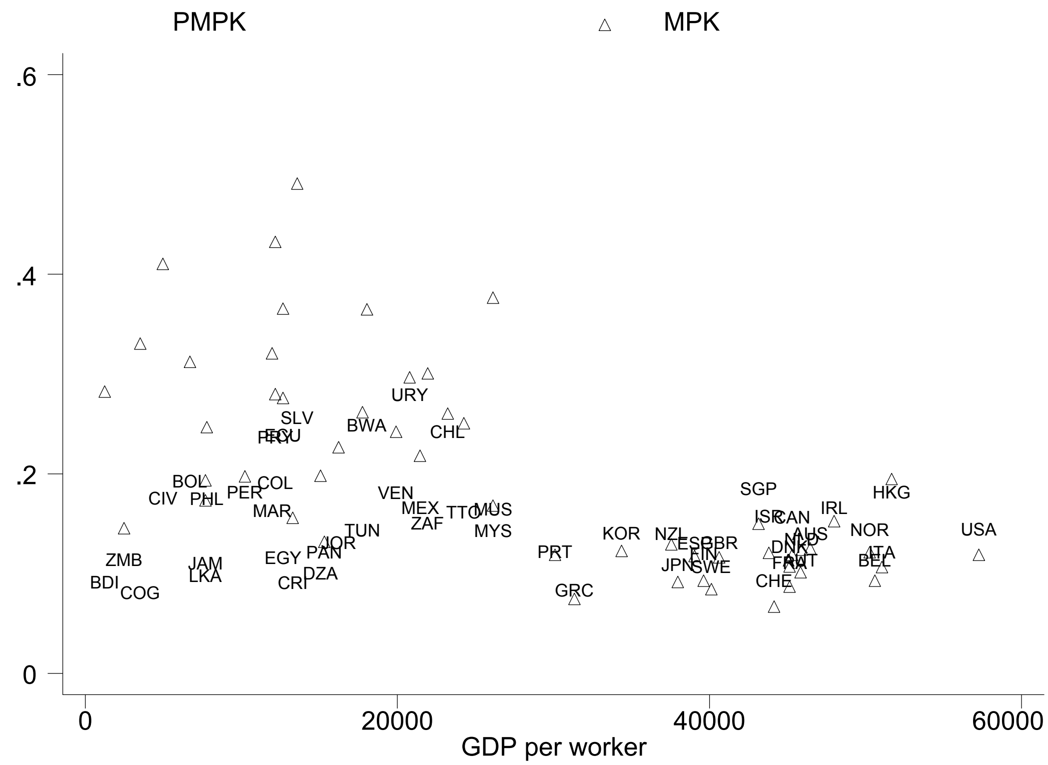

Figure 4: Implied PMPKs

3.1 Re-Quantifying the Deadweight Loss

While differences in $PMPK$ are much smaller than differences in MPK, they don't disappear completely. Since we have argued that it is the differences in $PMPK$ that can be more genuinely attributed to segmented world financial markets, we repeat the calculation of the deadweight loss of financial frictions by imposing that $PMPK$, and not MPK, is the same in all countries (hence we reallocate from low $PMPK$ to high $PMPK$ countries). One way to interpret this exercise is as a decomposition of the overall cost of variations in MPK into a part due to differential access to investment opportunities (the deadweight loss calculated in this section) and a part due to differences in the cost of machinery (the difference between the loss calculated in Section 2.1 and the one calculated here).

While our estimates of $PMPK$ in the previous sub-section were, as our estimates of MPK, free of functional form assumptions, to repeat the steps of Section 2.1 for the case in which $PMPK$ is equalized across countries we must return to Cobb-

Douglas. The new counter-factual assignment of capital per worker is

$$k^* = \left(\frac{P_y}{P_k} \frac{\alpha}{PMPK^*} \right)^{\frac{1}{1-\alpha}} X, \tag{4}$$

and the equation to be solved to obtain the counterfactual common-level of $PMPK$ is

$$\sum kL = \sum \left(\frac{P_y}{P_k} \frac{\alpha}{PMPK^*} \right)^{\frac{1}{1-\alpha}} XL.$$

The new counter-factual distribution of k^* is plotted in Figure 5 ($PMPK^*$ is 0.1284). Not surprisingly, the counter-factual experiment now involves much less reallocation of capital from rich to poor countries. The average developing country increases its capital-labor ratio by only 61 percent (against 300 percent in the MPK-equalization experiment), and the average developing-country worker by 46 percent (against 235 percent). In the average developed country the capital-labor ratio remains essentially unchanged, while the average rich-country worker loses 4 percent of his capital stock. The implication is that – given the observed pattern of the relative price of investment goods – a fully integrated and frictionless world capital market would *not* produce an international allocation of capital much different from the observed one.

Similarly, as shown in Figure 6, once capital is reallocated across countries so as to equalize the rate of return to physical-capital investment (corrected for price differences), the counter-factual world income distribution is much closer to the observed one than in the MPK-equalization case. The average developing country experiences a still significant 20 percent increase in GDP. However, as the figure makes clear these gains are concentrated in only a handful of outliers. When weighted by population, the average gain in the developing world is 16 percent. The impact on rich countries is essentially zero on average (both weighted and unweighted).

In terms of the overall share of world GDP lost to the failure to equalize $PMPK$, the deadweight loss is now only in the order of 0.01, or about one third of its value when the counterfactual is MPK equalization. Hence, it is not primarily capital-market segmentation that generates lower world income. Rather, it is the relative costliness of installing physical capital in poor countries.

Indeed, we believe that 1 percent is an upper bound on the cost of segmented credit markets. To see why let us rewrite the arbitrage condition under free capital flows as

$$\frac{P_y MPK}{P_k}(1 - t_k) + (1 - \delta) = R^*(1 - t^*). \tag{5}$$

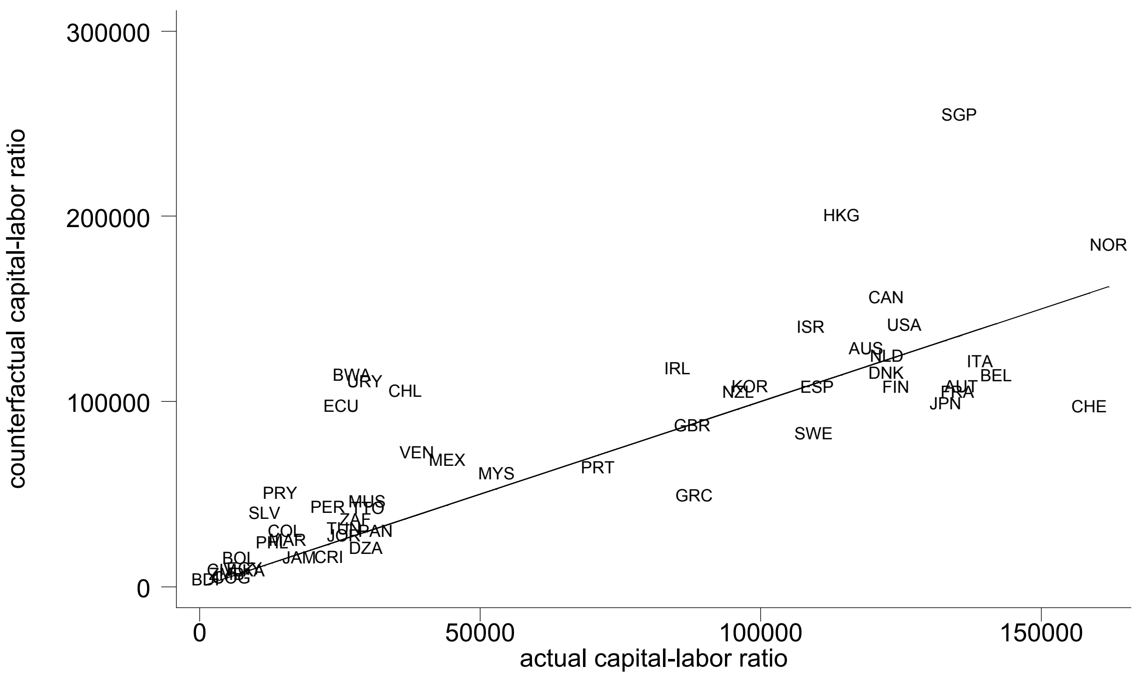

Figure 5: Effects of PMPK Equalization on Capital

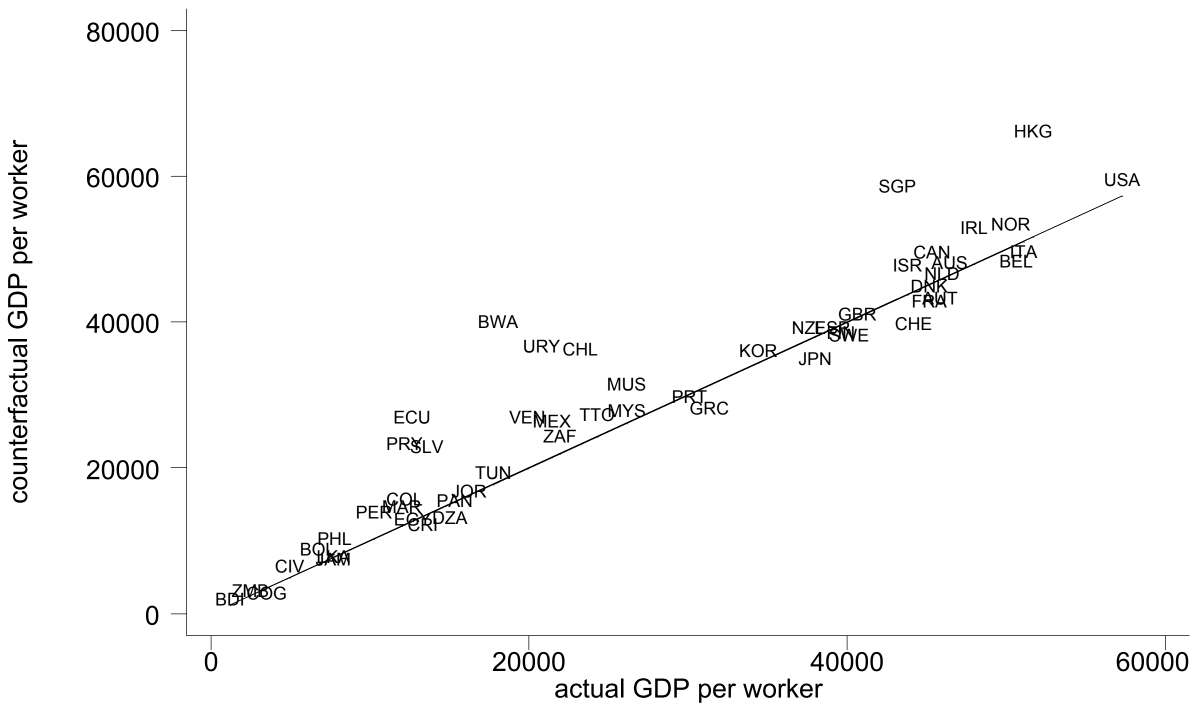

Figure 6: Effects of PMPK Equalization on Output

We think of t_k as an "effective physical-capital income tax rate," and t^* as an "effective financial-capital income tax." While macroeconomists are not used to draw distinctions between types of capital-income taxes, anecdotal evidence from developing countries suggests that physical capital installed domestically is more easily targeted by the tax authorities than various forms of financial investment, especially in offshore accounts. This is even more likely if one takes a broad view of physical-capital income taxation that includes expropriation by rent seeking governments, and of financial-capital income as more easily hidden from the tax authorities.[11]

While we do not have direct data on t_k and t^*, it seems very likely that the former is large in poor countries (partly as a result of corruption and rent seeking), and the latter is smaller in poor countries (largely as the result of greater opportunities for tax evasion). It is clear then that, with this pattern of effective taxation, one should

[11] Think about the relative attraction of investing in land and farm machinery vs Swiss bank accounts in contemporary Zimbabwe.

be able to explain an even greater fraction of the cross-country variance in MPKs, without appealing to segmented capital markets. Put another way, domestic factors (relative prices and relative taxes) would then account for more than two thirds of the deadweight loss from the failure to equalize MPKs, and imperfect access to world credit markets would only account for a relatively small remainder.[12]

4 Explaining Differences in Capital-Labor Ratios

One way of taking stock of our results is to look at their implications for Lucas' classic question as of the sources of large cross-country differences in the capital-labor ratio. In particular, we can now ask how much of this variation can be attributable to variation in the complementary country-specific factor X, how much to differences in the relative price of investment goods, P_y/P_k, and how remains unexplained, and must therefore be attributed to credit-market imperfections.

4.1 Overall variance

How much variance in capital labor ratios can be attributed to X? Equation (2) computes the counter-factual capital, k^*, that would prevail if credit markets were perfect and all countries had the same relative prices. As is clear from the equation, all the cross-country variation in k^* comes from variation in the complementary factor X (and from variation in α). The log-variance of this k^* is 0.683. The overall variance of $\log(k)$ in our sample is 1.371. Hence, things like human capital and TFP can explain roughly one half of the overall variance of k. Lucas' emphasis on complementary factors was appropriate: they are important.

As we argued above, an additional source of differences in k is due to differences in the relative price of equipment: countries where equipment is more expensive will invest less. Equation (4) computes capital stocks that would prevail in a world of perfect credit markets, but country-specific relative prices. These counterfactual capital stocks differ because of differences in X *and* differences in P_y/P_k. The startling result is that the variance of this version of $\log(k^*)$ is 1.563, i.e. *higher* than the observed variance in capital-labor ratios. This can actually be seen in Figure 6, where the range of

[12] Equation (5) also implies that a higher MPK in poor countries could be partially explained by higher "effective" depreciation rates, δ. Again, higher depreciation in poor countries is plausible in view of their physical environment.

variation of k^* is larger than the range of variation in k. Hence, one could argue that credit frictions – far from explaining why capital-labor ratios are not equalized – play actually a role in preventing capital from flowing from capital-poor to capital-rich ones! Instead, the biggest single source of cross-country differences in capital-labor ratios is that the relative cost of capital is higher in poor countries – an explanation that did not feature in Lucas' menu.[13]

4.2 Rich-Poor Differential

In the previous subsection we obtained the startling result that – absent credit imperfections – the counter-factual variance of k, k^* from equation (4), would be larger than the observed one. Inspection of Figure 6, however, suggests that this increased in variance largely reflects a (counter-factual) increase in variance within the rich-country group, rather than an increase in variance between the poor and the rich. Hence, this experiment does not fully capture the spirit of Lucas' question.

To focus on rich-poor differentials, then, we repeat the analysis for the ratio of (weighted) average k in the developed-country sample to the (weighted) average k in the developing-country group. The ratio of weighted-average k^*s from (2) is 1.4; the ratio of weighted-average k^*s from equation (4) is 3.3; and the actual rich-poor weighted average k is 5.3. Hence, these calculations seem to assign a relatively modest role to variation in X (1.4/5.3=0.26); and roughly equal roles to differences in prices [(3.3-1.4)/5.3=0.36] and credit-market imperfections [(5.3-3.3)/5.3=0.38].

How can we reconcile a seemingly large role for credit-market imperfections in determining rich-poor differences in k, with our previous evidence that credit-market imperfections play a modest role in generating MPK differences? The answer is, of course decreasing MPK. By the time countries are assigned their k^* from equation (4),they are sufficiently "up" their production function that relatively small differences in hypothetical and actual returns to investment can coexist with large differences in

[13] It is important to distinguish this conclusion from Hsieh and Klenow (2003)'s observation that most of the cross-country differences in investment per worker are due to lower P_y/P_k in developing countries. Hiseh and Klenow's point is that the amount of foregone consumption (as a share of GDP) for the purposes of investment does not vary much across countries, but that similar sacrifices deliver different amounts of physical capital because of differences in P_y/P_k. Our point is that given the overall amount of physical capital in the world, its allocation across countries is strongly determined by P_y/P_k. The two observations are complementary.

hypothetical and actual capital stocks.

5 Constant Capital Shares

Our main results are based on a sample of 53 countries, the constraint on sample size being determined by the capital share data. In this section we briefly produce an alternative set of estimates of MPK and $PMPK$ based on an assumption that the capital share is constant and equal to 0.33 in every country. The gain is a larger sample size, but the loss is a much more imprecise estimate because we do not use actual capital-share data.

With constant capital shares we now have 87 developing and 28 developed countries in our sample (the threshold for "developed" being, as before, at 30000 international dollars of GDP per worker). The average MPK in the developing sample is 30 percent, with a standard deviation of 11 percent. In the developed sample the average MPK is 13 percent with a 3 percent standard deviation. These numbers are in the same ballpark as the more precise estimates obtained with actual capital share data. So is the deadweight loss from MPK differentials, which is still approximately 3 percent of World GDP.

The results for "price-adjusted" MPK differentials are also in line with those with actual shares. The average $PMPK$ is actually 14 percent both in developing and developed countries (standard deviation 5 percent in the former, 2 percent in the latter), and the deadweight from failure to equalize $PMPK$s is less than 1 percent of World GDP.

6 Time Series Results

In this section we attempt a brief look at the evolution over time of our deadweight loss measures. The results should be taken with great caution because they are predicated on estimates of the capital stock. Since, in turn, the capital stock is a function of time series data on investment, the capital stock numbers become increasingly unreliable as we proceed backward in time.

With that (important) caveat, Figure 7 displays the time series evolution of the world's deadweight loss from MPK differentials and the deadweight loss from $PMPK$ differentials (both computed with observed capital shares). We find little – or perhaps

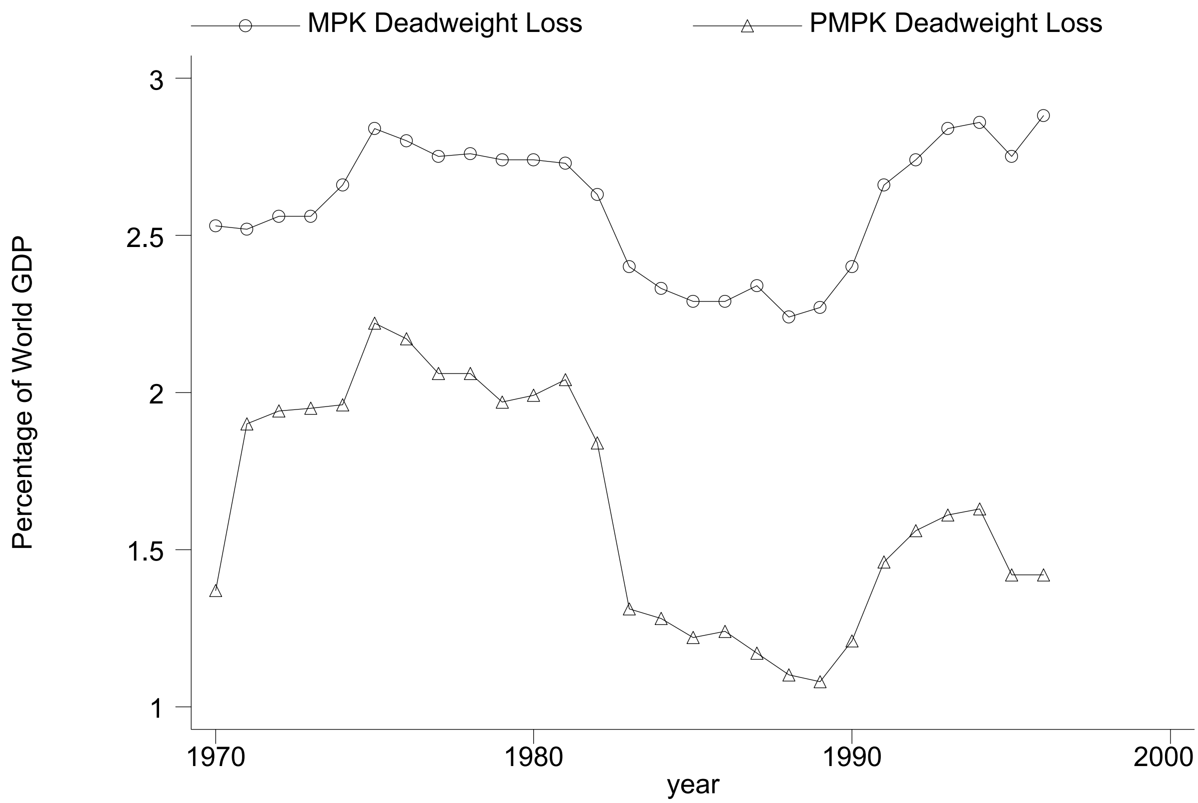

Figure 7: The Cost of MPK and PMPK Differentials

a slightly increasing – long-run trend in the deadweight loss from failure to equalize MPKs. On the other hand, there is some tentative evidence that the deadweight loss from failure to equalize financial returns – the cost of credit frictions – has fallen somewhat over time. This latter result is consistent with the view that world financial markets have become increasingly integrated. [14]

7 Conclusions

We make two main contributions. First, we propose a simple and very direct approach to measuring the aggregate marginal product of capital from national accounts data. We find that the MPK is substantially higher on average in capital-poor countries

[14]The pronounced decline in the deadweight losses during the 1980s may reflect historically low MPKs in developing countries during that decade's crisis. If MPKs in poor countries were low the cost of capital immobility would have been less.

than it is in capital-rich countries. While this result is commonly deemed to support theories emphasizing frictions on world capital markets, our second contribution is to show that differences in the financial rate of return on physical-capital investments are much smaller than differences in MPKs. Heterogeneity in MPKs, therefore, is not associated with financial frictions. Instead, it is caused by differences in the price of investment goods relative to consumption goods. One way to put this is to say that the main reason for capital's failure to flow to poor countries is that what it produces there is of little value, compared to the cost of installation.

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APPENDIX 1: Multi-sector models

Model 1: Complete Specialization

The fact that P_y/P_k varies across countries calls into question our implicit use of a one-sector framework. The simplest way to reinterpret our formulas for a multi-sector world is to assume that each country i produces a different tradable consumption good whose price, in dollars, is P_y^i. There is also a unique tradable investment good whose price, in dollars, is P_k. We assume that the investment good is unique because P_k – unlike P_y – varies little across countries, and also because of evidence that most of the world's equipment stock is imported from only a few countries [Eaton and Kortum (2001)]. Because of that evidence we also assume for simplicity that most countries in our sample only produce the (country-specific) consumption good. [Hence the consumption good must be tradable, so that they can pay for the capital good.]

Given these assumptions the formulas in the paper follow immediately with minor reinterpretation. The capital share in dollars is

$$\alpha^i = \frac{R^i K^i}{P_y^i Y^i}, \tag{6}$$

where R^i is the dollar rental rate (per unit of physical capital) in country i. Profit maximization implies $R^i = P_y^i MPK^i$, and therefore

$$\alpha^i = \frac{MPK^i K^i}{Y^i},$$

so our procedure correctly backs out the physical marginal product in each country.

Suppose now that investors worldwide can borrow and lend dollars at the common rate R^*. Then in each country we must have

$$\frac{P_y^i MPK^i}{P_k} = R^* - (1 - \delta), \tag{7}$$

which is exactly the equation we used.

Model 2: More general model

It may seem that this works only because we assumed that all countries specialize in a different consumption good, but this is not so. Consider a model where each country produces an identical tradable consumption good and a non-tradable consumption good (or a tradable but country-specific consumption good). In this case, the tradable sector generates capital income $P_T MPK_T^i K_T^i$, and the non-tradable sector generates capital income $P^i_{NT} MPK^i_{NT} K^i_{NT}$, where P_T is the world price of the tradable consumption good, P^i_{NT} is the country-specific price of the non-tradable (or specialized tradable) good, and the rest of the notation is self-explanatory. No-arbitrage between the tradable and non-tradable sectors implies $P_T MPK^i_T = P^i_{NT} MPK^i_{NT}$. Hence, the capital share is given by

$$\alpha^i = \frac{P_T MPK^i_T \left(K^i_T + K^i_{NT}\right)}{Y^i_D} = \frac{P_T MPK^i_T K^i}{Y^i_D},$$

where

$$Y^i_D \equiv P_T Y^i_T + P^i_{NT} Y^i_{NT}, \tag{8}$$

is GDP at domestic prices.

Hence, under this reinterpretation, the object that in the paper we call MPK is

$$MPK = \frac{\alpha^i Y^i}{K^i} = \frac{P_T MPK^i_T Y^i}{Y^i_D} = \frac{P_T MPK^i_T}{P^i_y}, \tag{9}$$

where in the last step we used the fact that, in the PWT, $P^i_y = Y^i_D / Y^i$. Now in this model the condition for free access to a world interest rate R^* is

$$\frac{P_T MPK^i_T}{P_k} = R^* - (1 - \delta),$$

and using the just-derived expression for MPK this reduces once again to (7).

Notice that the object that in the text we called the "physical" marginal product of capital, MPK, must now be reinterpreted as a kind of weighted average of the physical MPKs of the tradable and non-tradable sectors. In particular, starting from the definition of the domestic price level, $P_y = \gamma P_T + (1 - \gamma) P_{NT}$, substituting $P_y MPK / MPK_T$ for P_T, and $P_y MPK / MPK_{NT}$ for P_{NT}, one gets:

$$MPK = \frac{MPK_T MPK_{NT}}{\gamma MPK_{NT} + (1 - \gamma) MPK_T}.$$

Hence, our MPKs are still informative about broad differences in the physical returns to reallocating capital across countries.

However, an important caveat that needs to be added is that the deadweight loss calculations in Sections 2.1 and 3.1 are now only accurate under somewhat stringent conditions. In particular, they still go through if we assume that each of the two sectors has Cobb-Douglas technologies with the same capital share, α (though this share can of course vary across countries). Furthermore, we need to assume that labor is sector specific and in each sector there is a given fraction of the labor force, γ - though γ can vary across countries. With these assumptions, equating the financial marginal product of capital in each sector gives

$$P_T k_T^{\alpha-1} X_T^{(1-\alpha)} = P_{NT} k_{NT}^{\alpha-1} X_{NT}^{(1-\alpha)}$$

and the resource constraint is

$$k = \gamma k_T + (1-\gamma) k_{NT}.$$

One can then solve these two equations for the proportion of total capital allocated to each sector as a function of the sector specific X's, prices, and the proportion of labor in each sector.

The aggregate production function is the sum of output in each of the two sectors:

$$y = P_T k_i^{\alpha} X_i^{(1-\alpha)} \gamma + P_{NT}^{*} k_{NT}^{\alpha} X_{NT}^{(1-\alpha)} (1-\gamma),$$

where P_{NT}^{*} is the international-dollar price of non-tradables.

Plugging in the values for capital in each sector found earlier this simplifies to an equation of the form:

$$y = k^{\alpha} X^{(1-\alpha)}$$

where X is a function of the relative price levels, the X's and the share of labor in each sector. It is using this aggregate production function that we estimate the dead weight loss.

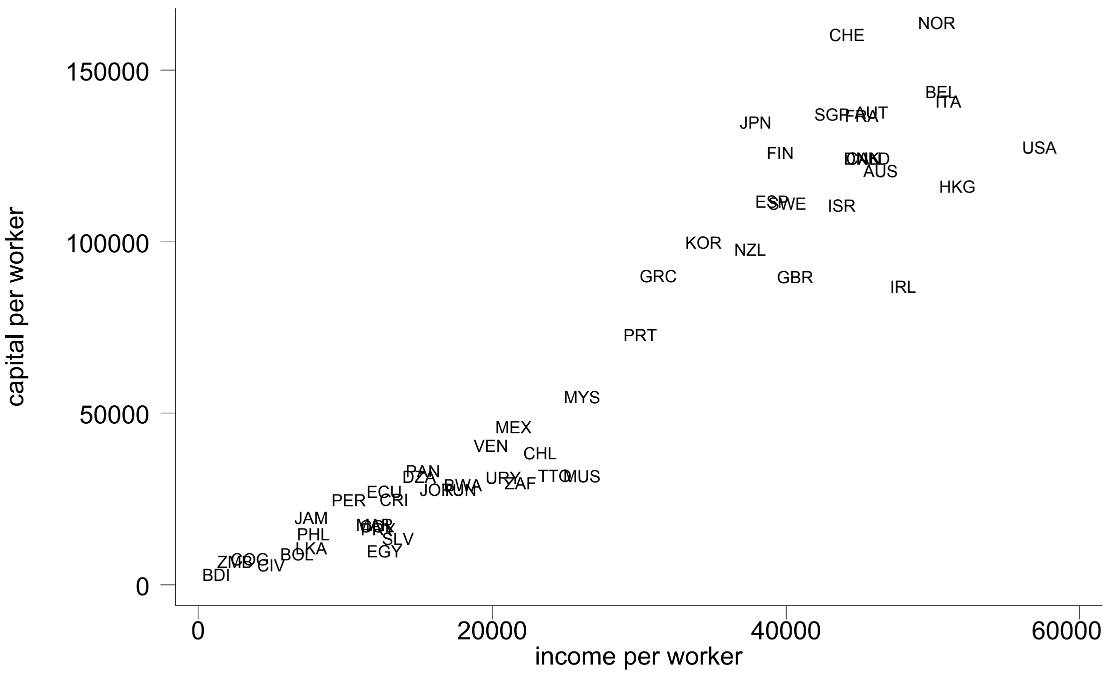

Figure 8: Capital Stocks

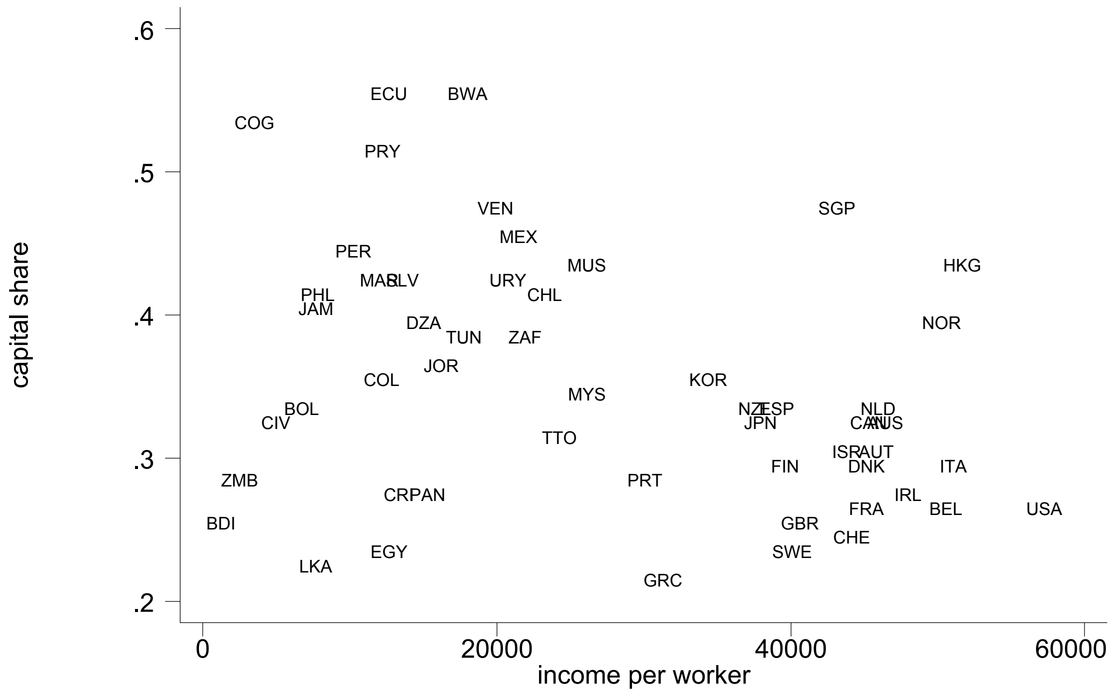

Figure 9: Capital Shares

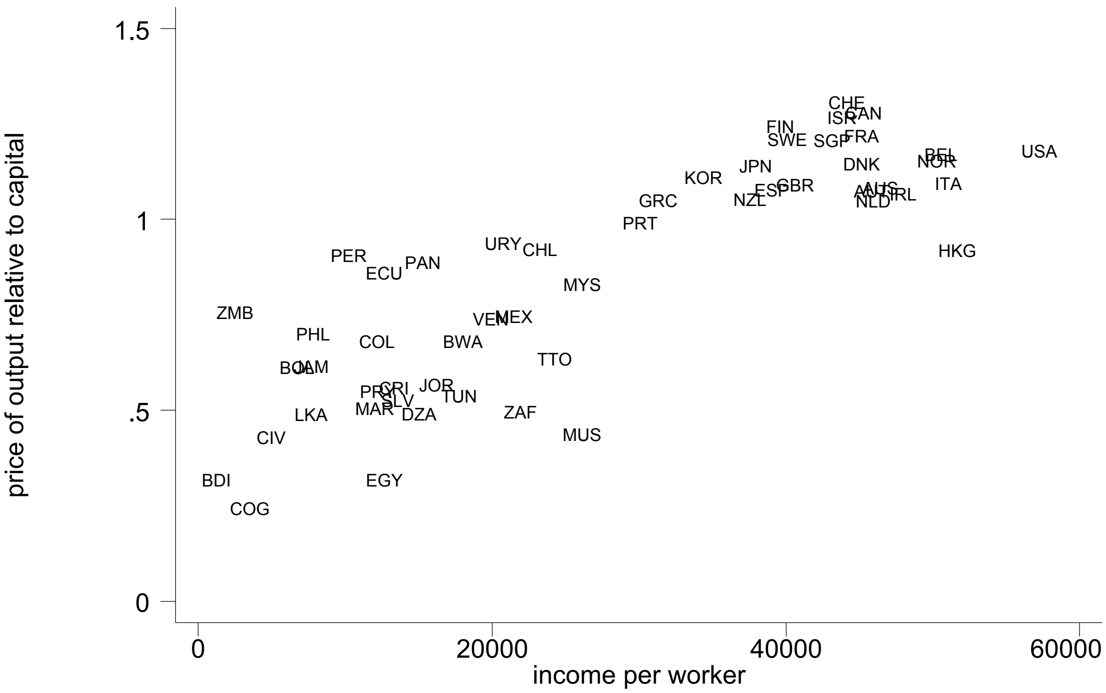

Figure 10: Relative Prices

Country	y	k	α	P_y/P_k	MPK	$PMPK$
AUS	46436	118831	0.32	1.07	0.13	0.13
AUT	45822	135769	0.30	1.06	0.10	0.11
BDI	1226	1084	0.25	0.30	0.28	0.08
BEL	50600	141919	0.26	1.15	0.09	0.11
BOL	6705	7091	0.33	0.60	0.31	0.19
BWA	18043	27219	0.55	0.66	0.36	0.24
CAN	45304	122326	0.32	1.26	0.12	0.15
CHE	44152	158504	0.24	1.29	0.07	0.09
CHL	23244	36653	0.41	0.90	0.26	0.24
CIV	4966	3870	0.32	0.41	0.41	0.17
COG	3517	5645	0.53	0.23	0.33	0.07
COL	12178	15251	0.35	0.66	0.28	0.19
CRI	13309	23117	0.27	0.54	0.16	0.08
DNK	45147	122320	0.29	1.13	0.11	0.12
DZA	15053	29653	0.39	0.47	0.20	0.09
ECU	12664	25251	0.55	0.84	0.28	0.23
EGY	12670	7973	0.23	0.30	0.37	0.11
ESP	39034	110024	0.33	1.06	0.12	0.12
FIN	39611	124132	0.29	1.23	0.09	0.11
FRA	45152	134979	0.26	1.20	0.09	0.10
GBR	40620	87778	0.25	1.07	0.12	0.12
GRC	31329	88186	0.21	1.03	0.07	0.08
HKG	51678	114351	0.43	0.90	0.19	0.18
IRL	47977	85133	0.27	1.05	0.15	0.16
ISR	43795	108886	0.30	1.25	0.12	0.15
ITA	51060	139033	0.29	1.08	0.11	0.11
JAM	7692	17766	0.40	0.60	0.17	0.10
JOR	16221	25783	0.36	0.55	0.23	0.12
JPN	37962	132953	0.32	1.12	0.09	0.10
KOR	34382	98055	0.35	1.09	0.12	0.13
LKA	7699	8765	0.22	0.47	0.19	0.09

Table 1: Data and Implied Estimates of MPK and $PMPK$

Country	y	k	α	P_y/P_k	MPK	$PMPK$
MAR	11987	15709	0.42	0.49	0.32	0.16
MEX	21441	44211	0.45	0.73	0.22	0.16
MUS	26110	29834	0.43	0.42	0.38	0.16
MYS	26113	52856	0.34	0.81	0.17	0.14
NLD	45940	122467	0.33	1.03	0.12	0.13
NOR	50275	161986	0.39	1.14	0.12	0.14
NZL	37566	95965	0.33	1.04	0.13	0.13
PAN	15313	31405	0.27	0.87	0.13	0.11
PER	10240	22856	0.44	0.89	0.20	0.18
PHL	7801	12961	0.41	0.68	0.25	0.17
PRT	30086	71045	0.28	0.97	0.12	0.12
PRY	12197	14376	0.51	0.53	0.43	0.23
SGP	43161	135341	0.47	1.19	0.15	0.18
SLV	13574	11606	0.42	0.51	0.49	0.25
SWE	40125	109414	0.23	1.19	0.08	0.10
TTO	24278	30037	0.31	0.62	0.25	0.15
TUN	17753	25762	0.38	0.52	0.26	0.14
URY	20772	29400	0.42	0.92	0.30	0.27
USA	57259	125583	0.26	1.16	0.12	0.14
VEN	19905	38698	0.47	0.72	0.24	0.17
ZAF	21947	27756	0.38	0.48	0.30	0.14
ZMB	2507	4837	0.28	0.74	0.15	0.11

Table 2: Continuation of Table 1