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Natural Resources and Global Misallocation*†

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Abstract

We explore the efficiency in the allocation of physical capital and human capital across countries. The observed marginal products can differ across countries because of differences in technology (i.e. production functions) and in distortions (i.e. differences in use of factors) across countries. To identify differences in technology, we use new data and propose a simple method to estimate output shares of natural resources, and thus adjust the estimated marginal products of physical and human capital. With a sample of 79 countries from 1970 to 2005, we find that the world has decidedly moved in the direction of efficiency in the allocation of physical capital, from global output losses around 7% in the 1970s to a still substantial 2% by 2005. This trend is accounted for by domestic capital accumulation, as external flows have had little impact. There is also a large degree of heterogeneity in the net gains across countries. For example, we find larger gains for countries with more interventionist policies. With respect to human capital, we uncover much larger global losses from its misallocation. Indeed, contrary to physical capital, we find that the human capital allocation had worsened over time.

JEL codes: O11, O16, O41
Keywords: Natural Resources, Factor Shares, Misallocation, Investment, Capital Flows, Human Capital

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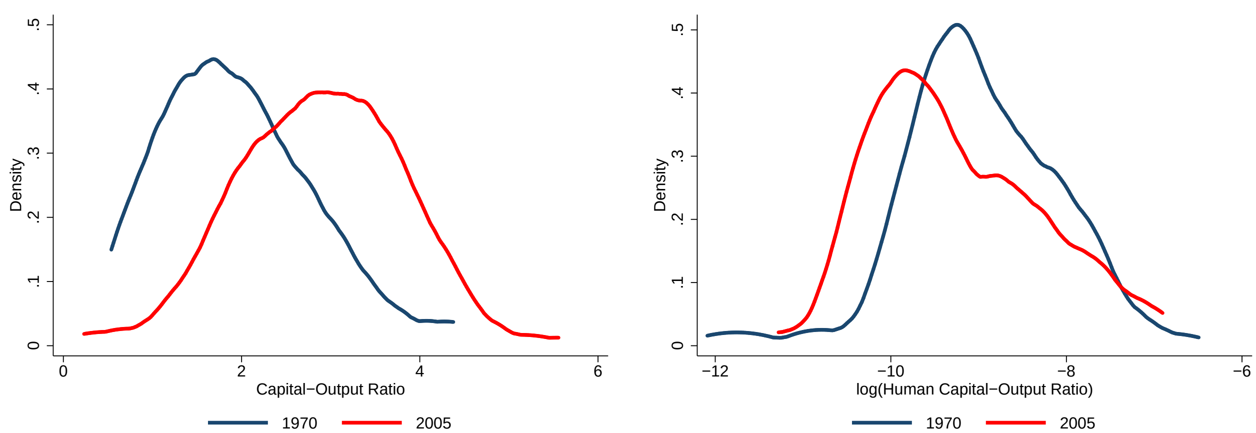
1 Introduction

The observed wide disparities in output per-capita across countries have motivated an extensive literature that separates the contribution of differences in total factor productivity (TFP) and differences in the supply of factors in each country.[1] Often, the economic framework used for such decomposition also leads to large cross-country disparities in the returns of factors. In particular, the standard growth model implies that the return to investment in physical capital is much larger in developing countries than in developed countries (e.g. Lucas, 1990).

The differences in the returns may be sustained by internal and external barriers that prevent the accumulation of inputs in the countries where their marginal products are higher. If so, the removal of those barriers—such as the worldwide movement towards openness observed since the 1980s—could drastically change the allocation of production factors across countries and the resulting world income distribution. In this paper we infer the differences in the marginal product of physical capital (MPK) and human capital (MPH) across countries and evaluate the efficiency and distributional consequences of observed and counter-factual changes in the barriers in a large number of countries for the years 1970 to 2005.

We argue that in order to infer the cross-country barriers and distortions, we should extend the standard Cobb-Douglas production function not only by allowing TFP differences but also by (i) introducing differences in the factor intensity across countries, and by (ii) allowing forms of capital that are not readily mobile across countries, as recently put forward by Caselli and Feyrer (2007). With these modifications, observing a country with a high capital-to-output ratio (K/Y) does not necessarily imply that the MPK of such a country is lower than the MPK of a country for which K/Y is low. It might be the case that production in the former is more capital intensive than production in the latter. This simple consideration is important since, as shown by Figure 1, the data shows a wide range of K/Y and H/Y ratios across countries.

Figure 1: Differences in physical and human capital across countries



Source: Authors' calculations based on PWT 8.0, WB, and FAO.

To illustrate the role of factor intensity differences, consider the physical capital and output of Japan and Costa Rica in 1996. The former is a developed country with a notably high K/Y,

[1] See the handbook chapter by Caselli (2005) and references therein.

almost 3.75, while the latter is a developing country with a very low K/Y, around 1.44. Assuming that both countries have the same production function would lead to the conclusion that Costa Rica heavily taxes or blocks capital in the country and/or that Japan subsidizes capital rather heavily. For example, if the output share of capital is 0.4 in both countries, then the MPK in Japan is 11 percent and 28 percent in Costa Rica. If so, once distortions were lifted, physical capital should flow from Japan to Costa Rica. However, we estimate that the output share of physical capital in Costa Rica and Japan are 0.23 and 0.35, respectively. This implies closer values for their MPKs, 16 percent for Costa Rica and 9.3 percent for Japan. While still significant, the predicted flows of capital and gains from reallocation would be smaller.

Our first contribution is to provide estimates on factor shares that are based solely on the *flow of rents*. Natural resources are predominant forms of capital that are not mobile across countries and whose rents should not be included as returns to the conventional measures of physical capital. Our measures of the rents to natural resources in each country are based on the benchmark countries' estimates from the World Bank.[2] Further, using data from the FAOSTAT, we apply the same methodology used by the World Bank and extend their estimates of natural resource rents to a larger sample period, from 1970 to 2005.

Second, we use our estimates of the output shares of natural resources in conjunction with data from the Penn World Table (PWT 8.0) to compute capital output shares and new measures of MPKs across time and space. We consider two concepts of marginal products. The first one is simply the real or quantity marginal product, which applies to reallocation experiments in which all barriers are removed and all prices are equalized across countries. The second concept incorporates, and takes as given, differences in prices. We refer to this concept as *value* marginal product. For physical capital, it incorporates differences in the relative price of capital across countries.[3] In the case of human capital, price differences are captured by real wages. Differences in those prices may be the result of technology (cost of installing capital) or distortions (legislation on labor practices) and we cannot differentiate between them. Thus, considering reallocation exercises that keep those differences in place seems meaningful. Finally, we analyze what accounts for changes in the global efficiency in the allocation of physical and human capital.

Regarding with physical capital, we find a significant and persistent dispersion in the MPKs across countries. Thus, despite the fact that countries with low K/Y also tend to have low capital shares of output, the data suggest that some barriers may be distorting the allocation of capital across countries. This finding holds for both real and value marginal product of capital (RMPK and VMPK, hereafter), so relative price corrections alone cannot explain cross-country differences in the return to capital. Our results also indicate interesting trends in the world economy from 1970 to the 2000s. Specifically, we show that median MPK has trended down over time. This has occurred because, while the capital income share has increased over time for many of the countries in our sample,[4] the capital-output ratios across countries have outpaced the movements in the factor shares. Further, the dispersion in both notions of MPKs went down substantially between 1970 and the mid 1980s. Such a trend would be expected from the worldwide movement towards liberalization and openness observed during that period (Buera et al. (2011)). However, our findings suggest that barriers are still relevant, even at the end of the sample. Interestingly,

[2] The World Bank uses these estimated rents from natural resources to compute measures of natural capital stock which are publicly available (World-Bank, 2006, 2011).

[3] This notion recognizes the fact that the output and capital prices differ across countries, as emphasized by Restuccia and Urrutia (2001) and Hsieh and Klenow (2007).

[4] A feature consistent with the global labor share decline documented in Karabarbounis and Neiman (2014).

the median MPK has trended down over time.

The notion that barriers have misallocated capital across countries is supported by the relationship of our inferred MPKs with observable measures of policy distortions. To the extent that those distortions have reduced capital formation inside a country, they should be reflected in a higher MPK. We find that, countries that according to the Sachs and Warner (1995) indicator have more interventionist polices, such as trade restrictions, price controls, and excessive regulations, exhibit higher (and also more dispersed) MPKs. The declining incidence of these policies helps explain the global movement towards efficiency in the allocation of capital.

Third, we quantitatively assess global misallocation losses restricting first our analysis to physical capital. While the dispersion of MPKs is informative, it is also far from being a sufficient statistic for global misallocation. This is because countries' sizes and curvatures of the production function both matters for the potential gains from eliminating barriers. We find that barriers have been—and still are—economically significant. Eliminating all frictions, distortions and barriers would have lead to an increase of almost 6% in global output in 1970. The same figure for 2005 would be around 2% of global output. Eliminating only the barriers to capital allocation but keeping those in the prices, would have led to smaller gains, peaking at around 4.4% in 1974, and otherwise flat around 2% over the sample period. Interestingly, both counterfactuals produce to similar figures for the end of the sample, perhaps suggestive that price differences have declined substantially in the latter years. Behind those global gains lie a great deal of heterogeneity across countries. Liberalization of capital flows would lead to output reduction in developed countries, as they export their capital to emerging markets and developing countries. More interestingly, some groups of developing countries, such as South America in the late 1990s and early 2000s, would also end up exporting their capital and contracting their internal output. Most notably, African countries would greatly gain if the barriers to global capital were to be removed.

To quantify the potential extent of global misallocation in more detail, we further explore the gains of reallocating human capital. There are three important findings. First, we find that reallocating human capital to equalize its real marginal return generates global output gains that are an order of magnitude larger than those of physical capital. This may not be surprising. There exist large barriers to labor mobility across countries. Some of those barriers are natural, as the emotional cost of reallocating human beings across countries with different cultures. Some other barriers exist because of legislation, mainly in more developed countries. Second, we find that the global gains from reallocation are much larger when both factors can be reallocated, which is greatly driven by the complementarity between physical and human capital. This holds even in some of our exercises in which there would be no gains if only human capital could be reallocated. Third, we find that if human and physical capital can be reallocated jointly, the direction of the flow of factors is reversed. While in the case of solely physical reallocation the flows are toward poor countries, when both factors are reallocated, we find that capital and labor would flow toward rich countries.

This paper is related to the literature studying the global allocation of capital. Using the standard growth model Lucas (1990) asked why capital didn't flow from rich to poor countries given that the rates of return to investment in physical capital should be much larger in developing countries than in developed countries. In the most interesting response to Lucas (1990), Caselli and Feyrer (2007) used data for 1996 and argued that such differences in rate of returns where an artifact of ignoring differences in natural resources and the relative price of capital and income. In particular, they argue that natural resources rents should not be included as returns to physical capital. Since natural resources rents are much higher in poorer countries, this omission inflates differences in MPK. In our analysis, we extend their work for the period 1970 to 2005 and to a larger set of countries. More importantly, while we agree with their insight about natural resources rents, we argue that we provide better estimates of those natural resources rents. They estimate natural resources rents using natural wealth stocks assuming the equalization of the returns to physical capital and natural resources. Instead, we only use rents flows and, thus, we avoid introducing additional biases in the estimation of factor shares. Interestingly, our results differ substantially from those of Caselli and Feyrer (2007). We argue that those authors's overestimated the importance of natural resources, and by doing so, their conclusion that the MPKs are equalized across countries need not hold.

When we explore the movement towards efficiency, we find that the accumulation of physical capital of countries over time can be predicted by the initial level and changes in MPK. This is an interesting result that seems to contradict the findings in Gourinchas and Jeanne (2013).[5] They argue that international capital flows have not been directed to the countries where the return to capital is the highest; i.e., *allocation puzzle*. The apparent contradiction is misleading, however. We recompute reallocation gains, now using for each year the capital allocation in 1970 plus the accumulated net capital flows. We find that the gains starting from this allocation are slightly higher than during this period: (i) capital flows have little impact on the efficiency in the world capital allocation, and (ii) that impact is toward worsening the allocation of capital, as in Gourinchas and Jeanne (2013).

Finally, our finding about human capital reallocation resembles some of the findings in Klein and Ventura (2009). Although our modelling of labor reallocation is simpler, our analysis is more extensive both in terms of the time period covered and the number of countries. Burstein and Monge-Naranjo (2009) also studied labor reallocation, but focused only in the reallocation of firm control and management.

The rest of the paper is organized as follows. In the next section, we discuss in detail our measurement of rents for natural resources and the implied output share of physical capital (Section 2). In Section 3 we present the simple model that is used to derive the key concepts and to compute counterfactuals. In Section 4, we describe the implied numbers of MPKs across countries and over time. We also examine the relationship of our implied MPKs with observed policy distortions. In Section 5 we define our counterfactual policies and explain the global and country-level gains. In Section 6 we examine the allocation of capital flows. In Section 7 we study how well human capital is allocated. Section 8 concludes.

2 Natural Resources and Output Factor Shares

Growth models most often abstract from natural resources as factors of production. Such an abstraction is, perhaps, of little consequence for a number of issues, specially for developed countries. We show in this section, however, that natural resources remain a substantial aspect of production of developing countries. Accounting for the rents to the owners of natural resources can lead to non-negligible changes on the imputed physical capital share of output and its marginal product in some countries. As a consequence, the output share of natural resources could play a key role in determining inefficiencies in the allocation of physical and human capital across countries.

[5] Ohanian et al. (2013) also study which are the key "wedges" that account for international capital flows.

2.1 The Rents of Natural Resources

A fairly diverse group of factors of production are not reallocateable across countries. Most of those resources can be interpreted as 'natural resources'. We adopt such an interpretation and estimate the payments to fixed factors as the rents accrued by natural resources across countries and over time. The World Bank's project *The Wealth of Nations* (see World-Bank, 2006), and its sequel, *The Changing Wealth of Nations*, classify natural resources into: (a) energy and mineral (subsoil) resources; (b) timber resources, (c) crop lands and (d) pasture lands.[6] We adopt this grouping, but also follow Caselli and Feyrer (2007) by adding an addtional category, (e) urban land, also as a non-reallocateable resource across countries.

For each of the different natural resources, the World Bank provides direct estimates of the rate of return using a set of benchmark countries. Using these benchmark estimates the World Bank extrapolates the rents for each natural resource for an extended sample of countries.[7] We further extend the sample of countries using data from the United Nation's Food and Agriculture Organization database (FAOSTAT).[8] Our estimates cover all the years from 1970 to 2005.

We wish to emphasize that while the final objective of the World Bank's project is to estimate the *stocks of wealth* of countries, in our calculations *we only use their rent flow estimates*, and not their wealth stocks estimates. Indeed, we argue below that factor shares estimates based on those wealth stocks are prompt to overestimate the importance of natural resources, and to do so even more for developing countries. We now explain how we estimate the factor shares for all items (a)-(e).

First, the rents for (a) energy and mineral (subsoil) resources, which include oil, natural gas, coal nickel, lead bauxite, copper, phosphate, tin, zinc, silver, iron and gold, were taken directly from the World Bank estimates. Second, the rents for (b) timber, were also taken directly from the World Bank.[9] Third, we construct our own estimates for the rents for items (c) and (d), crop and pasture lands, respectively. For crop lands (which includes apples, bananas, coffee, grapes, maize, oranges, rice, soybeans, wheat and many others), we follow the methodolgy in World-Bank (2006): For each crop, the World Bank estimates the average rate of return to the land for a set of countries that are major producers of that crop. The crop land rents are equal to output net of intermediate goods, retribution to labor, physical capital and other factors. The rate of return to the land is then computed as the ratio of total land rents and all the land used in producing this crop.[10] We apply those crop-specific rates of return to the quantities reported in FAOSTAT, using the U.S. prices for each crop as proxies of their respective international prices.[11] For each country

[6]While the World Bank includes non-timber forest resources and protected areas in the calculation of their estimated countries' stock of natural wealth (World-Bank, 2006, 2011), we do not include them in our computation of natural rents since they are almost certainly omitted in the GDP accounting of most countries, if not all of them. In any event, the rents for these two items are orders of magnitude smaller than the other categories.

[7]*The Wealth of Nations* dataset is available at http://data.worldbank.org/data-catalog/wealth-of-nations.

[8]Available at http://faostat.fao.org/, respectively.

[9]Both available at http://data.worldbank.org/sites/default/files/subsoil_and_forest _rents.xls.

[10]For example, rental rates estimated for some benchmark countries are: 27% for soybeans (from China, Brazil, Argentina), 8% for coffee (from Nicaragua, Peru, Vietnam, Costa Rica), 42% for bananas (from Brazil, Colombia, Costa Rica,d'Ivoire, Ecuador, Martinique, Suriname, Yemen), etc.

[11]In earlier versions of *The Wealth of Nations* database the World Bank used export unit values to value agricultural output. While export values might be poor predictors of output value when the country's markets are not well connected to the world market and/or the quality of what is traded, their use to measure output was partly due to the lack of country-specific producer prices for agricultural products. More recenlty, FAOSTAT has started to provide regular coverage of producer prices/gross value of production, and new versions of *'The Wealth of Nations'* value crop production using the newly available producer prices, which tend to be lower than export

and year, we compute the overall rental rate for croplands as the average rate weighted by area used for each crop. Total rents are computed using the estimated weighted rate to total quantities reported in the FAOSTAT. For the rents of pasture lands (which include beef, lamb, milk and wool) we follow the World-Bank (2006) by estimating that 45% of the total value of output from FAOSTAT accrues as rents to land. Last, we follow World-Bank (2006) and Caselli and Feyrer (2007) and estimate that the rents of (*e*) *urban land* are equal to 24% of the total rents of physical capital, whose estimates are discussed in the next subsection. While the valuation of urban lands may depend on aspects substantially different from other natural resources, their rents should neither be associated to labor or physical capital earnings. Therefore, for our purposes they are best seen as factors of productions that are not easily reallocateable across countries.

With those estimates, the natural resources rents for each country j in period t, $NRR_{j,t}$, is given by the sum of all rents from items timber, subsoil, crop land, pasture land and urban land for that country and year:

$$NRR_{j,t} = \sum_q \text{rents}_{q,j,t},$$

where $q = \{a, b, c, d, e\}$ are the different forms of non-reallocateable capital types, as indexed above. For our analysis, we need these rents as a fraction of the country's GDP. Since these rents are computed in current PPPs (in million 2005USD), then the output share of natural resources for country j in period t is simply

$$\phi^R_{j,t} \equiv \frac{NRR_{j,t}}{Y_{j,t}}, \tag{1}$$

where $Y_{j,t}$, is the country's GDP. To compute $\phi^R_{j,t}$, and for all other purposes, we use the variable *cgdpo* production-side real GDP at current PPPs (in million 2005USD) from the PWT 8.0.[12] Our benchmark final sample consists of 79 countries (see Appendix) with consistently available information throughout the entire sample period from 1970 to 2005.[13]

As shown by Figure 2, the years between 1970-2005 exhibit an increasing trend in the cross-country average share $\phi^R_{j,t}$. The average for all countries in the sample (blue dashed line) is about 5% in 1970 and gets more than twice as high, around than 11%, in 2005, remaining fairly stable between 5% and 7% for most of the 1980s and 1990s. That figure also reports the separate average for the oil exporting countries (red line), which we define as those with oil shares of output above 10%,[14] and all others (green line). As expected, the average $\phi^R_{j,t}$ is much higher, sometimes one order of magnitude higher, for oil countries than for non-oil countries. For oil exporters the share $\phi^R_{j,t}$ has an even more pronounced upward trend, with spikes clearly associated to periods of high oil prices. The group of oil exporting countries is small relative to the non oil exporters. The latter group exhibit smaller $\phi^R_{j,t}$ shares, ranging from 2.4% in 1970 to 6.5% in 2005.

A more interesting comparison is with respect to behavior of the share $\phi^R_{j,t}$ across development levels. To this end, Table 1 present the output shares of the different natural resources for the

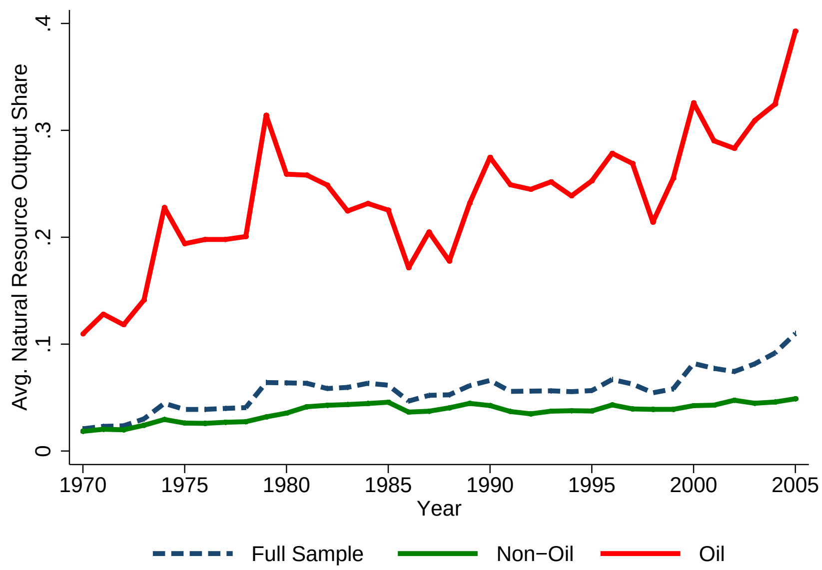
values (we thank Esther Naikal at the World Bank for this insight). We compare the old and new pricing strategies of the World Bankd with ours that uses US prices as proxies for crop international in the Appendix. We find very similar quantitative results either way.

[12]Since we focus on country-specific scales of operation to conduct a global reallocation exercise, we focus on the output measure *cgdpo* from PWT which reflects the production capacity of a country.

[13]We conduct further analysis for a larger sample of 122 countries for which consistent data is available from 1990 to 2005.

[14]These countries are Bahrain, Ecuador, Kuwait, Nigeria,Oman, Norway, Qatar, Saudi Arabia and Trinidad and Tobago. Venezuela is not included in our sample due to incomplete information on oil earnings for the most recent years.

Figure 2: Evolution of Average Output Share of Natural Resources
(Excluding Urban Land)



Source: Authors' calculations based on PWT 8.0, WB, and FAO.

year 2000. With the exceptions of oil/natural gas and urban land, the natural resources shares of output co-move negatively with the countries income per worker, as shown in the last column. In 2000, the correlation between the total share of natural resources and the countries' per capita output levels is −0.07 for the whole sample, but it is much more negative, −0.67, for the sample that excludes oil exporting countries. Disaggregating across of natural resources, we find that income per worker is negatively related to the share of output attributed to timber forest with a correlation coefficient of −0.29, subsoil resources other than oil and gas, −0.21, pasture, −0.27, and, in particular, cropland, −0.55.

Leaving urban land aside, the largest component of rents generated from natural capital are subsoil resources. For example, in 2000, they accounted an average of 5.44% of output, being oil and natural gas the major components, 4.03% and 1.21% of output, respectively. The second major component of natural resources is cropland with a share of output of 2.26%. Pasture rents and rents from timber forest account for lesser shares, respectively, 0.36% and 0.13% of output in average. Excluding the main oil exporting countries in our sample, the median share of oil rents in terms of output dramatically drops to 0.04% (i.e., close to 1% of its mean value) while the median share of cropland rents drops to 1.00%, i.e., about 38% of its mean value. This suggest a large dispersion in oil shares across countries which is confirmed by a large coefficient of variation in oil, 4.5 times larger than that of cropland shares. For non-oil countries, the largest subcategory is cropland rents, which account for 2.59%, with subsoil rents as low as 1.41%. For non-oil countries, the median share of natural resources in output is now close to the mean, the mean-to-median ratio is 1.41; this ratio is 2.04 when oil countries are included. For the non-oil sample, the coefficient of variation in the share is 5.06, while for the entire sample with oil countries it is was 17.07.[15]

[15] We find similar patterns with a larger sample of 122 countries for which $\phi^R_{j,t}$ are available from 1990 to 2005.

Table 1: Natural Resources Shares of Output (%), Year 2000

	Mean	Md.	CV.	$\rho_{x,y}$
Natural Resources:	8.19	4.01	1.44	-0.07
▷ Timber	0.13	0	3.76	-0.29
▷ Subsoil:	5.44	0.73	2.1	0.17
Oil	4.03	0.06	2.42	0.15
Gas	1.21	0.1	2.44	0.19
Other	0.28	0	2.79	-0.21
▷ Cropland	2.26	1.06	1.47	-0.55
▷ Pasture	0.36	0.17	1.53	-0.27
Nat. R. w/ Urban Land	17.75	14.72	0.62	-0.1
Obs.	79	79	79	79

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

Figure 3 illustrates further the relationship between the output share of natural resources (excluding urban land) and per worker income, also for the year 2000. The right panel single out the oil countries, showing that they have much higher $\phi^R_{j,t}$, averaging 36.80%, versus 4.51% of their non-oil counterparts, and relatively richer than their non-oil counterparts.[16] The left panel focuses on non-oil countries, shows a very negative relationship between the natural resources share and output. Non-oil countries with income per worker above $40,000 in the year 2000, the natural resources share of output is only 1.13%. The average of this share is much higher, 6.90%, for countries below $40,000 and 9.62% for countries below $10,000.[17] In other terms, the bottom 20% poorest countries in income per worker have a natural resources share of their output that is 8.81 times larger than the natural share of the top 20% richest countries in income per worker.[18]

To summarize, natural resources are an important input for production that accounts for more than 8% of total output per worker across countries with the largest components being oil rents and cropland rents. Further, the quantitative role of natural resources differs largely by country and, perhaps, more importantly it decreases with income per worker. Poor countries rely substantially more on natural resources than rich countries.

2.2 Output Share of Labor and Physical Capital

We now explain how we incorporate our estimates of the factor shares for natural resources for the computation of the output shares for capital and labor. We denote by $\theta_{j,t}$ the labor share of output. In this paper, we use the PWT variable *labsh*. This measure of the labor share aims to correct for the part of ambiguous income, mainly proprietors income (i.e., the self-employed), that needs to be attributed to labor income in order to avoid underestimating the contribution of

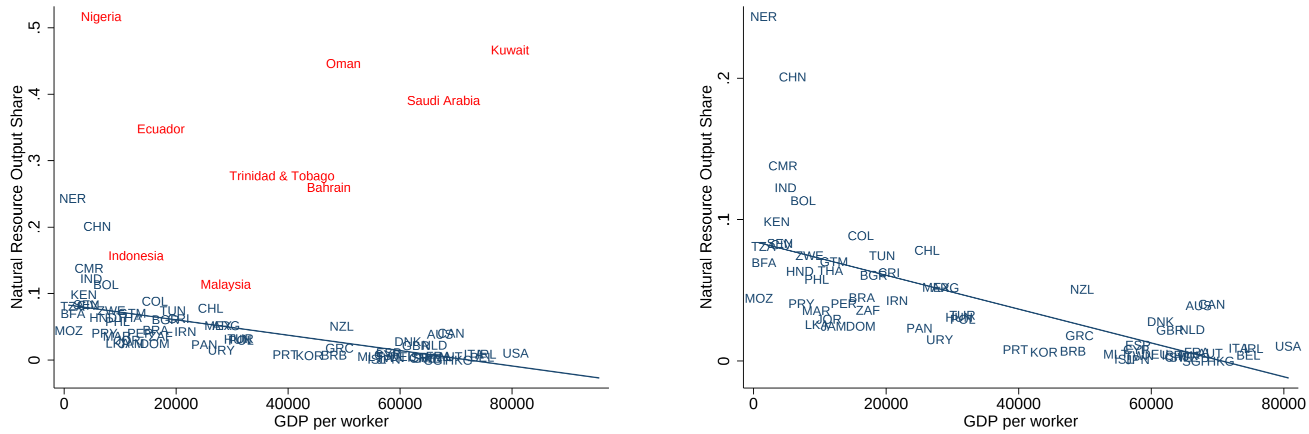
Results available upon request.

[16]The income per worker of oil countries averages $51,888, while that of non-oil countries is $4,963. That is, the non-oil countries include a relatively larger share of poor countries.

[17]In this context, and as external validation, it is reassuring that our estimates for crop land rents in poor countries are comparable to those attained from new micro representative farm production data in de Magalhaes and Santaeulàlia-Llopis (2015) and Restuccia and Santaeulàlia-Llopis (2015).

[18]Including oil countries this factor drops to 1.63.

Figure 3: Natural Resources (Excluding Urban Land) Output Shares, Year 2000



All Countries Non-Oil Countries

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

labor to output.[19] This is a particularly relevant issue in countries in which a significant amount of labor is allocated to family-owned farms and various forms of self-employment.[20]

In the PWT, as explained in Feenstra et al. (2015), the raw labor share defined as the ratio of unambigous compensation of employees (WN) to GDP, $\theta_{j,t}$ = WN/GDP, is adjusted using an algorithm along four different ways to compute ambiguous income (AMB) to select their best estimate of $\theta_{j,t}$, a choice that basically depends on the availability of data on ambiguous.[21] As we discuss below, the resulting $\theta_{j,t}$ from the PWT 8.0 are lower that those in Bernanke and Gurkaynak (2001). Some, but far from all, of the differences are driven by the sample of countries. With the interest in expanding our sample of countries and periods as much as possible, we take the measures from the PWT 8.0 as our benchmark.

For the output share of physical capital, denoted here by $\phi^K_{j,t}$, the standard practice is to equate it to one minus the labor share. All non-labor income must be capital income, an assumption driven a constant returns to scale production function with only physical and human capital as factors. Instead, as proposed by Caselli and Feyrer (2007), correctly accounting for the income shares of natural capital factors, the physical capital share should be calculated as

$$\phi^K_{j,t} = 1 - \theta_{j,t} - \phi^R_{j,t}, \tag{2}$$

[19]See Cooley and Prescott (1995).

[20]See Gollin (2002).

[21]The PWT considers four different adjustments: (1) add AMB to unambiguous labor compensation, resulting in $\theta_{j,t}$ = (WN+AMB)/GDP; (2) assume the labor share, $\theta_{j,t}$, is identical to the labor share of unambiguous output, $\theta_{j,t}$ = WN/(GDP-AMB); (3) if proxies for the number of employees (N) and self-employed (SE) are available, then assuming the same average wage for both leads to a labor share is $\theta_{j,t}$ = (WN/GDP)*(N+SE)/N; (4) add the value added in agriculture (AGRI) to unambiguous labor income, i.e., θ = (WN+AGRI)/GDP. The PWT 8.0 constructs their 'best estimate' of the labor share using the following procedure: If the unadjusted share is larger than 0.7, no adjustments are used, as the share never excess 0.66 when ambiguous income data are available in national accounts statistics. If the unadjusted share is smaller than 0.7, then: if the the ambiguous income data is available, they use adjustment 2, because adjustment 1 seems to extreme; otherwise, if the ambiguous income data is not available, then use the minimum of the resulting shares of adjustments 3 and 4.

that avoids inflating the income and return to physical capital.

3 The Model

We first set out our baseline model and derive the efficiency benchmarks needed to evaluate the degress of misallocation of mobile factors across countries.

3.1 The Baseline Environment

Consider a world economy, populated by an arbitrary number J of countries, indexed by $j = 1, 2, ..., J$. Given our data, we index the (yearly) time periods by $t = 1970, 1971, ...2005$. Our baseline model assumes a single tradeable good, which can be consumed or invested across all the countries. In each country, output is produced using the service flows of the country's stocks of physical capital , $K_{j,t}$, natural resources (land and other natural resources), $T_{j,t}$, and human capital-augmented labor, $H_{j,t} = h_{j,t}L_{j,t}$, where $L_{j,t}$ indicates the number of workers in country j in period t and $h_{j,t}$ their average skills or human capital. Production in the country is also function of the country's overall total-factor-productivity, $A_{j,t}$.

Our baseline model stems from the standard one-sector growth model, assuming that production of the good in country j at time t is Cobb-Douglas. Specifically, we consider a production function of $Y_{j,t}$ in the form

$$Y_{j,t} = A_{j,t}(K_{j,t}^{\gamma_{j,t}} T_{j,t}^{1-\gamma_{j,t}})^{1-\theta_{j,t}} (H_{j,t})^{\theta_{j,t}}, \tag{3}$$

where $0 < \theta_{j,t} < 1$ is the labor share of output. The capital share of output, $1 - \theta_{j,t}$, is divided between a share $\gamma_{j,t}(1 - \theta_{j,t})$ for produced capital $K_{j,t}$, and an output share $(1 - \gamma_{j,t})(1 - \theta_{j,t})$ for natural resources. We extend the standard model in two dimensions. First, we introduce non-produced capital $T_{j,t}$. Second, we allow for country-time variation in the factor shares as documented in the previous section.

From output data, $Y_{j,t}$, and measures of $K_{j,t}$, the physical capital in each country, and the data on factor shares $\theta_{j,t}$, $(1 - \gamma_{j,t})(1 - \theta_{j,t})$ of natural resources, we can readily compute the 'real' marginal product of physical capital ($RMPK_{j,t}$) as

$$RMPK_{j,t} = (1 - \theta_{j,t})\gamma_{j,t}\frac{Y_{j,t}}{K_{j,t}}. \tag{4}$$

Correcting for the output share $(1 - \gamma_{j,t})(1 - \theta_{j,t})$ of non-reallocateable capital leads to significant differences with the findings in the literature on the degree of misallocation of capital across countries. The use of the prefix R in the measures of MPK is for contrast with the 'value' counterparts developed below. To gauge the economic relevance of cross-country variations, we now specify the efficient benchmark with respect to which we can compare the actual allocations.

3.2 The Baseline Efficiency Benchmark

Throughtout the paper, we assume exogenously determined sequences of TFPs $\{A_{j,t}\}$ and service flows of natural resources $\{T_{j,t}\}$ across countries and over time. Cross-section distributions of those productive factors –and their behavior over time– are what they are, and there is nothing to evaluate. We first take as given the allocation of human capital $H_{j,t}$ across countries and examine the allocation of the world supply of physical capital, $K_{W,t}$. Then, in Section 7, we examine the joint allocation of the world's physical and human capital. In all the exercises, the quartet $\{A_{j,t}, T_{j,t}, \theta_{j,t}, \gamma_{j,t}\}$ for all countries is taken as given. Similarly, for brevity, we group the fixed factors within a country in a term $Z_{j,t} \equiv A_{j,t}T_{j,t}^{(1-\gamma_{j,t})(1-\theta_{j,t})}$, that embbeds total factor productivity $(A_{j,t})$ and the output contribution of natural resources.

Under the assumption that all output is tradeable, the optimal allocation of physical capital would maximize global output, i.e.,

$$Y_{W,t}^{K^*} = \max_{\{K_{j,t}\}} \sum_{j=1}^{J} Z_{j,t} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})} \left(H_{j,t}\right)^{\theta_{j,t}}, \tag{5}$$

subject to not surpassing the world's supply of capital,

$$\sum_{j=1}^{J} K_{j,t} \leq K_{W,t}.$$

Here $K_{W,t} \equiv \sum_{j=1}^{J} K_{j,t}^{O}$ where $K_{j,t}^{O}$, it the observed (PWT 8.0) data for the physical capital for country j in period t.

Naturally, this maximization requires the equalization of the marginal product of physical capital across all countries to a common world factor prices r_t^K:

$$RMPK_{j,t} = (1-\theta_{j,t})\gamma_{j,t}\frac{Y_{j,t}}{K_{j,t}} = \gamma_{j,t}\left(1-\theta_{j,t}\right) Z_{j,t} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})-1} \left(H_{j,t}\right)^{\theta_{j,t}} = r_t^K. \tag{6}$$

for all j and t. In particular, this indicates that countries with higher TFP and/or natural resources, $Z_{j,t}$, higher supply of human capital $H_{j,t}$, and higher output share of physical capital $\gamma_{j,t}\left(1-\theta_{j,t}\right)$ shall receive more physical capital as part of the efficient allocations.

The maximization does not lead to a closed form solution except when $\gamma_{j,t} = \bar{\gamma}_t$ and $\theta_{j,t} = \bar{\theta}_t$, i.e., when the cross-country heterogeneity in factor shares disappears.[22] Although there is not closed form solution using the heterogenous values of $\{\theta_{j,t}, \gamma_{j,t}\}$ finding the value $Y_{W,t}^{K^*}$ numerically is straightforward. In any event, we assess the degree of *global capital misallocation* according to the global efficiency loss $\ln\left[Y_{W,t}^{K^*}/Y_{W,t}^{O}\right]$, i.e. the percentual difference between the maximized global output and, $Y_{W,t}^{O}$, the sum of the country outputs observed in the data.

3.3 A Benchmark with Prices

Relative prices of capital goods have been highlighted as key to account for differences in investment rates, e.g. Hsieh and Klenow (2007), and for differences in the marginal product of capital, e.g. Caselli and Feyrer (2007). Since both of these aspects are closely related to our exercise, we incorporate cross-country differences in relative prices of capital in our analysis.

[22] In more detail, if factor shares are identical across countries, then the maximized output is equal to

$$Y_{W,t}^{K^*} = \left[\sum_{j=1}^{J}\left[A_{j,t}T_{j,t}^{(1-\bar{\gamma}_t)\left(1-\bar{\theta}_t\right)}\left(H_{j,t}\right)^{\bar{\theta}_t}\right]^{\frac{1}{1-\gamma\left(1-\bar{\theta}_t\right)}}\right]^{1-\bar{\gamma}_t\left(1-\bar{\theta}_t\right)} \left(K_{W,t}\right)^{\bar{\gamma}_t\left(1-\bar{\theta}_t\right)}.$$

When the dollar price of output $P^Y_{j,t}$ and of capital $P^K_{j,t}$ are different across countries, the 'value' marginal product of capital, $VMPK_{j,t}$, i.e. the value of the return to investing in capital in country j in period t'

$$VMPK_{j,t} = \frac{P^Y_{j,t}}{P^K_{j,t}}(1-\theta_{j,t})\gamma_{j,t}\frac{Y_{j,t}}{K_{j,t}}, \tag{7}$$

Differences in $P^K_{j,t}$ across countries lead to different numbers of machines per dollar invested, $1/P^K_{j,t}$, while differences in $P^Y_{j,t}$ lead to revenue differences for the same units of return physical output. In a world in which investors can freely adjust their portfolios, $VMPK_{j,t}$ would be the criterion for investment across countries, not the real $RMPK_{j,t}$ as defined in equation (4.) Thus, the relevant disparities to assess world capital market frictions is in terms of $VMPK_{j,t}$.

An alternative efficiency benchmark that takes $\left\{P^Y_{j,t},\, P^K_{j,t}\right\}$ as given can be also useful to assess the degree of misallocation of physical capital across countries. Consider an environment in which output is entirely tradeable, but capital entails installment costs. In fact, assume that to install one unit of capital in country j, requires a cost $\varpi_{j,t} = P^K_{j,t}/P^Y_{j,t}$ in units of output goods. Therefore, in terms of goods, the amount of resources required to install the observed $K^O_{j,t}$ in each country j in period t is given by $\left(P^K_{j,t}/P^Y_{j,t}\right)K^O_{j,t}$. In our benchmark with prices, we would like to compare the world output production relative to the optimized one given $K^N_{W,t} \equiv \sum_{j=1}^{J}\frac{P^K_{j,t}}{P^Y_{j,t}}K^O_{j,t}$ the total amount of goods invested across all countries.

Then, our second benchmark is based on the distance of current output with the upper bound for the maximized world's output (5), but subject to the current global used of resources for physical capital,

$$\sum_{j=1}^{J}\frac{P^K_{j,t}}{P^Y_{j,t}}K_{j,t} \leq K^N_{W,t}, \tag{8}$$

The optimality conditions required the equalization, across countries, of the price-corrected marginal product of physical capital across countries, i.e.

$$\begin{aligned} VMPK_{j,t} &= R^K_t \\ &= \frac{P^Y_{j,t}}{P^K_{j,t}}(1-\theta_{j,t})\gamma_{j,t}\frac{Y_{j,t}}{K_{j,t}} \\ &= \frac{P^Y_{j,t}}{P^K_{j,t}}\gamma_{j,t}\left(1-\theta_{j,t}\right)A_{j,t}T_{j,t}^{(1-\gamma_{j,t})(1-\theta_{j,t})}\left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})-1}\left(H_{j,t}\right)^{\theta_{j,t}}. \end{aligned} \tag{9}$$

Under this benchmark, prices also determine the allocation of capital for each country. The higher (lower) the relative price of output (capital) in a country, $P^Y_{j,t}/P^K_{j,t}$, the more physical capital should be allocated to it. For future reference, we will denote by

$$\mu^K_{j,t} \equiv \frac{\left(P^K_{j,t}/P^Y_{j,t}\right)K_{j,t}}{K^N_{W,t}},$$

the share of the world's investment in physical capital that is allocated to country j in period t. When factor shares differ across countries, neither $Y^{K^*}_{W,t}$ nor $\mu^K_{j,t}$ can be solved for in closed form. However, they are easily computed numerically.[23]

[23] Alternatively, under the assumption of identical factor share across countries we can derive the formula for the

4 The Marginal Product of Capital

We now compute the implied marginal products of physical capital for the countries and years in our sample. We use the factor shares data described in Section 2, along with PWT 8.0 measures of output, physical capital measures and the prices of output and capital goods.[24]

In particular, the capital stocks in each country/year, $K_{j,t}$, are taken as the variable *ck*, capital stocks at current PPPs (also in million 2005 USD).[25] The number of workers in each country and year, $L_{j,t}$, is measured with the variable *emp* in PWT 8.0 for our measure of aggregate labor, i.e., the number of persons, in millions, engaged in production. To estimate the human capital of the country, we use the variable *hc* in the PWT 8.0, the index of human capital per person, based on years of schooling (Barro and Lee (2013)) and returns to education (Psacharopoulos (1994)). We use that variable to define $h_{j,t}$ for each country and then the aggregate human capital augmented labor is $H_{j,t} = emp \times hc$. For the price of output, $P^Y_{j,t}$, we use the GDP deflator *pl_gdpo*, i.e. the price level of cgdpo (PPP/XR, normalized so that price level of USA GDP in 2005 = 1). The price level of capital, $P^K_{j,t}$, is taken to be *pl_k*, the price level of the capital stock (normalized so that the price for USA in 2005 is 1). Finally, for the price level of consumption, $P^c_{j,t}$, we use the variable *pl_c*, the price level of household consumption (also normalized so that the price for USA in 2005 is 1.)

Figures 4 present the distribution, across countries, of the real and nominal MPKs over the entire sample period. In each panel, the white line represents the median, the darkest blue region is the interquartile range, the middle-dark blue region is the 10-90 percentile, and the light blue area is the 5-95 percentile range.

A number of relevant patterns emerge from these figures. First, the median values of both exhibit a clear down-ward trend. suggesting that capital might have been accumulated across most countries at a faster pace than potential changes in the factor shares. Second, the dispersion of the MPKs have steadily decreased over the sample period. Third, the most dramatic declines in the median and dispersion of MPKs takes place in the 1970s to mid 1980s. Fourth, albeit some important differences remain, the aforementioned patterns are common across both $RMPK$ and $VMPK$, indicating that none of them are driven by the relative price of capital to goods across countries. However, the relative price of capital drive significant and persistent differences in levels. For instance, while the median RMPK is about 20 percent in 1970, the VMPK for that year is about 25 percent.

To explore the forces driving the trends in the cross-country dispersion of $MPKs$, we now explore the variance decomposition of the logs of $RMPK_{j,t}$ and $VMPK_{j,t}$. It is straightforward to show that we can decompose those variances in terms of the variance of the (logs) of physical

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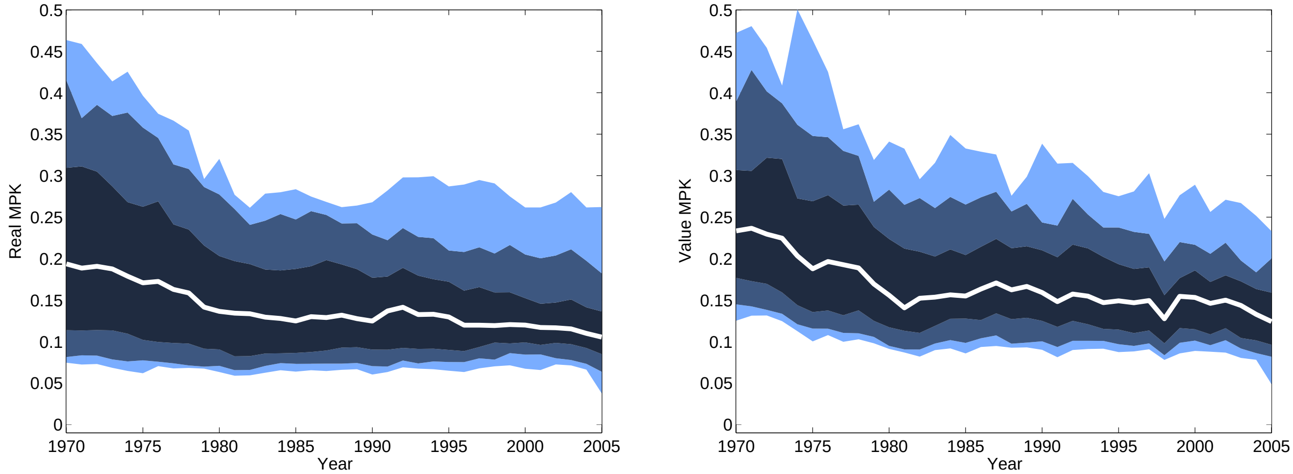
optimized global output:

$$Y^{K^*}_{W,t} = \left[\sum_{j=1}^{J} \left[A_{j,t} T_{j,t}^{(1-\bar{\gamma}_t)(1-\bar{\theta}_t)} (H_{j,t})^{\bar{\theta}_t} \left(\frac{P^Y_{i,t}}{P^K_{i,t}} \right)^{\bar{\gamma}_t (1-\bar{\theta}_t)} \right]^{\frac{1}{1-\gamma(1-\bar{\theta}_t)}} \right]^{1-\bar{\gamma}_t(1-\bar{\theta}_t)} \left[K^N_{W,t} \right]^{\bar{\gamma}_t(1-\bar{\theta}_t)} .$$

[24] Available online at http://www.rug.nl/research/ggdc/data/penn-world-table; see also Appendix.

[25] For each country, these aggregate stocks are computed applying the perpetual inventory method (PIM) separately for different types of investment that include structures (residential and nonresidential), equipment (separately for transportation, computers and communication), software, and other machinery and assets. Differences in the composition of investment flows leads to difference in aggregate investment prices and depreciation rates. See the detailed discussion in Feenstra et al. (2015), including a comparison with previous PWTs datasets.

Figure 4: Evolution of MPKs; percentiles 5, 10, 25, 50, 75, 90, and 95



$RMPK$ $VMPK$

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

capital output shares, output capital ratios and relative price of capital:

$$var\left[\ln RMPK_{j,t}\right] = var\left[\ln \phi^K_{j,t}\right] + var\left[\ln \frac{Y_{j,t}}{K_{j,t}}\right] + 2cov\left[\ln \phi^K_{j,t}, \ln \frac{Y_{j,t}}{K_{j,t}}\right],$$

and

$$var\left[\ln VMPK_{j,t}\right] = var\left[\ln RMPK_{j,t}\right] + var\left[\ln \frac{P^Y_{j,t}}{P^K_{j,t}}\right] + 2cov\left[\ln RMPK_{j,t},\ \ln \frac{P^Y_{j,t}}{P^K_{j,t}}\right].$$

The first columns of Table 2 reports the variances of the different objects, while the latter columns present their pairwise covariances. First of all, notice that there is a downward trend in the dispersion for both $\ln RMPK_{j,t}$ and $\ln VMPK_{j,t}$; for the former, the negative trend runs from 1970 till 2000, while for the latter it runs from 1975 till 2000. Second, these downward trends, are mostly driven by both a significant decline in the variation of the log of the output-capital ratio $Y_{j,t}/K_{j,t}$, and by a decline in the covariance between log-$\phi^K_{j,t}$ and log-$Y_{j,t}/K_{j,t}$. With respect to the former, the contribution of $var\left[\ln \frac{Y_{j,t}}{K_{j,t}}\right]$ on the variance of log $RMPK_{j,t}$ increases from 61% in 1970 to 82% in 2000. With respect to the covariance of $\ln \phi^K_{j,t}$ and $\ln \frac{Y_{j,t}}{K_{j,t}}$ we find that it changes sign between 1970 and 2000. Therefore, from a world in the 1970s where countries with a more capital intensive technology (i.e. high $\phi^K_{j,t}$) were exhibiting relatively lower accumulation of capital (i.e. higher $Y_{j,t}/K_{j,t}$), we have switched in the 2000 to world where the more capital-intensive countries are also endowed with relatively more capital. This switch is quantitatively important. In 1970, this covariance *enhanced* the variation in $\ln RMPK_{j,t}$ by 14%. By the end of the sample, it was *reducing* it by a similar magnitude.

A third finding is that during 1970 and 2000, the variation in the log of the capital-income shares $\phi^K_{j,t}$ has a positive but mildly declining contribution on the variance of log $RMPK_{j,t}$. Its contribution lies in a range between 20% and 33%. Factor intensity differences are relevant, but they are the main drivers of the dispersion in the marginal product of physical capital.

Table 2: Decomposition of the dispersion of $RMPK$ and $VMPK$

Year	Variances (logs of each variable)					Covariances (logs of each variable)			
	$RMPK_{j,t}$	$VMPK_{j,t}$	$\phi^K_{j,t}$	$\frac{Y_{j,t}}{K_{j,t}}$	$\frac{P^Y_{j,t}}{P^K_{j,t}}$	$\phi^K_{j,t}, \frac{Y_{j,t}}{K_{j,t}}$	$\frac{Y_{j,t}}{K_{j,t}}, \frac{P^Y_{j,t}}{P^K_{j,t}}$	$\phi^K_{j,t}, \frac{P^Y_{j,t}}{P^K_{j,t}}$	$RMPK_{j,t}, \frac{P^Y_{j,t}}{P^K_{j,t}}$
1970	0.357	0.148	0.088	0.219	0.159	0.025	-0.158	-0.026	-0.184
1980	0.260	0.176	0.085	0.165	0.064	0.005	-0.074	0.001	-0.074
1990	0.219	0.158	0.067	0.156	0.078	-0.002	-0.076	0.006	-0.070
2000	0.196	0.122	0.064	0.161	0.120	-0.014	-0.115	0.018	-0.097

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

We finally explore some simple results from Table 2 on the role of the relative price of capital, $P^Y_{j,t}/P^K_{j,t}$ in the behavior of $VMPK_{j,t}$. First, the dispersion of $\ln RMPK_{j,t}$ is always significantly higher than the dispersion in $\ln VMPK_{j,t}$. In the extreme, in 1970, $var\left[\ln RMPK_{j,t}\right]$ is almost 2.5 times the value $var\left[\ln VMPK_{j,t}\right]$, but this ratio is never below 1.38. This is just a manifestation of the strongly negative correlation between prices and physical marginal products. Indeed, the correlation between $\ln P^Y_{j,t}/P^K_{j,t}$ and $\ln RMPK_{j,t}$ is always between -0.54 and -0.77. Clearly, prices are partially correcting the cross-section dispersion in the physical marginal product of capital, and countries with high $RMPK$ tend to also have a higher relative cost of installing capital or a relatively lower value of their output, i.e. a low $\ln P^Y_{j,t}/P^K_{j,t}$. However, despite the fact that the counter-movement of prices with $\ln RMPK$ can easily overturn by itself the dispersion in $\ln VMPK$ (i.e., the contribution of $2cov\left[\ln RMPK, \ln P^Y_{j,t}/P^K_{j,t}\right]/var\left[\ln VMPK\right]$ is often 100%), this covariance is far from enough to offset the joint dispersion of prices $\ln P^Y_{j,t}/P^K_{j,t}$ and the physical $\ln RMPK$. As a matter of fact, both the physical $\ln RMPK$ and the value $\ln VMPK$ are always strongly, positively correlated across countries. Their correlation is as high as 0.87 (in 1975) and never below 0.64 (in 2000).

In sum, while the relative price of capital partially offsets the dispersion of physical $MPKs$, those prices are far from eliminating cross-country dispersion (in any point in time) and are not driving the downward trend in it observed between 1970 and 2005.

4.1 Observable Policies

Even after controlling for the countries' differences in their capital-intensity in production and in their observed relative price of physical capital, there remains a non-negligible dispersion in the marginal product of physical capital. The overall message from our results is that, despite a downward trend from the early 1970s, there are still significant and persistent distortions in the allocation of capital.

This section briefly explores whether the implied distortions can be related to directly observable measures of policy distortions. To this end, we employ a simple indicator, the Sachs and Warner (1995) openness $\{0,1\}$ indicator, hereafter SW. Specifically, SW require the following five criteria to classify a country as "open": (i) The average tariff rate on imports is below 40%; (ii) Non-tariff barriers cover less than 40% of imports; (iii) The country is not a socialist economy (according to the definition of Kornai (2000)); (iv) The state does not hold a monopoly of the major exports; (v) The black market premium is below 20%. The resulting indicator is a dichotomic variable. If in a given year a countrysatisfies all of these five criteria, SW call it open and set the indicator to 1. Otherwise, the indicator takes the value of 0.

Table 3: The MPK of Open and Closed Economies: 5-year averages, 1970-2000

Year	$RMPK_{j,t}$			$VMPK_{j,t}$			Obs.	
	Open	Closed	t-stat	Open	Closed	t-stat	Open	Closed
1970 - 1975	0.152	0.236	8.39	0.206	0.261	5.80	196	206
1976 - 1980	0.131	0.200	7.84	0.172	0.213	4.87	168	167
1981 - 1985	0.119	0.170	6.32	0.157	0.174	2.16	164	171
1986 - 1990	0.138	0.174	3.70	0.180	0.177	-0.34	207	128
1991 - 1995	0.138	0.185	3.94	0.165	0.195	2.31	294	41
1996 - 2000	0.132	0.235	5.69	0.150	0.186	2.91	310	25

Source: Authors' calculations based on PWT 8.0, WB, FAO, and Sachs and Warner (1995).

While originally, Sachs and Warner aimed to design their indicator to classify countries between being open or closed to international trade, the inclusion of criteria (iii)-(iv) makes SW to capture forms of government intervention that go clearly much beyond restrictions on international trade. A number of authors have argued that this indicator is better interpreted as an overall measure towards market friendly vs. interventionist policies. In the words of Rodriguez and Rodrik (2000), *"[The] SW indicator serves as a proxy for a wide range of policy and institutional differences,"* where *"trade liberalization is usually just one part of a government's overall reform plan for integrating an economy with the world system. Other aspects of such a program almost always include price liberalization, budget restructuring, privatization, deregulation, and the installation of a social safety net."* In a similar vein, Hall and Jones (1999) use the SW indicator as a proxy for the quality of social infrastructure. Likewise, Buera et al. (2011) use it as an indicator for the adoption of market oriented vs government interventionist. As these authors, we interpret SW as an indicator not only of barriers to the entry and exit of physical capital, but also to the domestic formation of human and physical capital. To be sure, black market premia is always joined by many other forms of financial market distortions. Moreover, the presence of a socialist government or a government that monopolizes major exports are most likely also good proxies for government rents that depress the accumulation and/or the effective use of human and physical capital in a country.

Obviously, a dychotomic indicator is at best a stark one, and it will miss some important liberalizations. Countries with very different degrees of state intervention, e.g. the U.S and France, may end up being classified equally. Moreover, the indicator fails to capture reforms if they do not simultaneously move countries in all five criteria, e.g. China in later years. Indeed, it classifies both India and China as closed economies, despite recent notable changes in their policies regimes. The main advantage of the SW, is by providing a simple indicator that is available for most of the country-years in our panel. Richer indicators, are only available for a reduced sample of countries, for a cross-section or for only a handful of recent years.

Tables 3 compares the marginal product of capital of closed and open countries. It compares the averages of both, $RMPK$ and $VMPK$, for open and closed countries, splitting the sample in five year intervals. The table also presents the t-statistics of a simple tests that the average $RMPK$ and $VMPK$ for closed economies are equal to the averages of open economies. The last columns of the table indicate the number of country-years in each window of years.

Some simple conclusions follow from Tables 3. First, the marginal product of capital in closed countries is always higher than in open countries. Those differences are quantitatively very large

Table 4: Factor Shares, Output-Capital Ratios and Relative Prices of Open and Closed Economies: 5-year averages, 1970-2000

Year	$\phi^K_{j,t}$			$\frac{Y_{j,t}}{K_{j,t}}$			$\frac{P^Y_{j,t}}{P^K_{j,t}}$		
	Open	Closed	t-stat	Open	Closed	t-stat	Open	Closed	t-stat
1970 - 1975	0.308	0.342	4.11	0.484	0.699	7.84	1.484	1.236	-5.41
1976 - 1980	0.303	0.334	3.40	0.420	0.609	7.84	1.401	1.139	-8.27
1981 - 1985	0.302	0.318	1.83	0.383	0.559	6.42	1.409	1.102	-8.92
1986 - 1990	0.322	0.318	-0.47	0.421	0.562	4.92	1.399	1.084	-8.91
1991 - 1995	0.331	0.324	-0.59	0.420	0.609	5.06	1.272	1.064	-3.92
1996 - 2000	0.333	0.335	0.17	0.407	0.766	5.80	1.197	1.038	-2.56

Source: Authors' calculations based on PWT 8.0, WB, FAO, and Sachs and Warner (1995).

are statistically significant. The only exception is that the average $VMPK$ is higher for open countries during the $1986 - 1990$ subperiod, but that difference is not statistically significant. Second, the marginal product of capital for closed countries tends to fall over, while those for open countries remains relatively flat (at lower levels). Third, the number of open countries drastically increases in the from 1981 onwards. The lower $MPKs$ of open countries and a higher fraction of them drive the overall downward trend in the average marginal product of capital. It is worth indicating essentially the same findings hold if the analysis is done in logarithms as opposed to levels.

Table 4 explores what drives the differences between open and closed countries. It reports the averages of capital-income shares, $\phi^K_{j,t}$, the average output-capital ratio, $Y_{j,t}/K_{j,t}$, and the average output-to-capital price ratio, $P^Y_{j,t}/P^K_{j,t}$, grouping countries in open and closed. The table also reports the t-statistic for the test of equality of means for each component.

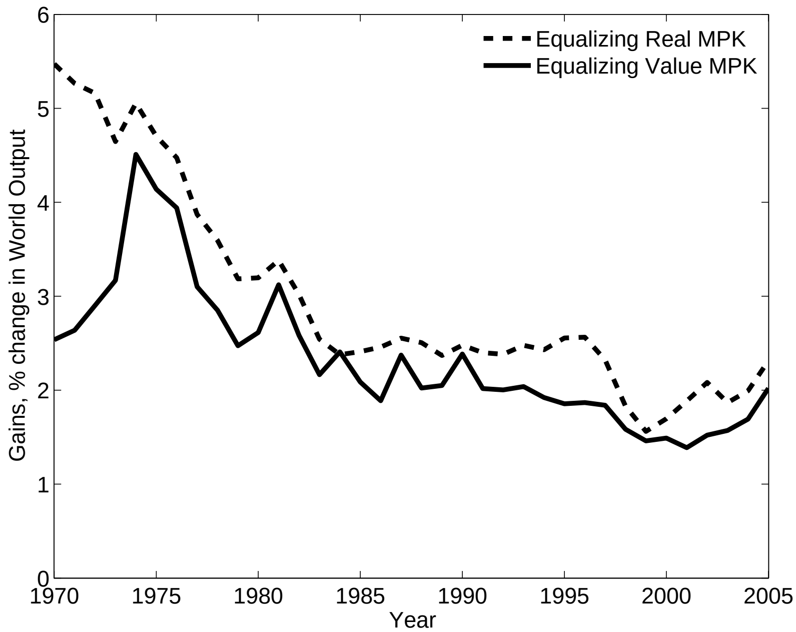
The results of Table 4 are highly suggestive about how market oriented countries differ from closed, state interventionist countries. Closed, interventionist countries have much higher output-capital ratios than open, market oriented countries, and those differences are statistically significative. On the other the relative cost of capital is higher in closed countries than in open countries, suggesting that probably, some of the interventionist policies act as a wedge in the cost of investment goods, which is highly plausible, given the fact that much of the equipment is produced (and exported) by a handful of industrialized countries (Mutreja et al., 2014).

Interestingly, the capital intensity differences, $\phi^K_{j,t}$, between open and closed economies are neither large nor statistically significant, specially in the second part of the sample. This finding lends support to our approach that factor shares are less distorted by policies and barriers than factor accumulation and the return to production factors.

5 Assessing Global Misallocation

In this section we present the global output gains of physical capital reallocation. Figure 5 presents the evolution of real and nominal gains of capital reallocation. They are both large, between 2 and 6 percent for entire period between 1970 and 2005. Notice that 2 percent gains are very large. For instance, in this period the total output in South America is around 5 percent and in Africa is around 2 percent of the world total output. The equalization of real MPK yields gains that

Figure 5: Global Gains of Physical Capital Reallocation

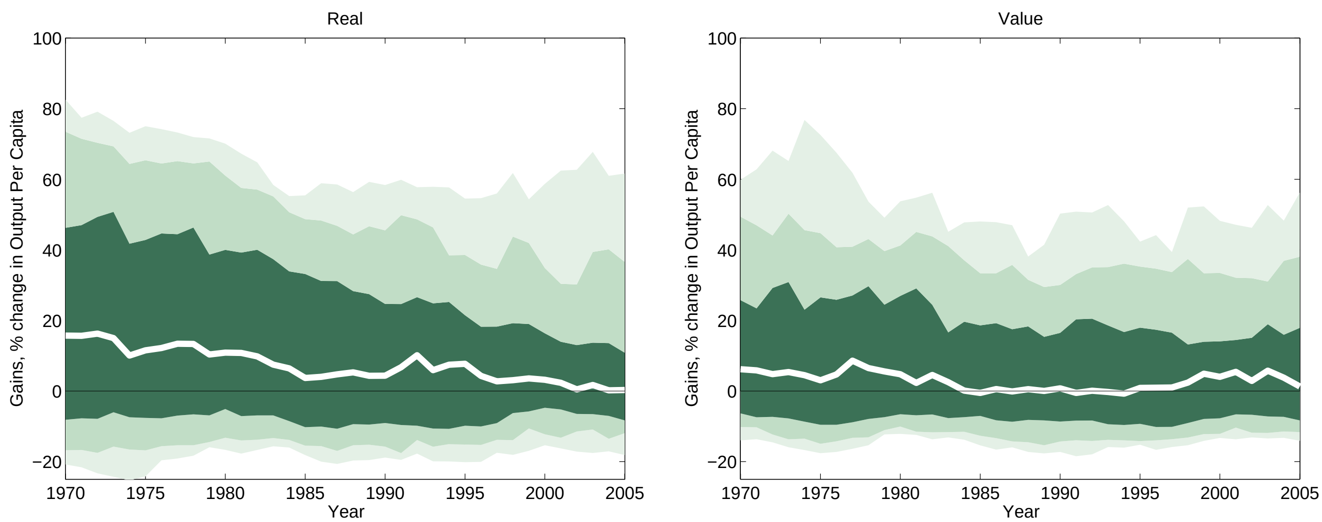


Source: Authors' calculations based on PWT 8.0, WB, and FAO.

start at 6 percent and decrease steadily until 2.5 in the 2000s. The equalization of nominal MPK yields smaller gains (they start at around 4 percent and decrease to 2 percent) but the trend is similar. In addition, for any particular year, nominal and real gains are very correlated at the country level. If we run a regression of nominal gains on real gains, the intercept is very close to zero and the slope coefficient is between 0.6 and 0.8.

Gains of capital reallocation vary greatly. Figure 6 shows the distribution of real and nominal gains for each year since 1970 to 2005. In general, the figures are quite similar. The white line represents the median, the dark green region the interquartile range, the lighter green region the 10-90 percentile range, and the lightest region the 5-95 percentile range. The distribution of gains are asymmetric: the percentiles 5, 10 and 25 are relatively close to the median and percentile 75, 90 and 95 are further away. For instance, in 1970 the median real gains are around 20 percent, the percentile 5 of gains is around -20 percent and the percentile 95 of gains is more than 80 percent. The median real gains decrease from about 20 percent in 1970 to around zero in 2005. The pattern for nominal gains is similar, but the median gains increase again at the end of the 90s and beginning of the 2000s.

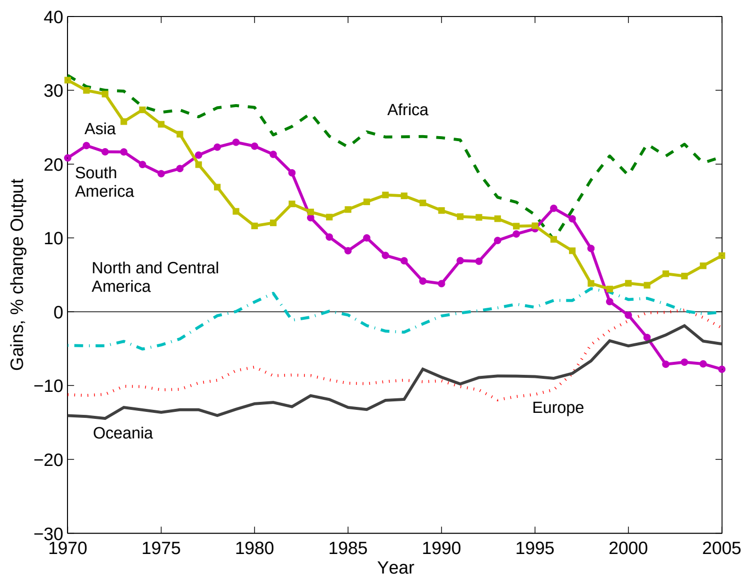
Figure 6: Global Gains of Physical Capital Reallocation; percentiles 5, 10, 25, 50, 75, 90, and 95



Source: Authors' calculations based on PWT 8.0, WB, and FAO.

To characterize the real gains further, we compute the gains by regions–see Figure 7. The differences are striking. Gains in Africa range between 30 percent in 1970 and 20 percent in 2005. In North America, Oceania, and Europe gains are negative in 1970 but very close to zero toward the end of the sample. This happens because in the reallocation capital flows away from this region. Asia and South America have large gains, between 20 and 30 percent, in the 70s and early 80s. Gains in South America decrease in the 90s and 2000s and eventually become negative; i.e. that region had too much capital in 2005. Gains in Asia decrease but remain positive; they are between 5 and 10 percent in the 2000s.

Figure 7: Regional Gains of Physical Capital Reallocation



Note: Results of equalizing RMPK across countries for each year.
Source: Authors' calculations based on PWT 8.0, WB, and FAO.

6 Examining the Reallocation of Capital, 1970-2005

A main finding in Section 5 is the improvement in the efficiency in the allocation of world physical capital over the sample period. Such result might seem to contradict those in the literature; in particular, the work of Gourinchas and Jeanne (2013) about international capital flows. In the words of those authors "capital flows from rich to poor countries are not only low (as argued by Lucas, 1990), but their allocation across developing countries is negatively correlated or uncorrelated with the predictions of the standard textbook model." They call this the "allocation puzzle."In this section, we synthetize these two seemingly contrary views.

The efficient allocation of capital, in our basic framework as well as in many others, does not distinguish between internal (domestic) or external (foreign) sources of capital. Looking at the changes in the total stock of capital in each country is the most direct –if not the only– test of whether, over time, allocations are moving in an inefficient direction. To this end, we perform two exercises. First, we report regressions in the spirit of Gourinchas and Jeanne (2013), but for changes in capital stocks, instead of capital flows. Second, we report the results of simple counterfactuals holding the shares of capital as of the beginning and end of the sample period.

6.1 Does Capital Accumulation follow MPKs?

Table 5 reports the results of regressing the growth rate of the capital stock of countries on the initial value of the marginal product of capital and its growth rate. The dependent variable is the cumulative growth rate (log-differences) of the capital of each country in 2005 relative to the stocks in 1970. We also report the results using $VMPK$ or $RMPK$ as the measure for MPK.We report the results for the whole sample of countries and for a sample without the OECD countries, to follow the focus of Gourinchas and Jeanne (2013) on developing countries.

Table 5: Population weighted OLS regression, $\Delta \ln K$, 1970-2005

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln Z$	0.425***	0.750***	0.358***	0.504***	0.817***	0.428***
	(0.095)	(0.164)	(0.094)	(0.092)	(0.157)	(0.104)
$\Delta \ln H$	-0.024	-0.034	0.074	0.185	0.300	0.371*
	(0.144)	(0.224)	(0.181)	(0.126)	(0.253)	(0.203)
$\Delta \ln \phi^K$	1.270***	1.631***	-	1.348***	1.597***	-
	(0.269)	(0.458)	-	(0.266)	(0.442)	-
$\Delta \ln \frac{P_Y}{P_K}$	1.687***	-	-	1.665***	-	-
	(0.124)	-	-	(0.110)	-	-
$VMPK_{1970}$	2.188***	-	-	2.055**	-	-
	(0.804)	-	-	(0.786)	-	-
$RMPK_{1970}$	-	6.729***	-	-	6.340***	-
	-	(1.081)	-	-	(1.124)	-
$\left(\frac{Y}{K}\right)_{1970}$	-	-	2.610***	-	-	2.400***
	-	-	(0.438)	-	-	(0.457)
Include OECD	Y	Y	Y	N	N	N
Observations	76	76	76	53	53	53
R^2	0.876	0.725	0.737	0.890	0.739	0.736

Note: Robust standard errors in parentheses.
Source: Authors' calculations based on PWT 8.0, WB, and FAO.

The results in Table 5 strongly indicate that from 1970 to 2005, capital accumulation has been positively–and rather strongly–aligned with in the direction of the marginal product of capital. First, capital is accumulated at a faster pace in countries with an initially higher marginal return to capital. Regardless of whether we take either values of $VMPK$ or $RMPK$ in 1970 as the relevant measure for the initial marginal product of capital, or the ratio of Y/K in 1970 as a proxy of initial capital scarcity, we find that capital flows are accumulated faster the higher is the MPK (and/or the higher is Y/K.) The effects are quantitative substantial and statistical significant.

Second, and even more importantly, capital is accumulated at a faster pace in countries in which the marginal product of capital, *ceteris paribus*, would have grown at a faster pace. To see this, notice that the growth in total factor productivity ($\Delta \ln Z$),[26] the growth in the share of physical capital ($\Delta \ln \phi^K$) and the ratio of the output-to-capital prices ($\Delta \ln P_Y/P_K$), all have positive, and statistically and quantitatively significant coefficients. A notable exception is with respect to $\Delta \ln H$, the accumulation of human capital, which exhibits sometimes the wrong sign and is statistically insignificant. A positive and marginally significant coefficient attains only in our least preferred specification, which includes only ($\Delta \ln Z$), ignore all other components that drive MPK, only use Y/K in 1970 as a proxy for initial capital scarcity and excludes all the OECD countries.

In third place, it is worth highlighting a number of other ancillary results. The first one is that the overall fit of the regression is rather high. In fact, our preferred specifications (1) and (4), as we explain below, which regress growth of physical capital with initial $VMPK$ and the

[26] Recall the definition $Z_{j,t} \equiv A_{j,t} T^{\phi^R_{j,t}}$. Here, using our values of $\theta_{j,t}$ and $\phi^K_{j,t} = 1 - \theta_{j,t} - \phi^R_{j,t}$, we impute the value of these TFP-like terms as $Z_{j,t} \equiv A_{j,t} T^{\phi^R_{j,t}} = Y_{j,t} / \left[K_{j,t}^{\phi^K_{j,t}} H_{j,t}^{\theta_{j,t}} \right]$.

growth of the factors driving $VMPK$ growth can account for almost 90% of the variation in the $\Delta \ln K$. Needless to say, the high goodness of fit of the regressions does not contradict our findings that there remains important inefficiencies at the end of the sample period. The high goodness of fit simply indicates the correlation in the direction of of capital accumulation with the drives of the MPK, and does not imply anything about whether the efficient magnitudes coincide with the observed ones.

Another relevant observation is that the main regression results are invariant to the inclusion of OECD countries. Indeed, the fit is marginally better when the OECD countries are excluded. From here, there does not seem to be an allocation puzzle for capital in emerging and developing countries vis-a-vis developed countries.

Finally, our preferred specification is based on the value marginal product of capital, $VMPK$, as the driver of capital accumulation. Our simple model indicates that both, changes in capital intensities, $\Delta \ln \phi^K$, and in the relative price of output to capital, $(\Delta \ln P_Y/P_K)$, should be included as explanatory variables, if anything to avoid a missing variable bias. Such indication is vindicated by the regression results. Both regressors are not only statistically significant at any confidence level, but also, they greatly improve the predictive power of the regression.

6.2 Evaluating counterfactual allocations

We now use our model to conduct simple reallocation counterfactuals that provide different–and complementary– examination on whether the allocation of capital has improved or worsened during our sample period, from 1970 to 2005. In these counterfactual exercises, we compute that amount of capital that each country would have if the shares of all countries, relative to the world's total, remain fixed at the levels observed of a given year. Then, we compare the implied efficiency losses with that counterfactual with those based on the actual series, as reported in the previous section. The difference between the gains starting from the actual allocation and those starting from this counterfactual allocation serves as a metric, measured in terms of global output, to evaluate the importance of the changes in capital stocks over time.

In the first counterfactual exercises, assume that the relative allocation of capital across countries remains fixed at the values observed in 1970, $\mu^K_{j,1970} \equiv K_{j,1970}/K_{W,1970}$, where $K_{W,1970} = \Sigma_j K_{j,1970}$ is the world's total physical capital as of 1970. Then, we construct a counterfactual sequence of capital stock for each country j as

$$\tilde{K}^{1970}_{j,t} = \mu^K_{j,1970} K_{W,t}.$$

With the series $\left\{\tilde{K}^{1970}_{j,t}\right\}$, we compute the counterfactual levels of output $\{\tilde{Y}^{1970}_{j,t}\}$ for each country and the implied world's total $\tilde{Y}^{1970}_{W,t}$, assuming that everything in the world economy, i.e. the technologies $\{Z_{j,t}, \phi^K_{j,t}, \theta_{j,t}\}$ and labor inputs $H_{j,t}$ for all cuntries evolve according to the observed levels. Then, by comparing the attainable gains from the actual allocations, ln $\left[Y^{K*}_{W,t}/Y_{W,t}\right]$ with those from the counterfactual allocation ln $\left[Y^{K*}_{W,t}/\tilde{Y}^{1970}_{W,t}\right]$, we could discern whether changes in the relative allocation of capital since 1970 have moved the world allocation of capital closer or farther from efficiency. Exactly the same calculations are done for the nominal benchmarks as defined in Section 3, where the shares are defined as $\mu^K_{j,t} \equiv \left(P^K_{j,t}/P^Y_{j,t}\right) K_{j,t}/K^N_{W,t}$ and $K^N_{W,1970} = \Sigma_j \left(P^K_{j,t}/P^Y_{j,t}\right) K_{j,t}$.

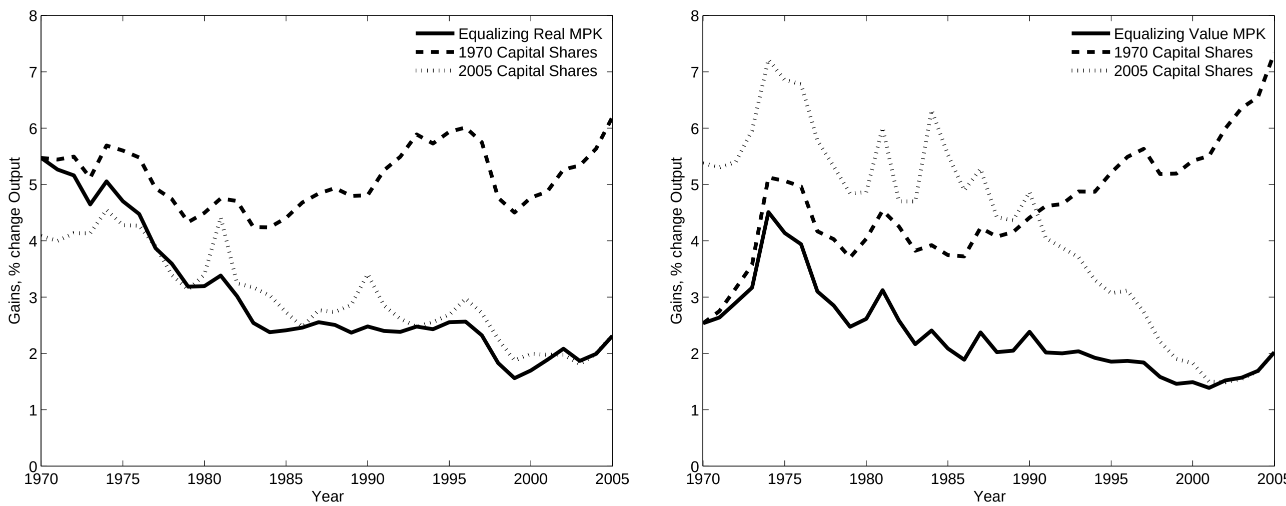
The second set of of counterfactual exercises are done from the vantage view of 2005. That is, we compute the shares $\mu^K_{j,2005} \equiv K_{j,2005}/K_{W,2005}$, compute the shares

$$\tilde{K}^{2005}_{j,t} = \mu^K_{j,2005} K_{W,t},$$

and follow the same steps to compute the world outputs $\tilde{Y}^{2005}_{W,t}$, and the counterfactual global efficiency loss $\ln\left[Y^{K*}_{W,t}/\tilde{Y}^{2005}_{W,t}\right]$. These second set of countefactuals complement the first ones by indicating how efficient would have been the current distribution of capital for the first years in our sample.

Figures 8 display the results for the counterfactuals based on physical and value marginal products of capital, $RMPKs$ and $VMPK$. In each panel, the solid lines represent the global efficiency loses from actual allocations; the dashed and dotted lines represent, respectively, the global counterfactual efficiency loses from an allocation that keeps constant the shares as of 1970 and 2005.

Figure 8: Comparing Gains of Counterfactual Allocations



Equalizing RMPK　　Equalizing VMPK

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

In terms of the physical $RMPK$, the left panel unambiguously shows that the the global efficiency losses would have remain approximately flat over time, around 5.5% of global output. The changes over time in the allocation of capital across countries has more than halved the efficiency loses by the end of the sample. Interestingly enough, if over the sample period, the allocation of capital had been that of 2005, the global efficiency losses would have been the same, except for the early 1970s and a handful of years in the early 1980s and early 1990s.

As shown in the right panel, the counterfactuals based on value marginal products of capital, $VMPK$, convey an only slightly different message. As with $RMPK$, this counterfactual shows that keeping constant the relative capital allocations as in 1970 would have lead to a much more inefficient world, with three times the global output losses by the end of the sample. The difference is that the counterfactual using the relative allocation of 2005 would have led to much more inefficient for any of the years prior to 2000.

Overall, both counterfactual exercises coincide in their verdict the reallocation caused by capital accumulation between 1970 and 2005 was conducive to higher efficiency.

6.3 External Capital Flows

We now show that domestic savings drive the movement towards efficiency from 1970 to 2005. In essence, those countries whose MPK grow the faster were also the ones saving the most. Then, more than contradicting, our findings reinforce and trascend the negative results of Gourinchas and Jeanne (2013) on the role foreign capital flows in attaining efficiency. We argue that, at least for the second part of our sample period, foreign capital flows have been all but irrelevant for the cross country capital allocation, echoing the old result of Feldstein and Horioka (1980).

To this end, we perform an additional, simple, counterfactual exercise. We compute how the changes in the allocation of capital across countries would change over time solely on the basis of external capital flows. As in the previous exercises, we do this for the initial year and for the final year in a given period. For this version of the paper those are 1982 and 2000.[27] For the former, the shares $\mu^K_{j,1982} = K_{j,1982}/K_{W,1982}$ describe the relative world capital allocation that year. Then, for each country, we construct the counterfactual capital series for 1983 to 2000, as augmented or reduced by net capital inflows $\{XK_{j,s}\}^{2000}_{s=1982}$ –outflows if negative– defined by:

$$\bar{K}_{j,t} = \mu^K_{j,1982} K_{W,t} + \sum_{s=1982}^{t} (1-\delta)^{s-1982} XK_{j,s}.$$

The counterfactuals from the vantage point of 2000, are exactly the same formula, but using $\mu^K_{j,2000}$.

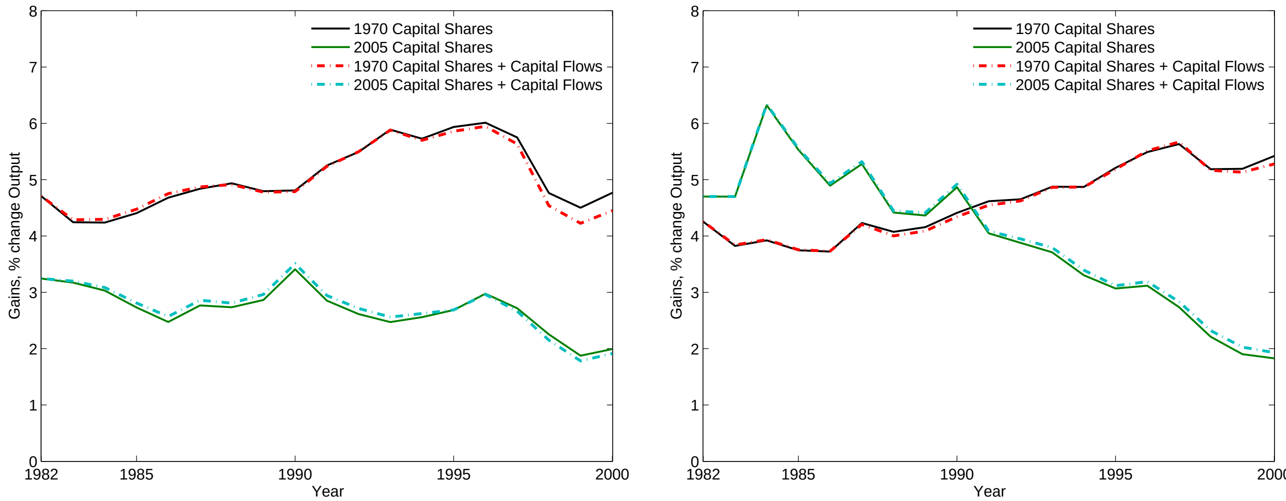
For $XK_{j,s}$ we use the negative of the trade balance of the countries. [28] We depreciate the capital flows at $\delta = 4,64\%$, the depreciation rate for the US in PWT 8.0. Data limitations, in particular, the desire to include China, restricts us to the period $1982-2000$ and only 69 countries.

Figures 9 reports the results for the exercises based on $RMPK$ and $VMPK$, respectively. In each graph, the exercises with 1982 shares are in darker lines and lighter ones for 2000. Dashed lines are used for the counterfactuals with the observed $XK_{j,s}$. The finer, solid lines are the cases when $XK_{j,s} = 0$.

[27] Current data limitations restrict our exercise to run from 1982 to 2000 and to only 69 countries.

[28] The US$ figures from the IMF are converted in PPP units using $P^K_{j,t}$ and $P^K_{j,t}$ from the PWT 8.To attain global balance we need an adjustment. We multiply all the positive net inflows by a ratio greater than 1 so that the sum of $XK_{j,s}$ over all countries in the sample add up to zero. Very similar results attain using the current account deficits to measure $XK_{j,s}$, but the required adjustment for global balance is much larger in that case.

Figure 9: Comparing Gains of Counterfactual Allocations, Role of Capital Flows



Equalizing RMPK   Equalizing VMPK

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

The most striking results is how little foreign flows change the allocation of capital and the potential global output losses. External capital flows are dwarfed by domestic savings and the overall capital formation of countries. The irrelevance of external capital flows for global efficiency is succinctly shown by almost undistinguishable dashed and solid lines in both graphs. If anything, the magnitude of the external flows are so small that, effectively, it does not really matter whether they are misallocated or not.

7 The Allocation of Human Capital

We now switch the attention to human capital and the cross-country distribution of its marginal product. Our treatment of human capital is different than, and to some extend subordinate to, that of the physical capital for a number of reasons. First of all, to be sure, reallocating humans is more complex than reallocating machines. Machines do not have attachments, do not require compensating differences and are not resisted by the pre-existent machines installed in countries. Yet, human capital is reallocated across countries. Universities, hospitals, research institutions, but also stores, restaurants and farms in the U.S. and many other countries agglomerate workers from all over the world. Second, contrary to physical capital (for which we have $P^K_{j,t}/P^Y_{j,t}$, the goods cost for physical capital), we do not have a direct measurement of the relative cost of human capital in each country and period. To overcome that limitation, we would conduct experiments that take two extreme and opposite views about the observed cost of labor across countries.

7.1 The Marginal Product of Human Capital

First, we report salient differences in the behavior of the cross-country dispersion in human capital and its marginal product (MPH) relative to what we see for physical capital. The dispersion of MPH is large and growing over time, and the accumulation of human capital does not track the behavior of the determinants of MPH. Second, to the extent that differences in MPH are driven by barriers to the mobility of labor across countries, the global gains of reallocating human capital would be an order of magnitude higher than those of reallocating physical capital. Third, the ability to reallocate workers would not only enhance the gains in global output from reallocating physical capital, but, more interestingly, induces a reversal in the direction of reallocation of capital across countries. Instead of flowing from richer to poorer countries, capital from poorer countries would follow some of their workers in the direction of richer countries. This simple result could be useful in understanding the difference between integration agreements with labor mobility (e.g. the EU) and without it (e.g. NAFTA.)

In our framework, the marginal product of one unit of human capital in terms of quantity of goods ($RMPH_{j,t}$), is simply given by

$$RMPH_{j,t} = \theta_{j,t}\frac{Y_{j,t}}{H_{j,t}}.$$

Therefore, as we did with MPK, we can simply decompose the cross-section variance of $\ln RMH_{i,j}$ in terms of the labor share of output and the output-to-human capital ratios:

$$var\left[\ln RMPH_{i,j}\right] = var\left[\ln \theta_{j,t}\right] + var\left[\ln\left(Y_{j,t}/H_{j,t}\right)\right] + 2cov\left[\ln \theta_{j,t}, \ln\left(Y_{j,t}/H_{j,t}\right)\right].$$

Table 6 reports the values of these variances and the covariance for a number of years over the sample period. The right side of the panel also reports a number of covariances of interest with respect to the joint reallocation of human and physical capital across countries.

Table 6: Decomposition of the variance of $\ln RMPM_{j,t}$ and $VMPK_{j,t}$: 1970-2000

Year	Variances (logs of each variable)			Covariances (logs of each variable)				
	$RMPH_{j,t}$	$\theta_{j,t}$	$\frac{Y_{j,t}}{H_{j,t}}$	$\theta_{j,t}, \frac{Y_{j,t}}{H_{j,t}}$	$RMPH_{j,t}, RMPK_{j,t}$	$RMPH_{j,t}, \frac{P^Y_{j,t}}{P^K_{j,t}}$	$RMPH_{j,t}, \frac{Y_{j,t}}{H_{j,t}}$	$RMPH_{j,t}, \frac{Y_{j,t}}{K_{j,t}}$
1970	0.756	0.064	0.788	-0.048	-0.082	-0.019	0.740	-0.042
1980	0.713	0.061	0.726	-0.037	-0.169	0.058	0.689	-0.105
1990	0.748	0.058	0.642	0.024	-0.149	0.111	0.666	-0.107
2000	0.978	0.059	0.899	0.010	-0.038	0.029	0.909	-0.021

Source: Authors' calculations based on PWT 8.0.

Contrary to physical capital, there is an upward trend in the dispersion in the $\ln RMPH$. From a low value of 0.713 in 1980, the variance in $\ln RMPH$ grows from there on until reaching its highest value of 0.978 in 2000. Almost all of the variation is driven by the dispersion in $\ln\left[Y_{j,t}/H_{j,t}\right]$. Indeed, the cross-country correlation $\ln RMPH$ and $\ln\left[Y_{j,t}/H_{j,t}\right]$ is always above 0.95. Differences in the labor share of output, $\ln \theta_{j,t}$ account at most 9% of this variations, a contribution that remains flat around $7\% - 8\%$ during the sample period. The covariance between $\ln \theta_{j,t}$ and $\ln\left[Y_{j,t}/H_{j,t}\right]$ provides a negligible contribution.

The cross-country covariation between the marginal products of human and physical capital is key for the potential gains of jointly reallocating these factors. We find that while negative, the magnitude of this covariation is rather weak. From the the variances and covariances of $\ln RMPH$ and $\ln RMPK$, reported in Tables 2 and 6, we see that $\ln RMPH$ and $\ln RMPK$ are always negatively correlated. The magnitude of this correlation increases and then decreases back at the end of the sample. A very similar pattern is followed by the correlation between $\ln RMPH_{j,t}$ and $\ln\left[Y_{j,t}/K_{j,t}\right]$ On the other hand, the correlation of $\ln RMPH_{j,t}$ with $\ln\left(P^Y_{j,t}/P^K_{j,t}\right)$ and with $\ln VMPK_{j,t}$ exhibit quite the opposite pattern. Their correlations are negligible at the beginning and at the end of the sample, but reach levels about 0.4 in the middle of the sample period.

7.2 Gains of Human (and Physical) Capital Reallocation

We now use the same framework to analyze the efficiency losses from misallocating both, capital and labor. In our setting, the fixed factors in each country are the TFP and the natural resources, group in the term $Z_{j,t} \equiv A_{j,t} T_{j,t}^{(1-\gamma_{j,t})(1-\theta_{j,t})}$. Notice that the output share of natural resources is important for our computations because it determines the returns to scale of mobile factors, human and physical capital, in each of the countries.

Baseline. The optimal global allocation is defined by the same objective as before; i.e.,

$$Y_{W,t}^{K^*,H^*} = \max_{\{K_{j,t},\, H_{j,t}\}} \sum_{j=1}^{J} Z_{j,t} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})} \left(H_{j,t}\right)^{\theta_{j,t}},$$

but instead of setting human capital at observed levels, $H_{j,t} = H_{j,t}^{O}$, the constrain becomes

$$\sum_{j=1}^{J} H_{j,t} \leq H_{W,t}$$

where $H_{W,t} \equiv \sum_{j=1}^{J} H_{j,t}^{O}$ for all t. In addition to equalizing the $RMPK_{j,t}$ of all countries to a common world price, r_t^K, efficiency requires that all $RMPH_{j,t}$ be equalized to a common price

$$r_t^H = \theta_{j,t} Z_{j,t} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})} \left(H_{j,t}\right)^{\theta_{j,t}-1}. \tag{10}$$

Thus, the world supply levels $K_{W,t}$ and $H_{W,t}$, and the productivities and endowments of natural resources $Z_{j,t}$ of all countries pin down the equilibrium r_t^K and r_t^H. Those prices and the factor shares determine the factor intensity of each country,

$$\frac{K_{j,t}}{H_{j,t}} = \frac{\gamma_{j,t}\left(1-\theta_{j,t}\right)}{\theta_{j,t}} \frac{r_t^H}{r_t^K}.$$

The efficient allocation implies that human and physical capital are allocated across countries to complement their TFP and natural resources as allowed by their country specific returns to scale to mobile factors. As before, there is not a closed form solution except for the case of common (time-varying) factors shares, but the numerical optimization is trivial.[29]

Value benchmark. The previous benchmark presumes that workers are indifferent as to where to work, and output-per-worker cross-country differences are sustained by barriers to worker migration. The completely opposite view is that barriers are not the key limitation, and wage differences are sustained by compensating differences; differences in RMPK, and thus is wages, are sustained because workers demand different wages to live in different places.

Trying to model and empirically discipline the behavior of compensating differences lies outside the limits of this paper.[30] Instead, we focus on a simple exercise that reallocates workers and

[29] Under the assumption of common factor shares across countries, efficient world output can be solved analyitcally as,

$$Y_{W,t}^{K^*,H^*} = \left[\sum_{j=1}^{J} \left(A_{j,t} T_{j,t}^{(1-\bar{\gamma}_t)\left(1-\bar{\theta}_t\right)}\right)^{\frac{1}{(1-\bar{\gamma}_t)(1-\bar{\theta}_t)}}\right]^{(1-\bar{\gamma}_t)\left(1-\bar{\theta}_t\right)} \left(K_{W,t}\right)^{\bar{\gamma}_t\left(1-\bar{\theta}_t\right)} \left(H_{W,t}\right)^{\bar{\theta}_t}.$$

[30] For that, see Klein and Ventura (2009).

capital but subject to keeping constant the real wages of workers, in terms of consumption goods, $w^h_{j,t}P^C_{j,t}/P^Y_{j,t}$, as inferred in the data in each country in each period. Since we do not have direct measurements on the wage in terms of output, $w^h_{j,t}$, we use our model and infer it as $w_{j,t} = \theta_{j,t}Y_{j,t}/H_{j,t} = RMPH_{j,t}$. Thus, by fixing the real wages of all countries in a point in time, this counterfactual is consistent with any decomposition of those wages arising from compensating differentials or barriers to mobility of workers. Notice also that if only workers, but no physical capital, is allowed to move, the reallocation would be minimal, due only to the small variation in the data for the relative price $P^C_{j,t}/P^Y_{j,t}$. For the maximization in this benchmark, the natural resource constraint is that the global amount of goods paid for human capital services in each period is equal to the one inferred in the data

$$\sum_{j=1}^{J} \frac{P^C_{j,t}}{P^Y_{j,t}} w^h_{j,t} H_{j,t} \leq H^N_{W,t}, \tag{11}$$

where $H^N_{W,t} \equiv \sum_{j=1}^{J} \frac{P^C_{j,t} w^h_{j,t}}{P^Y_{j,t}} H^O_{j,t}$, and $H^O_{j,t}$ the observed data value for country j in period t. As in the case when only capital can move, we impose the restriction

$$\sum_{j=1}^{J} \frac{P^K_{j,t}}{P^Y_{j,t}} K_{j,t} \leq K^N_{W,t}, \tag{12}$$

and subject to providing the same amount of consumption goods to workers as implied by the data.

There is an intuitive interpretation for this exercise. Imagine a firm owner that is able to reallocate resources across countries and it is small enough that takes prices as given. In terms of wages, imagine this person is limited by country specific regulations (unions, minimum wages, etc.) to pay the period t wage in country i for any worker that he reallocates to country i in period t. She is given the task of reallocating workers across countries to maximise real output subject to keeping constant the company's payroll. Since we measure wages by $RMPK$ (disregarding $P^C_{j,t}/P^Y_{j,t}$ differences), the firm's owner has no incentives to reallocate workers if capital cannot be reallocated. In this sense, this exercise provides a lower bound for the global gains of human capital reallocation. Once capital can also be reallocated, there are potential gains of reallocating workers even subject to the countries of constant wages in each country.

The optimality conditions required the equalization, across countries, of the price-corrected marginal product of physical and human capital across countries, i.e.

$$R^K_t = \frac{P^Y_{j,t}}{P^K_{j,t}} \gamma_{j,t} \left(1 - \theta_{j,t}\right) A_{j,t} T_{j,t}^{(1-\gamma_{j,t})(1-\theta_{j,t})} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})-1} \left(H_{j,t}\right)^{\theta_{j,t}}, \tag{13}$$

for physical capital and

$$R^H_t = \frac{P^Y_{j,t}}{P^C_{j,t} w^h_{j,t}} \theta_{j,t} A_{j,t} T_{j,t}^{(1-\gamma_{j,t})(1-\theta_{j,t})} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})} \left(H_{j,t}\right)^{\theta_{j,t}-1}. \tag{14}$$

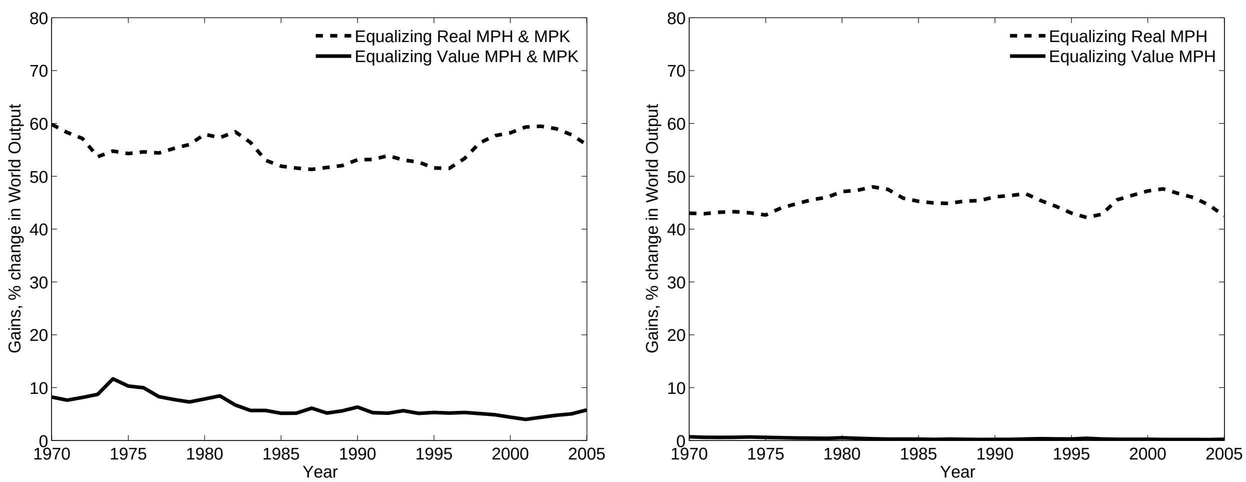
Notice that, given world's returns R_t and R^H_t, the physical-to-human capital ratio in country j should be

$$\frac{K_{j,t}}{H_{j,t}} = \frac{\gamma_{j,t} \left(1 - \theta_{j,t}\right)}{\theta_{j,t}} \frac{P^C_{j,t} w^h_{j,t}}{P^K_{j,t}} \frac{R^H_t}{R^K_t},$$

Thus, in the efficient allocation, the physical capital intensity, relative to human capital, varies across countries according to their (i) factor shares in production, (ii) relative price of consumption and capital goods, and (ii) effective cost of labor. While natural resources $T_{j,t}$ and pure TFP $A_{j,t}$ enhance the amount of human and physical capital a country should receive, the cost in terms of output of both factors, respectively $P^K_{j,t}/P^Y_{j,t}$ and $P^C_{j,t}w^h_{j,t}/P^Y_{j,t}$ reduce them. It is trivially true that this maximization dominates the one where only capital can be reallocated. The interesting question is how much and whether capital flows change in magnitude and direction.[31]

Results. Figure 10 shows the global output gains of reallocating both physical and human capital and human capital only, respectively. In each figure, the dashed lines represent the gains from the benchmark. The solid lines represent the gains from the value benchmark as defined above.

Figure 10: Global Output Gains of Production Factors Reallocation



Reallocating H and K

Reallocating only H

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

The most salient result is that the global gains of reallocating workers and physical capital can

[31]While our quantitative results are based on the numerical solution of the general case for which factor shares are allowed to differ across countries, again, with uniform shares we can derive a closed-form expression for the world's output. The shares of each country j in the world's total expenditures in physical and human capital in period t, $\mu^K_{j,t} \equiv \frac{(P^K_{j,t}/P^Y_{j,t})K_{j,t}}{K^N_{W,t}}$ and $\mu^H_{j,t} \equiv \frac{(P^C_{j,t}w^h_{j,t}/P^Y_{j,t})H_{j,t}}{H^N_{W,t}}$ can be solved as

$$\mu^K_{j,t} = \mu^H_{j,t} = \frac{T_{j,t}\left[A_{j,t}\left(\frac{P^K_{j,t}}{P^Y_{j,t}}\right)^{-\gamma(1-\theta)}\left(\frac{P^C_{j,t}w^h_{j,t}}{P^Y_{j,t}}\right)^{-\theta}\right]^{\frac{1}{(1-\gamma)(1-\theta)}}}{\sum_{j=1}^{J} T_{j,t}\left[A_{j,t}\left(\frac{P^K_{j,t}}{P^Y_{j,t}}\right)^{-\gamma(1-\theta)}\left(\frac{P^C_{j,t}w^h_{j,t}}{P^Y_{j,t}}\right)^{-\theta}\right]^{\frac{1}{(1-\gamma)(1-\theta)}}}.$$

The maximized global output also has closed form solution:

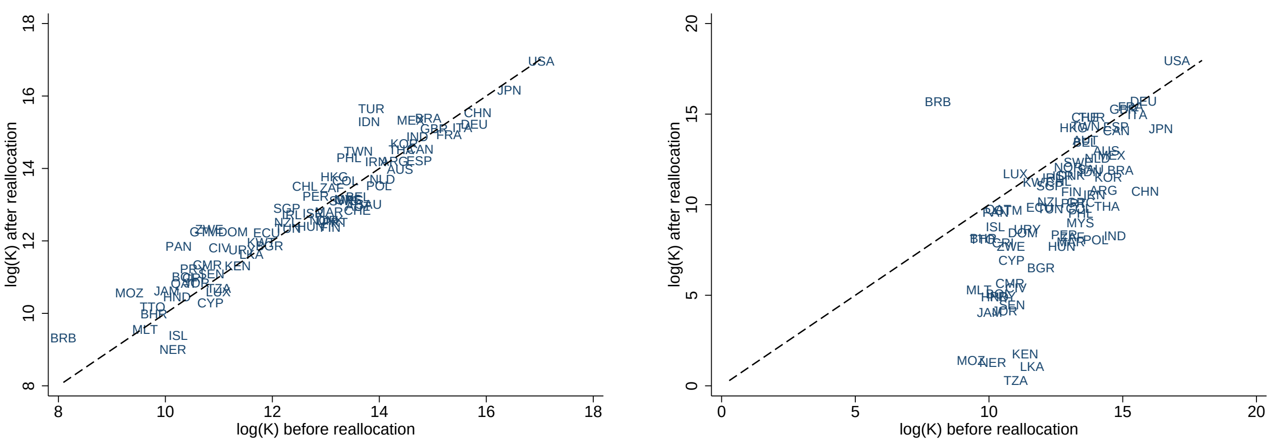
$$Y^{N;\,K^*,\,H^*}_{W,t} = \left\{\sum_{j=1}^{J} T_{j,t}\left[A_{j,t}\left(\frac{P^K_{i,t}}{P^Y_{i,t}}\right)^{-\gamma(1-\theta)}\left(\frac{P^C_{i,t}w^h_{i,t}}{P^Y_{i,t}}\right)^{-\theta}\right]^{\frac{1}{(1-\gamma)(1-\theta)}}\right\}^{(1-\theta)(1-\gamma)} \left[K^N_{W,t}\right]^{\gamma(1-\theta)}\left[H^N_{W,t}\right]^{\theta}.$$

be much higher—more than one order of magnitude higher—than the global gains of reallocating only physical capital. The benchmark indicates that, for all the years in the sample, the global gains would be approximate 55% of world output. Those gains remain relatively flat over the sample period. The value benchmark also indicates a larger gain, but only around twice that of reallocating capital only.

A second important result is that the complementarity between human and physical capital is a key determinant for the larger gains from their joint reallocation. As shown by the right panel, reallocating human capital per se leads to very large gains in the quantity benchmark counterfactual, but they are far from accounting for the difference between the joint reallocation and the physical capital only reallocation. This finding is even more clear in the value benchmark, where the gains of reallocating labor only would be negligible.

Yet, perhaps the most interesting result is a reversal of the direction of capital flows. When only capital can be re-allocated, capital would tend to flow to poorer countries. Instead, when both factors can be reallocated, capital would flow from poorer to richer countries. Figure 11 illustrates this for the year 1996, by comparing actual physical capital stocks (in logs) for that year, with the resulting physical capital stocks after the two different reallocations. In the first case, most countries in the data would increase their physical capital, receiving it from a smaller group of the countries, including a handful of the rich ones. In the second case, most of the countries would lose physical capital, sending it, along with part of their human capital, to USA and a handful of rich countries because of their high TFP and endowment of natural resources.

Figure 11: Changes in the Allocation of Production Factors



Reallocating only K   Reallocating K and H

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

Note: The results here correspond to the benchmark setup without differences in prices.

7.3 A Human Capital Reallocation Puzzle

To examine whether there is a reallocation puzzle for human capital, we now perform the same analyses we did for physical capital. In this case, however, there is little evidence that the countries with the largest increase in human capital were those with the highest return. In general, the measure of the initial marginal product of human capital appear insignificant in the regression to account for the change in human capital, displayed in Table 7. Changes in TFP and physical capital are also insignificant in accounting for changes in human capital. The R squared of these regressions are also much lower than those for physical capital, indicating that these driving forces are much less important driving investment in human capital.

Table 7: Population weighted OLS regression, ΔH, 1970-2005

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln Z$	0.081	0.098	0.044	-0.044	-0.021	-0.067
	(0.085)	(0.091)	(0.093)	(0.095)	(0.089)	(0.083)
$\Delta \ln K$	0.092	0.033	0.070	0.117*	0.065	0.109
	(0.069)	(0.070)	(0.106)	(0.067)	(0.062)	(0.081)
$\Delta \ln \phi^H$	-1.133**	-0.935**	-	-0.706	-0.568	-
	(0.429)	(0.385)	-	(0.429)	(0.383)	-
$\Delta \ln \frac{P_Y}{P_C}$	1.157**	-	-	1.083***	-	-
	(0.455)	-	-	(0.373)	-	-
$VMPH_{1970}$ $\times 10^{-3}$	-0.015	-	-	-0.025	-	-
	(0.014)	-	-	(0.015)	-	-
$RMPH_{1970}$ $\times 10^{-3}$	-	-0.024*	-	-	-0.030	-
	-	(0.014)	-	-	(0.018)	-
$\left(\frac{Y}{H}\right)_{1970} \times 10^{-3}$	-	-	-0.014	-	-	-0.011
	-	-	(0.013)	-	-	(0.013)
Include OECD	Y	Y	Y	N	N	N
Observations	76	76	76	53	53	53
R^2	0.411	0.340	0.176	0.471	0.349	0.174

Note: Robust standard errors in parentheses.

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

These results seem to be in lines with the findings in Easterly (2002) who argues that "the growth response to the dramatic educational expansion of the last four decades has been distinctly disappointing ... Creating skills where there exists no technology to use them is not going to foster economic growth."

To measure the extend of the misallocation we also construct a counterfactual sequence of human capital stock for each country $\tilde{H}_{j,t}$, as we did for physical capital. More precisely, the stock of human capital of country j in year t is

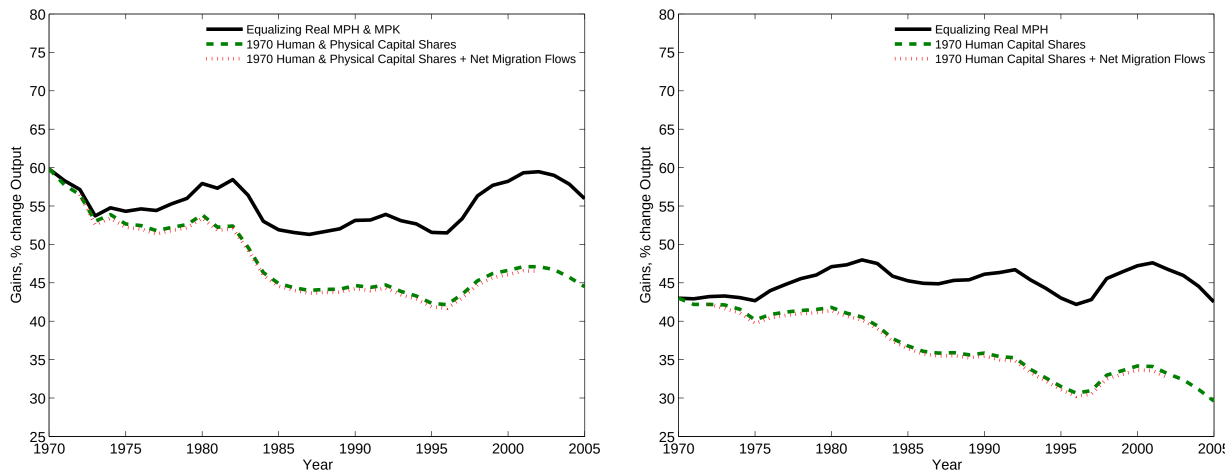
$$\tilde{H}_{j,t} = s_{j,1970} \cdot H_{W,t}$$

where $H_{W,t}$ is the world stock of human capital and $s_{j,1970} = \frac{H_{j,1970}}{H_{W,1970}}$. We also looked at the flows of human capital by analyzing net migration flows to each particular country $\{f^H_{j,t}\}$. In this case, however, we do not have information about the human capital of the migrants. Therefore, we assume that migration changes the number of persons living in a country but not the average human capital index or the share of people that is employed.[32]

[32]For example, that would be the case if the net flows from each country have the same characteristics than the population of that country.

We find that the changes in human capital since 1970 made the global allocation of human capital significantly worse (Figure 12). If in 2005 human capital was distributed according to the shares per country of 1970, the gains of reallocation would be 30 percent instead of 43 percent. The difference, 13 percent of global output, is a measure of much worse is the allocation of human capital due to changes that took place since 1970. Adding migration flows does not change the picture, so the changes in human capital that worsen the allocation of human capital are internal.

Figure 12: Counterfactual Global Output Gains of Production Factors Reallocation



Reallocating H and K | Reallocating only H

Source: Authors' calculations based on PWT 8.0, WB, and FAO.

8 Conclusions

The purpose of this paper was to examine the efficiency in the allocation of physical and human capital across countries. Those factors can be reallocated across countries, while others, such as natural resources cannot. The first step of our work was to collect estimates of the rents of natural resources and then use these estimates to improve the inference on the marginal product of physical capital across the different countries. Netting out the output shares of natural resources also allowed us to assess the overall returns to scale in each country with respect to the mobile factors and thus to evaluate the gains of jointly reallocating physical and human capital.

For our panel of countries for the past thirty five years, we found that, on average, 4 percent of the income of countries accrues to natural resources. The share varies greatly across countries and tends to be higher for lower-income countries. The standard neoclassical model would overestimate the marginal product of capital for poorer countries, thus overestimating the extent of misallocations of mobile factors across countries. Our estimates are based on rent flows and are free of ancillary assumptions used to estimate wealth stocks in natural resources. We document that those assumptions, as employed by the World Bank, lead to significant overestimation of the natural resources rents and incorrectly lead to the conclusion that there are no distortions in the allocation of physical capital across countries. Instead, we argue that, even at the end of the sample, non-negligible global output losses persist due to the misallocation of physical capital.

We then examined a number of patterns for the global misallocation of resources, over time, across policy regimes, and across regions. A number of those results are worth highlighting again. First of all, there is a clear indication that the global allocation of physical capital has improved over time. In the 1970s, the global output losses were around 6%. By the end of the sample, global output losses were on the order of 2%. A second finding worth mentioning is that the relative price of capital is not the only driver of the differences in the marginal product of capital and the trends in the global output losses. We use pure quantities or correct for the relative price of output to capital, and both measures exhibit similar behavior. A third crucial finding is that disparities in the marginal product of capital are indeed associated with a broad indicator of policy differences. Indeed, those countries with more interventionist policies, which a priori inhibit and distort the accumulation of capital, exhibit larger and more disperse marginal products. Interestingly, those policy distortions seem to not only reduce the supply of capital in the most distorted countries, but also increase the cost of physical capital in terms of output goods. Moreover, our results suggest that the trends towards global efficiency are clearly aligned to the trends towards market orientation from the policy indicator.

A fourth key result is that during the sample period the movement towards global efficiency is accounted for by the strong association between the accumulation of capital and the changes in the marginal product of capital. What is surprising about this finding is its strength. Indeed, initial marginal product of capital and changes in the factor shares, TFP-cum-natural resources and relative prices explain almost 90% of the variation in the accumulation of capital. Furthermore, capital accumulation across countries is mostly driven by domestic or internal accumulation. Foreign or external capital flows have a mostly negligible contribution, which often goes in the wrong direction.

Finally, a quantitatively important aspect of global misallocation, however, is human capital. The implied global efficiency losses of the misallocation of human capital are one order of magnitude higher, around 60%. Moreover, while the allocation of physical capital has moved towards global efficiency, quite the opposite appears to have happened for the cross-country allocation of human capital. This finding might not be surprising, since it is well known that the dispersion in output per worker, if anything, has increased in the past few years. When both physical and human capital can be reallocated at the same time, a number of crucial changes take place. First of all, the gains are substantially higher. For instance, in one of the benchmarks the reallocation of workers is so heavily restricted that, by itself, it would not occur. Even in this case, the ability of reallocating both physical and human capital more than doubles the gains of reallocating physical capital alone. A second, and perhaps even more salient result, is that the direction of reallocation can change. As in most of the literature since Lucas (1990), we find that the efficient reallocation of physical capital is, grosso modo, from the richer to the poorer countries. Once both labor and capital can move, the direction is reversed; and the physical capital of poorer countries, along with some of their workers, would be efficiently allocated in developed countries. Before asking why, one should start by asking whether capital should flow from rich to poor countries. In any event, it seems to be human, rather than physical capital, where the most pressing issues lie.

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A Further Data Details

We compute the share of natural resources of output for 79 countries with data available for every year since 1970 to 2005. They are: Argentina, Australia, Austria, Bahrain, Barbados, Belgium, Bolivia, Brazil, Bulgaria, Burkina Faso, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Cote dIvoire, Cyprus, Denmark, Dominican Republic, Ecuador, Finland, France, Germany, Greece, Guatemala, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Kuwait, Luxembourg, Malaysia, Malta, Mexico, Morocco, Mozambique, Netherlands, New Zealand, Niger, Nigeria, Norway, Oman, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Saudi Arabia, Senegal, Singapore, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Trinidad & Tobago, Tunisia, Turkey, United Kingdom, United States, Uruguay, Zimbabwe. Only 3 of these countries do not have data available for human capital: Burkina Faso, Nigeria, Oman. We exclude those countries for the reallocation exercises.

B Proxying the Natural Resources Share of Output with Natural Resources Stocks

In their seminal paper, Caselli and Feyrer (2007) use the World Bank's *stocks of wealth* estimates to compute the output share of natural resources for the year 1995. In this appendix, we briefly overview their method and assumptions and compare their results with ours.

First, for the different natural resources items $q \in \{a, b, c, e, f\}$ as detailed in Section 2, the World Bank, computes natural stocks, $WSNR_{q,j,\mathbf{1995}}$, for each country j in their sample. They obtain their estimates by multiplying their data on the flow of rents $\text{rents}_{q,j,1995}$, by a present value term $PVF_{j,q}$

$$WSNR_{q,j,\mathbf{1995}} = \text{rents}_{q,j,1995} \times PVF_{j,q}$$

where the present value factor $PVF_{j,q}$ depends not only on the natural resources q but also in the country j,

$$PVF_{j,q} = \sum_{s=0}^{\mathbf{T}_{j,q}} \frac{(\mathbf{G_{j,q}})^s}{(1+\mathbf{r}^*)^s},$$

where r^* is the discount rate, $\mathbf{G_{j,q}}$ is the growth rate in the rent flows, and $\mathbf{T}_{j,q}$. Unfortunately, the World Bank does not have direct measures of r^*, $\mathbf{G_{j,q}}$, and $\mathbf{T}_{j,q}$. Thus, computing the stocks requires making additional assumptions. They assume that the discount rate r^* is the same across all countries, 4%. More importantly, they assume that the growth rate in the rent flows, $\mathbf{G_{j,q}}$ and the terminal or exhaustion date of the resource $\mathbf{T}_{j,q}$ both vary by country j and resource q. In particular, they group countries between developed and developing countries, and assume that the rents for the developing countries grow significantly faster ($\mathbf{G_{developing,\ q}} > \mathbf{G_{developed,\ q}}$) and exhaust later ($\mathbf{T_{developing,\ q}} > \mathbf{T_{developed,\ q}}$) than for developed countries. Table 8 shows the implied values for $PVF_{j,q}$ for range of values of $\mathbf{G_{j,q}}$, $\mathbf{T}_{j,q}$ assumed by the World Bank.

Table 8: World Bank's Present Value Factors, $PVF_{j,q}$

	Developed Countries			Developing Countries		
Resources	$G_{j,q}-1$	$T_{j,q}$	$\mathbf{PVF_{j,q}}$	$G_{j,q}-1$	$T_{j,q}$	$\mathbf{PVF_{j,q}}$
	(%)			(%)		
Subsoil Res.	0	13	**10.5**	0	17	**12.7**
Timber	0	25	**16.3**	0	25	**16.3**
Croplands	0.97	25	**17.9**	1.94	25	**19.9**
Pasturelands	0.89	25	**17.8**	2.95	25	**22.2**

Table 8 two important aspects in the resulting values for $PVF_{j,q}$. First, their numbers are fairly large, meaning that given the rents, the present value factors can lead to very large wealth stock estimates. Second, the numbers are even larger for developing countries. This second assumption is important for our exercise. Imagine a countries P (poor) and R (rich), where country's P GPD is 100 while country's P GDP is 1000. In addition, imagine the original rents estimated by the World Bank are 5 percent of GDP; 5 for country P and 50 for country R. The implication of the second assumption is that the difference between the natural resources stocks of these two countries will be narrower.

In any event, summing over all the natural resources, the World Bank esimates a country's total natural wealth stock in 1995 to be

$$N_{j,1995} = \sum_q NRR_{q,j,1995}.$$

The World Bank estimation finishes in this step. Caselli and Feyrer (2007) take those natural resources stocks and recover the rents using the following method. They notice that on the basis of these stocks, it is possible to compute the fraction of non-labor income that should accrue to natural resource owners. In particular, if $r^K_{j,1995}$ and $r^N_{j,1995}$ represent the rental rate of physical and natural capital, and $K_{j,1995}$ indicates the stock of physical capital in country j in 1995, then one could compute the output share of natural resources as

$$\phi^R_{j,1995} = \frac{r^N_{j,1995} N_{j,1995}}{r^N_{j,1995} N_{j,1995} + r^K_{j,1995} K_{j,1995}} \times \left[1 - \text{labor share}_{j,1995}\right].$$

However, the required cross-country data for $r^K_{j,1995}$ and $r^N_{j,1995}$ is simply not available. The key assumption in Caselli and Feyrer (2007)'s method is that $r^N_{j,1995} = r^K_{j,1995}$ for all countries j. Notice that this is not a non-arbitrage condition, since N and K are two different production factors, as well as labor.

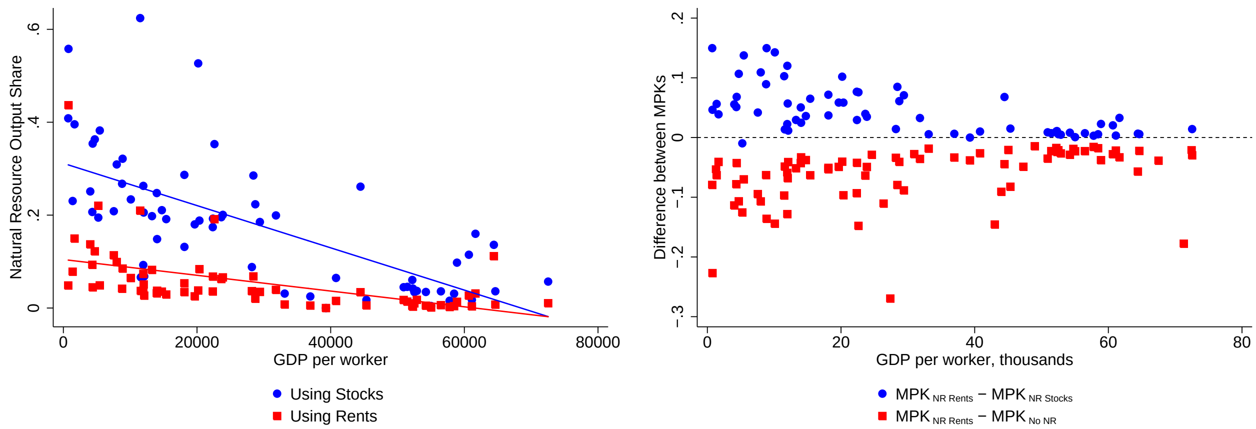
With this assumption, their estimate of the share of natural resources is simply

$$\phi^R_{j,1995} = \frac{N_{j,1995}}{N_{j,1995} + K_{j,1995}} \times \left[1 - \text{labor share}_{j,1995}\right]. \qquad (15)$$

We view our measure of $\phi^R_{j,t}$ to be superior than the one derived by Caselli and Feyrer (2007) for a number of important reasons. First, it is available for many years, and not only for 1995. Second, it does not rely on the assumptions made by the World Bank on growth rates and exhaustion dates

Figure 13: Comparing Alternative Methods

(A) Natural Resources Shares of Output (B) Marginal Product of Physical Capital



Source: Authors' calculations based on PWT 8.0, WB, and FAO.

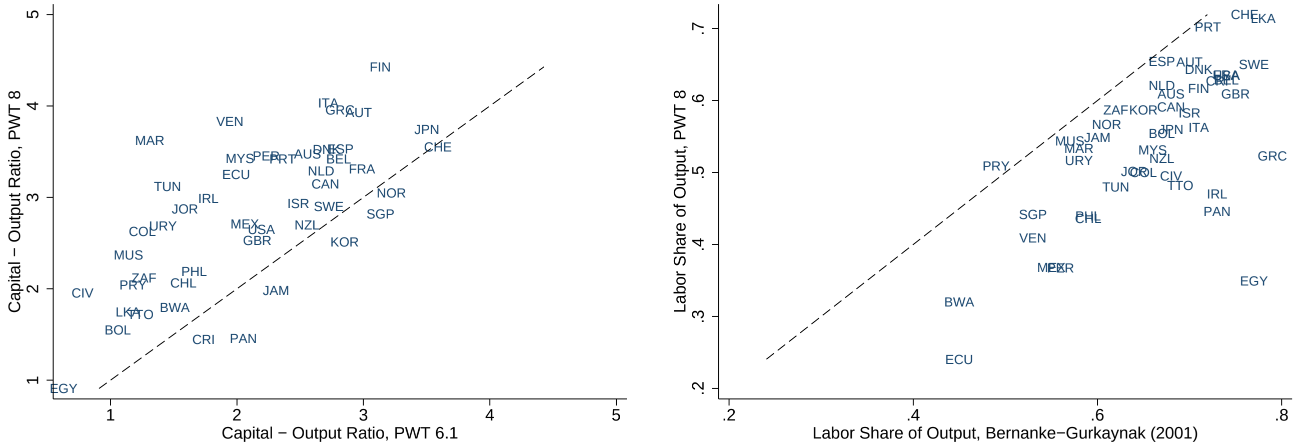
to construct wealth stock estimates. Third, it does not rely on the assumption made by Caselli and Feyrer (2007) that the rental rates for natural resources and physical capital are the same. Our strong prior is that these two assumptions strongly overestimate the importance of natural resources, specially for developing countries.

Panel A in Figure 13 compares our measure $\phi^R_{j,t}$ with the implied by the formula (15) from Caselli and Feyrer (2007) using data from PWT 8.0 for physical capital stocks and labor shares. The differences are are striking. Our measure indicates that for countries with per capita income levels below 15,000, the output share of natural resources is on average 7%. The average using the measurement of Caselli and Feyrer (2007) is much higher, above 30%. This stark difference reinforces our prior that the additional assumptions made in the measurement using wealth stocks overestimates the relevance of natural resources.

The overestimation of natural resources comes at the cost of the underestimation of the output share of physical capital. As shown by the Panel A in Figure 13, this bias seems stronger for the poorest countries. For instance, countries with incomes under 20,000 the difference between our implied output share of $\phi^K_{j,t}$ with those using wealth stocks is around 15% of GDP. Not surprisingly, these differences translate into large differences in the implied $MPK_{j,t}$. As depicted in the Panel B in Figure 13, the differential of MPKs computed with rents with respect to those proxied with stocks (i.e. Caselli and Feyrer, 2007) is positive and largest for the poorest countries. Albeit smaller, accounting for natural resources has a substantial impact on the implied MPK relative to the standard model (i.e. Lucas, 1990). Panel B in Figure 13 also shows that our implied measures of MPK is substantially lower than the standard measure using uniform physical capital shares, while the gap between richer and poorer countries is less pronounced than in the standard model.

The differences between our results and those of Caselli and Feyrer (2007) in terms of global output gains of reallocating physical capital derive also from differences in the data on physical capital, output, and labor shares. While we use PWT 8.0, the use data on physical capital and output from PWT 6.1 and on labor shares from Bernanke and Gurkaynak (2001). Figure 14 shows that there are differences between those sources. The most obvious patterns are (i) the K/Y ratios are higher in PWT 8.0 than in PWT 6.1, and (ii) the labor shares are larger in PWT 8.0 than in Bernanke and Gurkaynak (2001).

Figure 14: Differences in K/Y and θ



Source: Authors' calculations based on PWT 6.1 and 8.0, and Bernanke and Gurkaynak (2001).

Finally, Table 9 presents the global output gains of physical capital reallocation for alternative combinations of available data sets. The comparison is done for 47 countries that are available in all data sets. The first row reproduces Caselli and Feyrer (2007)'s results for these 47 countries. The bottom row reproduces our results for this subsample. The three differences contribute to amplify the gains of reallocating physical capital.

Table 9: Global Output Gains from MPK Equalization, Comparison

Data Source			Gains	N
ϕ_{NR}	(K,Y)	θ		
CF	CF	CF	0.5%	47
MSS	CF	CF	1.3%	47
CF	CF	MSS	1.0%	47
CF	MSS	CF	1.5%	47
MSS	MSS	MSS	2.5%	47

Note: CF stands for Caselli and Feyrer (2007) and MSS for this paper.
Source: Authors' calculations based on PWT 6.1 and 8.0, Bernanke and Gurkaynak (2001), WB, and FAO.

C Counter-factual Series of Physical and Human Capital

Physical Capital. Data on net exports is from the IMF International Financial Statistics (IFS). We exclude 7 countries from our sample due to data limitations: Belgium, Greece, Hong Kong, Luxembourg, Qatar, Taiwan, Zimbabwe.

It is important to note that the sum of net exports across countries in our sample does not add up to zero; this is not surprising as we only include a subset of global capital flows. This issue can be addressed by adjusting net exports so they sum to zero and countries maintain their status as senders or receivers of capital. For instance, we can adjust net exports by a factor λ_t and define the adjusted flows as $\hat{f}^K_{j,t} = \lambda_t \mathbf{1}_{f_{j,t} \geq 0} \cdot f_{j,t} + f_{j,t} \cdot \mathbf{1}_{f_{j,t}<0}$. Results from equalizing real marginal product of physical capital using the adjusted flows are similar to those shown in Figure 9.

$$\text{where } \lambda_t = \frac{|\sum_j^N \mathbf{1}_{f_{j,t}<0}\ f^K_{j,t}\ |}{\sum_j^N \mathbf{1}_{f_{j,t}\geq 0}\ f^K_{j,t}}$$

Human Capital. Data on net migration is taken from the World Bank and is available at five year intervals starting 1972 and we use linear interpolation to infer missing flows. To construct human capital flows $\hat{f}^H_{j,t}$ from population flow data $f^H_{j,t}$ we make several assumptions.

Firstly, we assume that a share $d_t$of migrants $f^H_{j,t}$ are employees. This share is equal to the average employment-population ratio : $d_t = \frac{\sum_j^N \frac{L_{j,t}}{P_{j,t}}}{N}$. To convert these employment flows $d_t f^H_{j,t}$ to human capital - augmented labor $\hat{f}^H_{j,t}$ we assume that migrants human capital is equal to the human capital in the country $h_{j,t}$ into/out of which labor is flowing so that $\hat{f}^H_{j,t} = h_{j,t} \cdot (d_t f^H_{j,t})$. Assuming migrant human capital is equal to the global mean yields similar results.

As with physical capital, the sum of human capital flows do not add up to zero. We can perform an analogous adjustment as above to ensure that these flows net to zero and find similar results.