ECONOMIC RESEARCH
FEDERAL RESERVE BANK OF ST. LOUIS

WORKING PAPER SERIES

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| **Authors** | Alexander Monge-Naranjo, Juan M. Sánchez, and Raul Santaeulalia-Llopis |
| **Working Paper Number** | 2015-036D |
| **Revision Date** | March 2018 |
| **Citable Link** | https://doi.org/10.20955/wp.2015.036 |
| **Suggested Citation** | Monge-Naranjo, A., Sanchez, J.M., Santaeulalia-Llopis, R., 2018; Natural Resources and Global Misallocation, Federal Reserve Bank of St. Louis Working Paper 2015-036. URL https://doi.org/10.20955/wp.2015.036 |

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| **Published In** | American Economic Journal-Macroeconomics |
| **Publisher Link** | https://doi.org/10.1257/mac.20170381 |

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# Natural Resources and Global Misallocation*

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April 2, 2018

**Abstract**

Are production factors allocated efficiently across countries? To differentiate misallocation from factor intensity differences, we provide a new methodology to estimate output shares of natural resources based solely on current *rent flows* data. With this methodology, we construct a new dataset of estimates for the output shares of natural resources for a large panel of countries. In sharp contrast with Caselli and Feyrer (2007), we find a significant and persistent degree of misallocation of physical capital. We also find a remarkable movement toward efficiency during last 35 years, associated with the elimination of interventionist policies and driven by domestic accumulation.

**JEL codes:** O11, O16, O41.

**Keywords:** Natural Rents, Factor Shares, Misallocation, International Flows

*We thank Manuel Amador, Andrew Atkeson, Ariel Burstein, James Feyrer, Giovanni Gallipoli, Jeremy Greenwood, Berthold Herrendorf, Chang Tai Hsieh, Rody Manuelli, and seminar participants at many venues for comments and suggestions. We would also like to thank Esther Naikal and Glenn-Marie Lange of *The Changing Wealth of Nations* group at the World Bank for their guidance with their data. We are also thank Faisal Sohail and Brian Greaney for superb research assistance. *The views expressed here are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of St. Louis or the Federal Reserve System.*

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# 1 Introduction

The wide cross-country disparities in output per capita have motivated an extensive literature that decomposes them into total factor productivity (TFP) and factor supply differences.[1] It is well known that such decompositions often carry with them large cross-country disparities in the returns of factors, e.g. Lucas (1990). The impact of the distortions and the barriers that can sustain the cross-country factor returns differences are often left unexplored. Yet, the removal of such distortions, as observed since the early 1980s (Buera et al., 2011) could drastically change the cross-country allocation of factors and the resulting world income distribution.

This paper evaluates the distributional and global efficiency consequences of observed and counterfactual changes in the barriers to factor accumulation and mobility for many countries and years. Given that natural resources remain a substantial aspect of production in some developing countries, correcting for the rents to the owners of natural resources can change the estimated physical capital share of output and its marginal product in some countries (Caselli and Feyrer, 2007) (from this point on, CF). Our contribution is twofold. First, we provide a new methodology based solely on current natural *rent flows* to compute the output share of natural resources. Using *rent flows* data alone, we avoid using the assumptions on (i) the present value capitalization of future natural rents into *natural stocks* embedded in the CF methodology and (ii) the equalization of the rate of return of natural and other physical capital assumed by CF. Our methodology based solely on *rent flows* not only renders the assumptions (i)-(ii) in CF unnecessary, but also shows that these assumptions imply an overestimation of the output shares of natural resources, in particular, for poor countries, which bias the results in the direction towards MPK equalization in CF. In sharp contrast with CF, we find that global output gains from physical capital reallocation are large: roughly five times larger than previous estimates. Second, we document a number of salient patterns in the global and regional production efficiency over the years. The persistence of a significant degree of global misallocation notwithstanding, these last 35 years witnessed a remarkable movement toward efficiency.

As indicated above, for each country in our sample (indexed by $j$), we construct estimates of the output shares of natural resources, $\phi^R_{j,t}$, based solely on *rent flow* data for the country in each period $t$. For some of the years, we can directly use the rent measures constructed by the World Bank (WB). To extend the estimates for the years from 1970 to 2005, we apply the same methodology used by the WB using data from the United Nations' Food and Agriculture Organization database (FAOSTAT) and the rent share estimates for benchmark countries from the World Bank. Over the sample period, we find that the average share is 6.0% over countries and over years. There is a substantial heterogeneity. As expected, the natural resource output shares can be quite high for a handful of oil-producing countries, with an average above 25%. More interestingly, the average share is higher for poorer countries. Excluding oil producing countries, the average share for the poorest quartile of countries is 5.7%, while it is only 0.58% for the richest quartile of countries.

Then, we use our estimates of the output shares of natural resources with the labor share of income, denoted $\theta_{j,t}$, and output $Y_{j,t}$, capital $K_{j,t}$, and other data from the Penn World Table

[1]See Caselli (2005), Klenow and Rodríguez-Clare (1997) and references therein.

(PWT 8.0) to compute capital shares of income, $\phi^K_{j,t} = 1 - \phi^R_{j,t} - \theta_{j,t}$, and corrected measures of marginal products of physical capital (MPK.) We consider two concepts of marginal products. The first one is simply the physical or quantity marginal products that applies to reallocation experiments with "zero gravity", in which all barriers are removed and all prices are equalized across countries. The second concept is the revenue or *value* marginal product and incorporates differences in output and input prices. For instance, for physical capital, the differences in output and capital prices, $P^Y_{j,t}/P^K_{j,t}$, observed across countries and over time may be the result of technology (the cost of installing capital) or distortions (legislation on labor practices);[2] the quantity and value MPKs are defined as $QMPK_{j,t} = \phi^K_{j,t} Y_{j,t}/K_{j,t}$ and $VMPK_{j,t} = QMPK_{j,t} P^Y_{j,t}/P^K_{j,t}$, respectively.

We first characterize the behavior of MPKs over time and across countries. A number of clear patterns arise. First, we show that the median MPK has trended down over the entire sample period 1970-2005. It is particularly noteworthy that the global upward trend in the capital income shares, $\phi^K_{j,t}$, has been outpaced by the increasing capital-to-output ratio, $K_{j,t}/Y_{j,t}$, during the sample period.[3] Second, there is a substantial and persistent dispersion in the MPKs across countries. Despite finding that countries with low $K/Y$ also tend to have low capital output shares of output, the data suggest the presence of barriers to the formation of capital of some countries, especially the poorer ones. This finding holds for both QMPK and VMPK, so relative price corrections alone cannot explain cross-country differences in the return to capital. Third, the dispersion in both notions of MPKs decreased substantially between 1970 and the mid-1980s.

To assess the implied level of global capital misallocation—and how its behavior has changed over time—we conduct counterfactuals of equating the $QMPK$ and $VMPK$ across countries subject to the same amount of global capital as measured in the data. Two major findings arise. First, we find a large amount of global capital misallocation, ranging from around 5% of global output in the early 1970s to a rather stable level around 2% since the 1990s. Our numbers are always significantly different from zero and robust to the alternative measure of MPK, the sample of countries, and are unlikely to arise from measurement errors in the output and capital of countries.[4] To put our results in perspective, the global output gains are 2.52% in 1996, which is five times the global output gains in Caselli and Feyrer (2007). Interestingly, for some countries and years (e.g., China in the 1970s), the individual country losses from the implied capital wedges are at par with the cost of misallocation for India and China (Hsieh and Klenow, 2009). In 1970, the elimination of all frictions to physical capital implies a global output gain that is twice the GDP of South America or six times the GDP of Africa. For 2005, the global output gains are still twice as large as the GDP for the latter group. The implied global gains from removing barriers to capital are comparable to the other gains from openness studied in the

[2]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).

[3]This is consistent with the global labor share decline documented in Karabarbounis and Neiman (2014) and Aum et al. (2018).

[4]Specifically, our MPKs are strongly related to the observable policies (see Section 4.2). We also dispel the possibility that measurement errors in a frictionless benchmark can account for the observed heterogeneity in observed MPKs and implied deadweight losses unless those measurement errors are implausibly large as argued in Restuccia and Rogerson (2008) (see Appendix).

literature. For international trade, Costinot and Rodríguez-Clare (2014) report that, according to the basic models, moving from the current level of tariffs to a globally uniform tariff of 40%, the average country would lose between 1% and 2% of real income. For foreign direct investment (FDI), Burstein and Monge-Naranjo (2009) obtain global gains of 1.1% when barriers to FDI to developing countries are removed.[5]

A second major finding is a global movement toward efficiency from the 1970s to the mid-1980s. We show that such global movement is indeed associated with the worldwide movement toward market liberalization and openness observed during that period (Buera et al., 2011). Specifically, we show that according to an extended Sachs and Warner (1995) indicator, the countries with more interventionist polices (such as trade restrictions, price controls, limited convertibility, and heavy government appropriation) exhibited higher implied wedges in their MPKs according to our model. Much of the global improvement in the allocation of capital takes place when most countries switch to market-oriented regimes. Yet, we also find an indication of a narrowing gap in the wedges for some of the remaining interventionist countries, most notably China and India. To reinforce this finding, we show that capital accumulation closely follows the behavior of the MPKs of countries. Specifically, we find that the initial levels of MPK and the growth of their underlying factors (human capital, augmented TFP, relative price of capital and factor shares) can explain up to 90 percent of the cross-country variation in the growth of physical capital during the sample period. Consistent with the work of Gourinchas and Jeanne (2013) and Ohanian et al. (2013), our results indicate that external capital flows are not driving the world toward an efficient allocation of physical capital. Instead, the internal accumulation of capital closely follows the countries' MPKs and may be the culprit for the apparent inaction and misallocation of external flows.

In this paper, we focus on the global allocation of physical capital. A more comprehensive assessment of global factor misallocation would also considers human and physical capital. As shown in our sequel work Monge-Naranjo et al. (2018), the complementarity between physical and human capital would lead these two factors towards countries with higher fixed productivity, either because of TFP or natural resources. Observed allocations deviate from such an alignment. More interestingly, if human and physical capital can be reallocated jointly, the direction of the physical capital flows can be reverted relative to the case when physical capital is the only mobile factor. In fact, the premise that capital should flow from rich to poor countries is unwarranted: When both factors are reallocated, capital and labor would flow from some of the poor and middle-income countries toward some of the richer countries. This simple yet often ignored point could be one of the keys to understanding the consequences of alternative integration schemes with or without labor mobility for countries and regions with different productivities and fixed endowments (e.g. the US and Puerto Rico and the European Community one one side with NAFTA on the other).

The paper is organized as follows. The next section presents our organizing model framework. Section 3 describes our measurement of rents for natural resources comparing our methodology

[5]For both trade and FDI, the gains could be significantly higher in models that incorporate intermediate goods, technology spillovers, and the diffusion of nonrival factors. However, introducing the features in our model will also enhance the implied global gains for improving the allocation of physical capital.

to that of CF. Section 4 describes the behavior of MPKs across countries and policy regimes over time. Sections 5 and 6 examine the global allocation of physical capital. Section 7 shows that domestic accumulation and not internal flows account for the observed trends. Conclusion follows. The appendices contain numerous extensions, comparisons, and additional details.

# 2 The Model

In this section, we set out a simple theoretical framework to assess the efficiency in the allocation of capital in the world economy. We first derive the appropriate efficiency benchmarks for two alternative scenarios on the tradability of output across countries. We then show how we extend the standard one sector growth model to allow for differences in factor intensities across countries and over time. Distinguishing between factor intensities and factor misallocation is crucial for our measurement and counterfactual exercises.

## 2.1 Efficiency Benchmarks

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 $t = 1970, 1971, ...2005$. In each country, a single good 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. Specifically, we assume that production of $Y_{j,t}$ units of the good in country $j$ at time $t$ is according to

$$Y_{j,t} = F_{j,t}(T_{j,t}, H_{j,t}, K_{j,t}) \tag{1}$$

where $F_{j,t}(\cdot, \cdot, \cdot)$ a constant returns to scale technology, with the standard differentiability and concavity assumptions.

To characterize the efficient allocations, assume that a social planner assigns a relative weight $\lambda_j$ to the utility of country $j$. The preferences of the agents in country $j$ are represented by a stand-in utility function $u_{j,t}(C_{j,t})$, which is increasing and weakly concave in the aggregate consumption $C_{j,t}$ of the country.

Our attention is on the efficient allocation of physical capital, assuming that both, natural resources $T_{j,t}$ and the human capital $H_{j,t}$ of countries are exogenously given and cannot be reallocated. Let $K_{W,t}$ denote the world's total physical capital, which results from aggregating the capital owned by all countries $j$. Consider first the case in which the output $Y_{j,t}$ is **perfectly tradeable across all countries.** The planner's problem is to maximize

$$\max_{\{c_j, K_{j,t}\}} \sum_{j=1}^{J} \lambda_j u\left(C_{j,t}\right) \tag{2}$$

subject to:

$$\left[\pi_t^C\right] \quad : \quad \sum_{j=1}^{J} C_{j,t} \leq \sum_{j=1}^{J} F_{j,t}\left(T_{j,t}, H_{j,t}, K_{j,t}\right) \tag{3}$$

$$\left[\pi_t^K\right] \quad : \quad \sum_{j=1}^{J} K_{j,t} \leq K_{W,t}. \tag{4}$$

The first constraint 3 is simply that total world consumption cannot exceed total world output. The second constraint 4 requires that total capital used cannot exceed the world supply $K_{W,t}$. As expected, the optimal allocation of capital is completely independent of the world allocation of consumption and it is only directed towards maximizing total world output. Denote by $\pi_t^C$ the Lagrange multiplier associated to the adding-up constraint on consumption and $\pi_t^K$ the multiplier associated with the adding up constraint of world capital. For the efficient allocation, $\pi_t^C$ is the shadow price of consumption for one additional unit of consumption available to the world as a whole, since the optimal allocation of consumption would be governed by the condition

$$\pi_t^C = \lambda_j u_j'\left(C_{j,t}\right)$$

Similarly, $\pi_t^K$ is the world's shadow price of capital. In the efficient allocation, each country $j$ would operate physical capital according to

$$\pi_t^K = \pi_t^C \frac{\partial F_{j,t}}{\partial K_{j,t}}.$$

Regardless of the world distribution of consumption and of the total availability of capital, the efficient allocation of capital requires the equalization of the **physical or quantity** marginal products of capital $QMPK$ across countries, i.e., for all countries $i$ and $j$

$$QMPK_{j,t} = \frac{\partial F_{j,t}}{\partial K_{j,t}} = \frac{\partial F_{i,t}}{\partial K_{i,t}} = QMPK_{i,t}, \tag{5}$$

Consider now the case when the output $Y_{j,t}$ is **perfectly non-tradeable across all countries.** Moreover, assume that installing capital in country $j$ requires an additional iceberg cost $\kappa_{j,t} \geq 0$. The planner's problem is to maximize (2) subject to:

$$\left[\pi_{t,j}^C\right] \quad : \quad C_{j,t} \leq F_{j,t}\left(T_{j,t}, H_{j,t}, K_{j,t}\right), \text{ for } j = 1, ..., J \tag{6}$$

$$\left[\hat{\pi}_t^K\right] \quad : \quad \sum_{j=1}^{J} (1 + \kappa_{j,t}) K_{j,t} \leq K_{W,t}. \tag{7}$$

Instead of just restricting global consumption to not exceed total world output, with nontradeability of output, the constraint (3) is replaced by $J$ constraints (6) so that the consumption of each country must be provided by the country's internal output. For the planner, each multiplier $\pi^C_{j,t}$ is the shadow price of consumption in country $j$, which now should be allocated according to

$$\pi^C_{j,t} = \lambda_j u' \left(C_{j,t}\right)$$

The potential additional costs involved in installing capital in each country $j$ may also distort the allocation of capital. Defining $\pi^K_{j,t} \equiv \hat{\pi}^K_t (1 + \kappa_{j,t})$, then capital in each country should now obey the condition:

$$\pi^K_{j,t} = \pi^C_{j,t} \frac{\partial F_{j,t}}{\partial K_{j,t}}.$$

In principle, the efficient allocation of capital can be quite different because it is now closely linked to the valuation of consumption $\pi^C_{j,t}$ and the differential cost of investment $\pi^K_{j,t}$ across the different countries. Yet, once we incorporate these differences in the relative shadow prices across countries, the efficient allocation of capital requires the equalization of the **value or nominal** marginal products of capital $VMPK$ across countries, i.e., for any pair of countries $i$ and $j$

$$VMPK_{j,t} = \frac{\pi^C_{j,t}}{\pi^K_{j,t}} \frac{\partial F_{j,t}}{\partial K_{j,t}} = \frac{\pi^C_{i,t}}{\pi^K_{i,t}} \frac{\partial F_{i,t}}{\partial K_{i,t}} = VMPK_{i,t}. \tag{8}$$

In sum, different assumptions about the tradeability of output lead to two different criteria for evaluating the efficiency in the allocation of output. In the first one, the physical or quantity $QMPK$ should be equated across countries. In the second, the value or nominal $VMPK$, which incorporates relative price differences of consumption goods should be the one equated. The former is appealing since it is the most basic and transparent notion of efficiency. The latter case is appealing in light of the variation in the price of consumption relative to investment observed in the data, as highlighted by Hsieh and Klenow (2007)) and Caselli and Feyrer (2007). In what follows, we consider both criteria to assess the efficiency of the global allocation of capital.

## 2.2 Distortions vs. Factor Intensity Differences

The efficiency benchmarks derived in the previous section are valid in the presence of arbitrary differences in the countries' production functions $F_{j,t}(\cdot)$. Allowing for such differences is crucial to distinguishing the presence of distortions in the global allocation of capital from cross-country factor-intensity differences. However, our cross-country differences cannot be arbitrary and must be disciplined using observable data. In particular, we must extend the standard one sector growth model, the workhorse of growth and dynamic macroeconomics, because it only allows for differences in total factor productivity (TFP), i.e. Hicks-neutral shifts of the production function that do not alter the factor intensities of countries. In that model, any observed variation in capital-output ratios $K_{j,t}/Y_{j,t}$ are sufficient conditions for the conclusion that there are distortions to the mobility of capital. Indeed, as we discuss below, we observe substantial $K_{j,t}/Y_{j,t}$ differences, especially between rich countries (e.g. Japan) and poor countries (e.g. Kenya). Instead, for our quantitative exercises, we measure the factor shares of the different factors of production directly, allowing for factor-intensity difference that vary across countries and over time.

Specifically, for our quantitative analysis, we consider country-and-time varying Cobb-Douglas production functions of the form

$$Y_{j,t} = A_{j,t}(K_{j,t}^{\gamma_{j,t}} T_{j,t}^{1-\gamma_{j,t}})^{1-\theta_{j,t}} (H_{j,t})^{\theta_{j,t}}, \tag{9}$$

where $A_{j,t}$ is the TFP of the country and $0 < \theta_{j,t} < 1$ is the labor share of output. The non-labor 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. In addition to introducing non-produced capital (natural resources) $T_{j,t}$, this specification allows for country-time variation in the factor shares as documented in the previous section. In particular, it allows for variation in capital-output ratios $K_{j,t}/Y_{j,t}$ even if there are no distortions in the cross-country allocation of capital. For instance, it is possible that that the observed high capital-output ratio observed in Japan is entirely driven by a high output share of physical capital in that country.

In the next section, we explain in detail our measurement of the output shares $\theta_{j,t}$, and natural resources shares, $(1-\gamma_{j,t})(1-\theta_{j,t})$ for a large number of country and years. Having estimates of those shares and using data on output, $Y_{j,t}$, the stock of physical capital, $K_{j,t}$, labor shares $\theta_{j,t}$, and natural resources shares, $(1-\gamma_{j,t})(1-\theta_{j,t})$, we can readily compute the "quantity" marginal product of physical capital ($QMPK_{j,t}$) as

$$QMPK_{j,t} = (1-\theta_{j,t})\gamma_{j,t}\frac{Y_{j,t}}{K_{j,t}} = \phi_{j,t}^{K}\frac{Y_{j,t}}{K_{j,t}}. \tag{10}$$

Our second measure of global misallocation incorporates data on the dollar price of output $P_{j,t}^{Y}$ and of capital $P_{j,t}^{K}$ 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 $t$) is

$$VMPK_{j,t} = \frac{P_{j,t}^{Y}}{P_{j,t}^{K}}(1-\theta_{j,t})\gamma_{j,t}\frac{Y_{j,t}}{K_{j,t}}. \tag{11}$$

As above, differences in $P_{j,t}^{K}$ across countries lead to different numbers of machines per dollar invested, $1/P_{j,t}^{K}$, while differences in $P_{j,t}^{Y}$ 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.

Correcting for the output share of natural resources across countries and over time leads to substantially different findings relative to the literature on the degree of misallocation of capital across countries. It is important to highlight that once we have corrected for those factor share differences, we can interpret the remaining cross-country dispersion in both $QMPKs$ and $QMPKs$ as distortions in the allocation of capital. As we show in Section 4.2, we find strong evidence that for most years in our sample, policy distortions are not related to factor shares across countries. Instead, we find strong evidence that policy distortions drive large variations in the capital-output ratios $K_{j,t}/Y_{j,t}$ and in the relative cost of capital $P^K_{j,t}/P^Y_{j,t}$.

# 3 Natural Resources and Output Factor Shares

Growth models most often abstract from natural resources as factors of production. Such an abstraction is of little consequence for most developed countries. However, in this Section we show that natural resources remain a substantial aspect of production in many developing countries. Accounting for the rents from natural resources can lead to nonnegligible changes on the imputed physical capital share of output and its marginal product in some countries, and, in the end, the assessment of inefficiencies in the allocation of physical capital across countries.

## 3.1 The Output Share of Natural Resources

First, we estimate the output shares of natural resources across countries and over time using a new methodology solely based on *rent flows* from natural resources in Section 3.1.1. Second, we compare our estimates to those of Caselli and Feyrer (2007) where these output shares are obtained with a different approach based on *natural* capital *stocks* discussed in Section 3.1.2.

### 3.1.1 A Methodology Based on *Rent Flows*

The first contribution of our work is the introduction of a simple methodology to compute the output share of natural resources based on *rent flows* data. The WB's project *Where is the Wealth of Nations?* (World-Bank, 2006), and its sequel, *The Changing Wealth of Nations* (Bank, 2011), classify natural resources into ($a$) energy and mineral (subsoil) resources; ($b$) timber resources, ($c$) croplands and ($d$) pasturelands.[6] We adopt this grouping, but also follow Caselli and Feyrer (2007) by adding an additional category, ($e$) urban land, also as a non-relocatable resource across countries.

For each different natural resource, the WB provides direct estimates of the rate of return using a set of benchmark countries. With these benchmark estimates the WB 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 Nations' FAOSTAT database.[8] Our estimates cover all years from 1970 to 2005. The final objective of the WB'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, as we show extensively in Appendix B, factor share

[6]The WB includes non-timber forest resources and protected areas in the calculation of the estimated countries' stock of natural wealth (World-Bank, 2006; Bank, 2011). We do not include these 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/.

estimates based on wealth stocks overestimate the importance of natural resources, especially for developing countries.

We now explain how we estimate the factor shares for all natural resource 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 WB estimates. Second, the rents for ($b$) timber were also taken directly from the WB.[9]

Third, we construct our own estimates for the rents for items ($c$) and ($d$), crop and pasture lands, respectively. For croplands (which includes apples, bananas, coffee, grapes, maize, oranges, rice, soybeans, wheat, and many others), we follow the World-Bank (2006)'s methodology: For each crop, the WB estimates the average rate of return to the land for a set of countries that are major producers of that crop. The cropland 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. We apply those crop-specific rates of return to the quantities reported in FAOSTAT using the U.S. prices for each crop as proxies for their respective international prices.[10] For each country and year, we compute the overall rental rate for croplands as the average rate weighted by the land area used for each crop. Total rents are computed using the estimated weighted rate to total quantities reported in FAOSTAT. For the rents of pasturelands (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.[11] Last, we follow the 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 with labor nor physical capital earnings. Therefore, for our purposes they are best seen as factors of productions that are not easily relocatable across countries.[12]

[9] Kunte et al. (1998) describes the methodology employed by the World Bank in *The Changing Wealth of Nations* project to compute rental rates for the different natural resources. While the specifics of the methodology differs across items (a)-(d), the general approach is if there is no data for rental rate for a country-resource pair, the rental rate is constructed using the estimate available for the most similar country with measurement. For example, in the case of cropland rental rates, these 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, Ivory Coast, Ecuador, Martinique, Suriname, Yemen); etc.

[10] In earlier versions of *The Wealth of Nations* database, the WB 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, their use to measure output was partly due to the lack of country-specific producer prices for agricultural products. More recently, FAOSTAT has started to provide regular coverage of producer prices/gross value of production, and the newest version of The Wealth of Nations values crop production using the newly available producer prices, which tend to be lower than export values (we thank Esther Naikal at the WB for this insight). We compare the implications for global misallocation of producer prices with our benchmark use of US prices as proxies for crop international prices in the Appendix A. We find very similar quantitative results.

[11] For values of 30% and 60% for the share of pasture land we find global misallocation results almost identical to our benchmark value of 45%.

[12] The value of the share of urban land, 24%, used in World-Bank (2006) and Caselli and Feyrer (2007) is an estimate for Canada. We tried alternative values for urban land rents ranging from 0%, 12%, 24% (our benchmark) and 36%. Quantitatively, we find that reducing the amount of rents accrued to urban land would

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

| | Mean | Median | Coefficient of variation | $\rho_{x,y}$ |
|---|---|---|---|---|
| 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 |
| ▷ Pastureland | 0.36 | 0.17 | 1.53 | -0.27 |
| Natural resources with urban land | 17.7 | 14.7 | 0.62 | -0.1 |
| Obs. | 79 | 79 | 79 | 79 |

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

With these 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, cropland, pastureland 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-relocatable 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 Purchasing Power Parity (PPP) in millions of 2005USD, then the output share of natural resources for country $j$ in period $t$ is simply

$$\phi^R_{j,t} \equiv \frac{NRR_{j,t}}{Y_{j,t}}, \tag{12}$$

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 millions of 2005USD) from the PWT 8.0.[13] Our benchmark final sample consists of 79 countries (see Appendix A.1) with consistently

increase the implied degree of misallocation and would imply a steeper trend towards efficiency between 1970 and mid-1980s. Our assessment is that the rent of 24% is the most appropriate for our exercise for several reasons. First, it allows our results to be comparable with CF, and as such, allows us to make it clear that it is the difference in the measurement of the other natural resources that drives the differences in the results. Second, returns to urban land should not be assumed to be part of physical capital and a rate of 24%, while coming from an isolated study for Canada, remains as the only measure available.

[13]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.

available information on natural resources throughout the entire sample period from 1970 to 2005.[14] Later, for the reallocation exercises, the sample is restricted to 76 countries because of the availability of human capital data.

For our purposes, it is important to compare the behavior of the share $\phi^R_{j,t}$ across development levels. To this end, Table 1 presents the output shares of the different natural resources for the 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 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; pastureland, −0.27; and, in particular, cropland, −0.55.

Disregarding urban land, 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, with oil and natural gas the major components, representing 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 land rents and rents from timber forest account for lower shares, respectively, 0.36% and 0.13% of output on average. Excluding the main oil-exporting countries in our sample, the median share of oil rents in terms of output dramatically drops to 0.02% (i.e., close to 3% of its mean value), while the median share of cropland rents drops to 1.06% (i.e., about 53% of its mean value). This suggests a large dispersion in oil shares across countries, which is confirmed by a large coefficient of variation in the third column for oil, 1.6 times larger than that of cropland shares. For non-oil exporting countries, the largest subcategory is cropland rents, which account for 2.01% on average, with subsoil rents being 1.25% on average. For non-oil countries, the median share of natural resources in output is now close to the mean—the mean-to-median ratio is 1.40; this ratio is 2.04 when oil countries are included. For the non-oil sample, the coefficient of variation in the share is 1.08, while for the entire sample with oil countries it is 1.44.[15]

Figure 1 further illustrates the relationship between the output share of natural resources (excluding urban land) and income per worker also for the year 2000. The left panel singles out the oil-exporting countries (marked in red), which we define as those with subsoil shares of output above 10%,[16] Oil-exporting countries have much higher $\phi^R_{j,t}$, averaging 36.80%, versus 4.51% of their non-oil-exporting counterparts and relatively richer than their non-oil counterparts.[17] The right panel focuses on non-oil countries, shows a negative relationship between the natural resources share and output. For non-oil countries with income per worker above $40,000 in 2000,

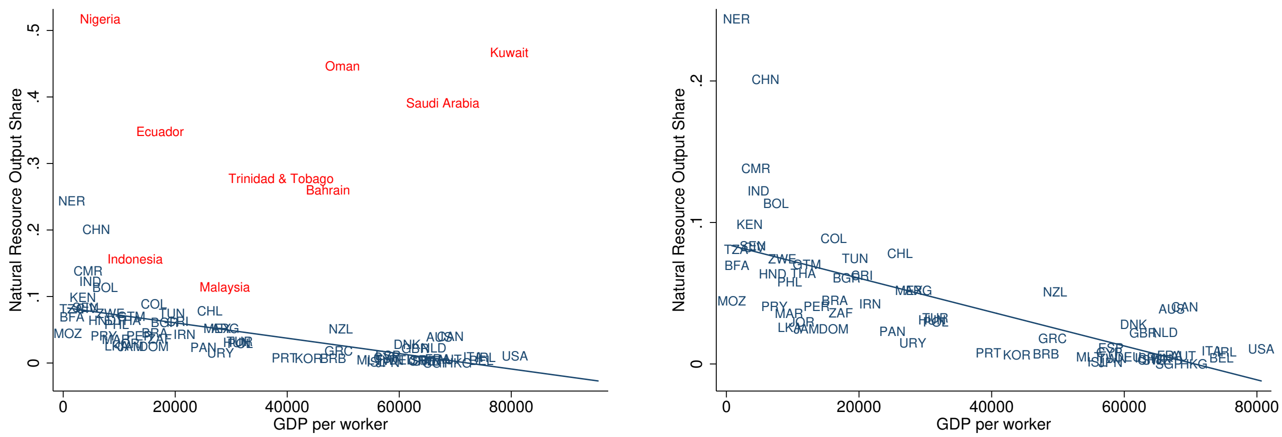
[14]Section 5.3 presents a further analysis for a larger sample countries with consistent data for 2005.

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

[16]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.

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

Figure 1: Output Share of Natural Resources (Excluding Urban Land), 2000

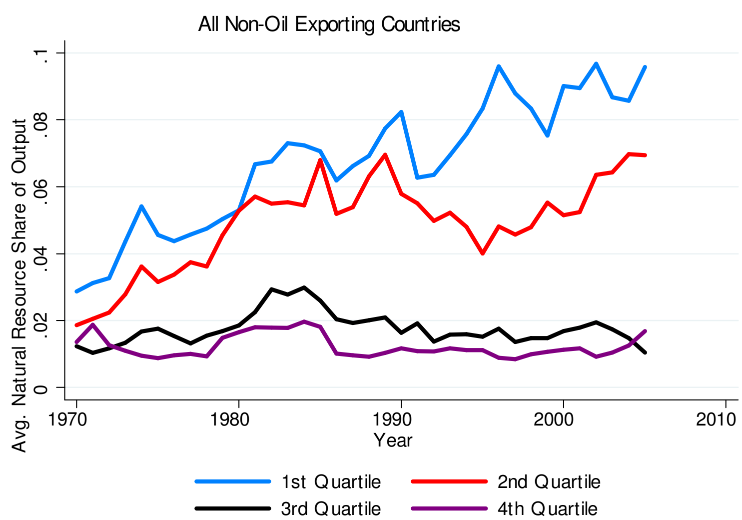



All Countries

Non-Oil-exporting Countries

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

Figure 2: Average Output Share of Natural Resources: By Income quartiles (Non-oil-exporting countries)




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

the natural resources share of output is only 1.13%. The average of this share is much higher, 6.90%, for countries with income per worker below $40,000 and 9.62% for countries with income per worker below $10,000.[18] 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.[19]

Figure 2 shows that these cross-sectional patterns are persistent over time. The figure shows the average shares for each different quartile of countries, as ordered by their GDP per capita, for each year from 1970 until 2005. The figure excludes oil-exporting countries, which display a higher and increasing shares. In general, the figure shows clearly that for developed countries (fourth quartile) and higher-income developing countries (third quartile) the output share of natural resources is low and relatively constant, around 1% over the sample years. However, the share is significantly higher for the other half of the countries in the sample (quartiles 1 and 2.) This is particularly stronger by the end of the sample, when natural resources consistently accounted for more than 8% of the income of the countries in the poorest quartile.

#### 3.1.2 A Methodology Based on Natural Stocks (Caselli and Feyrer, 2007)

In their seminal paper, Caselli and Feyrer (2007), henceforth CF, use the WB's *natural* capital *stocks* to estimate the output share of natural resources for the year 1995. We now review the CF's method and estimates and compare them with ours. In short, the CF's methodology requires a set of assumptions on the computation of *natural stocks* and an additional no-arbitrage assumption between natural capital and other forms of physical capital that our methodology based on *rent flows* does not require.

First, for the different natural resources items $q \in \{a, b, c, e, f\}$ (detailed in Section 2), the WB computes natural stocks, $N_{q,j,\mathbf{1995}}$, for each country $j$, in their sample. The WB obtains these estimates by multiplying their data on the flow of rents $\text{rents}_{q,j,1995}$ by a present value term $PVF_{j,q}$:

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

[18] An entirely different approach to obtain cropland shares of output consists of using farm-level payments to rented in (or rented out) land from micro data. Unfortunately, farm surveys that incorporate rental payments of land are scarce. One notable exception are the Integrated Surveys of Agriculture (ISA) described in DeMagalhaes and Santaeulàlia-Llopis (2017). Two of the country surveyed by ISA overlap with our FAOSTAT sample data, Nigeria and Tanzania. With these ISA data we can compute rates of return as the ratio of land rental payments to cultivated rented land. This measurement is not free of caveats, as roughly only 15% of land is in the market for rents in these countries (Restuccia and Santaeulàlia-Llopis, 2017), and we need to use the renting sample to impute rents to other farms for example by assuming that the average return from the renting sample is the same across all farms. With these caveats in mind, we compute the value of cropland share for Nigeria as the product of the ratio of land rental payments to agricultural output from ISA data, 6.10%, and the agricultural share of value added from the WB, 32.75%. This implies a cropland share of output of 2.00% for Nigeria based on micro ISA data. Analogously we find a cropland share of output of 8.53% for Tanzania based on micro ISA data. Note that this implies that the micro-data pushes down even further the estimates based on FAOSTAT for which we find values of cropland shares for Nigeria of 6.78% and for Tanzania of 12.8%. That is, further improvements in the data tend to lower the estimates for natural resource shares in output.

[19] Including oil-exporting countries this factor drops to 1.63.

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

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

where $\mathbf{r}^*$ is the discount rate, $\mathbf{G_{j,q}}$ is the growth rate in the rent flows, and $\mathbf{T}_{j,q}$ is the terminal or exhaustion date of the resource. Unfortunately, the WB does not have direct measures of $\mathbf{r}^*$, $\mathbf{G_{j,q}}$, and $\mathbf{T}_{j,q}$. Thus, computing the stocks requires making additional assumptions. WB assumes that the discount rate $\mathbf{r}^*$ 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 into 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 2 shows the implied values for $PVF_{j,q}$ for a range of values of $\mathbf{G_{j,q}}$ and $\mathbf{T}_{j,q}$ assumed by the WB.

Table 2: 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 Resource. | 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 |

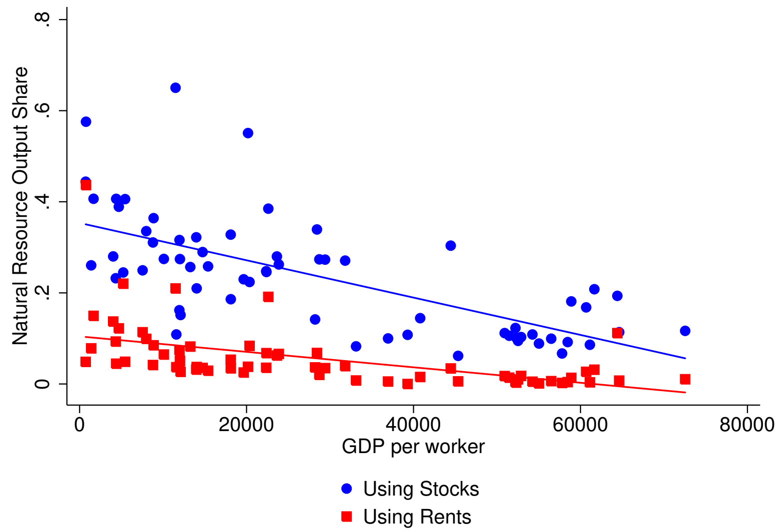
Table 2 shows two important aspects in the resulting values for $PVF_{j,q}$. First, their numbers are fairly large, meaning that given the rents, the present value factors can lead to very large *natural stock* estimates. Second, even given the same rents, the implied $PVF$ (and *natural stocks*) are larger for poorer countries. This second assumption is key because it implies that the natural resources shares estimated with this method will be artificially larger for poorer countries than for richer countries even if the natural recourses rents are the same proportion of GDP.

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

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

The WB estimation ends in this step. CF 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

Figure 3: Estimates of Output Shares of Natural Resources: MSS vs CF




Notes: The blue circles refer to the estimates of output shares of natural resources based on *natural* capital *stocks* computed following the methodology in Caselli and Feyrer (2007). The red squares refer to the estimates of output shares of natural resources based on *rent flows* of natural resources described in Section 3.1.1.
Source: Authors' calculations based on PWT 8.0, WB, and FAO stat.

to impute 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 respectively, 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 $r^N_{j,1995}$ are simply not available. This gives rise to the second key assumption in CF's method: $r^N_{j,1995} = r^K_{j,1995}$ for all countries $j$. Notice that this is not a non-arbitrage condition, since $N$ and $K$ (as well as human capital, $H$), are two different production factors.

With this assumption, the CF's estimate of the share of natural resources is simply

$$\phi^R_{j,1995} = \frac{N_{j,1995}}{N_{j,1995} + K_{j,1995}} \times \left[1 - \text{labor share}_{j,1995}\right]. \tag{13}$$

We next show that the resulting estimates from CF strongly overestimate the importance of natural resources when compared to our *rent flows* estimate specially for developing countries

#### 3.1.3 Estimates of the Output Shares of Natural Resources $\phi^R_{j,t}$: MSS vs CF

In Figure 3 we compare our measure $\phi^R_{j,t}$ from equation (12) based on *rent flows* that we label MSS with that implied by the equation (13) from CF based on *natural stocks*. In both cases we use data from PWT 8.0 for physical capital stocks and labor shares. The differences 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 CF is much higher, above 30%. This stark difference shows that the additional assumptions made in the measurement using natural capital stocks overestimate 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 in Figure 3, this bias is stronger for the poorest countries. For instance, countries with per capita incomes below \$20,000, the difference between our implied output share of $\phi^R_{j,t}$ and those by the CF's methodology using natural capital stocks is around 15% of GDP. Clearly, the estimates from CF strongly overestimate the importance of natural resources when compared to our *rent flows* estimate specially for developing countries.

Which measure of $\phi^R_{j,t}$ is better? We argue that our direct measure based on *rent flows* proposed in Section 3.1.1 is superior to that derived by CF and summarized by equation (13) because ours avoids using the two sets of assumptions described above. First, we do not rely on the assumptions on interest rates, future growth rates of natural rents, and exhaustion dates for natural resources (i.e., $\mathbf{r}^*$, $\mathbf{G_{j,q}}$, and $\mathbf{T}_{j,q}$) to construct *natural stock* estimates. These assumptions are important because, as we showed in Table 2, they generate larger *natural stocks* for poor countries than for rich countries even in the event that both groups face the same *rent flows*. Ultimately, this implies that the estimates of $\phi^R_{j,t}$ for poor countries will be biased upward compared with the estimates for rich countries in the CF's methodology. This artificial discrepancy in $\phi^R_{j,t}$ between poor and rich countries is not present in our methodology. The reason is straightforward, our methodology based on *rent flows* does not require natural stock estimates at all. Second, we do not rely on the assumption made by CF that the rental rates for natural resources and physical capital are the same. Again, this assumption on the equalization of returns between natural capital and other forms of physical capital is not needed at all in our methodology based on *rent flows*.

### 3.2 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 labor to output. 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]

[20]See Cooley and Prescott (1995) and Gollin (2002).

In the PWT, as explained in Feenstra et al. (2015), the raw labor share, defined as the ratio of unambiguous 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 income.[21] As we discuss below, the resulting values for $\theta_{j,t}$ 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. In the interest of expanding our sample of countries and periods as much as possible, we take the measures from the PWT 8.0 as our benchmark.[22]

For the output share of physical capital, denoted here by $\phi^K_{j,t}$, the standard practice is to equate it to 1 minus the labor share. This practice relies on the assumption of a constant returns to scale production function with only physical and human capital as inputs. Instead, as highlighted by Caselli and Feyrer (2007), in the presence of natural capital the correct accounting of the physical capital output share is

$$\phi^K_{j,t} = 1 - \theta_{j,t} - \phi^R_{j,t}. \tag{14}$$

This avoids inflating the returns to physical capital with the returns to natural resources.

# 4 The Marginal Product of Capital

We now compute the implied marginal products of physical capital $MPK$. We use the factor share data described in Section 3, along with PWT 8.0 measures of output, physical capital measures, and the prices of output and capital goods.[23]

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 millions of 2005USD).[24] The number of workers in each country

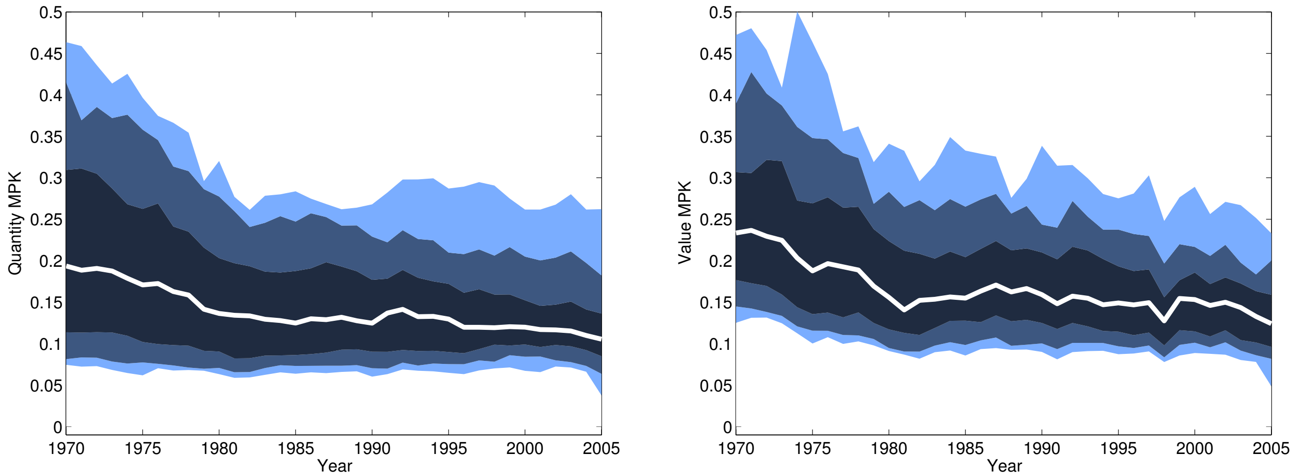
[21] The PWT considers four different adjustments: (i) Add AMB to unambiguous labor compensation, resulting in $\theta_{j,t}$ = (WN+AMB)/GDP; (ii) Assume the labor share, $\theta_{j,t}$, is identical to the labor share of unambiguous output, $\theta_{j,t}$ = WN/(GDP-AMB); (iii) If proxies for the number 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; (iv) Add the value added in agriculture (AGRI) to unambiguous labor income (i.e., $\theta_{j,t}$ = (WN+AGRI)/GDP). The PWT 8.0 constructs its "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 ambiguous income data are available, they use adjustment (ii) because adjustment (i) is regarded as too extreme. Otherwise, if the ambiguous income data are not available, then use the minimum of the resulting shares of adjustments (iii) and (iv).

[22] Table 8 in the Appendix shows that our choice of labor share is not the main driver of our results.

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

[24] For each country, these aggregate stocks are computed applying the perpetual inventory method 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 lead to differences in aggregate investment prices and depreciation rates. See the detailed discussion in Feenstra et al. (2015), including a comparison with previous PWT datasets.

Figure 4: Global Evolution of MPKs




$QMPK$ $VMPK$

Notes: The white line represents the median, and gradually from dark to light blue shade (i.e., as we move away from the median) we show the interquartile (25th-75th percentile) range, the 10th-90th percentile range, and the 5th-95th percentile range.
Source: Authors' calculations based on PWT 8.0, WB, and FAOSTAT.

and year, $L_{j,t}$, is measured with the variable *emp* in PWT 8.0 for our measure of aggregate labor—that is, 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*; that is, the price level of cgdpo (PPP/XR, normalized so that the 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 United States in 2005 = 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 the United States in 2005 = 1). Next, we describe the behavior of our $MPK$ measures across time and space. Then we relate our $MPK$ measures to observable policies.

## 4.1 Across Space and Across Time

The panels in Figure 4 present the distribution, across countries, of the quantity and value MPKs over the entire sample period. A number of relevant patterns emerge from these figures. First, the median values of both panels exhibit a clear downward 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 has steadily decreased over the sample period. Third, the most dramatic declines in the median and dispersion of MPKs take place in the 1970s to mid-1980s. Fourth, even though some important differences remain, the aforementioned patterns are common across both $QMPK$ 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 drives significant and persistent differences in levels. For instance, while the median $QMPK$ 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 $QMPK_{j,t}$ 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 capital output shares, output-to-capital ratios, and the relative price of capital:

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

and

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

The left side of Table 3 shows the variances of the different objects, while the right side presents their pairwise covariances. First, note that there is a downward trend in the dispersion for both $\ln QMPK_{j,t}$ and $\ln VMPK_{j,t}$; for the former, the negative trend runs from 1970 until 2000, while for the latter it runs from 1975 until 2000. Second, these downward trends are mostly driven by both a significant decline in the variation of the log of the output-to-capital ratio $Y_{j,t}/K_{j,t}$ and 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 $var\left[\ln \frac{Y_{j,t}}{K_{j,t}}\right]$ to the variance of log $QMPK_{j,t}$ 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 1970$s$ 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 $Y_{j,t}/K_{j,t}$), in the year 2000 we have switched to a 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 $\ln QMPK_{j,t}$ by 14%. By the end of the sample, it was *reducing* it by a similar magnitude.

A third finding is that between 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 $QMPK_{j,t}$. 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 MPK.

We finally explore some simple results from Table 3 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 $\ln QMPK_{j,t}$ is always significantly higher than the dispersion in $\ln VMPK_{j,t}$. In the extreme, in 1970, $var\left[\ln QMPK_{j,t}\right]$ is almost 2.5

Table 3: Decomposition of the dispersion of $QMPK$ and $VMPK$

| Year | Variances (logs of each variable) | | | | | Covariances (logs of each variable) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $QMPK_{j,t}$ | $VMPK_{j,t}$ | $\phi^K_{j,t}$ | $\frac{Y_{j,t}}{K_{j,t}}$ | $\frac{P^Y_{j,t}}{P^K_{j,t}}$ | $\phi^K_{j,t}, \frac{Y_{j,t}}{K_{j,t}}$ | $\frac{Y_{j,t}}{K_{j,t}}, \frac{P^Y_{j,t}}{P^K_{j,t}}$ | $\phi^K_{j,t}, \frac{P^Y_{j,t}}{P^K_{j,t}}$ | $QMPK_{j,t}, \frac{P^Y_{j,t}}{P^K_{j,t}}$ |
| 1970 | 0.367 | 0.147 | 0.089 | 0.223 | 0.161 | 0.027 | -0.160 | -0.030 | -0.190 |
| 1980 | 0.257 | 0.174 | 0.084 | 0.166 | 0.062 | 0.004 | -0.073 | 0.000 | -0.073 |
| 1990 | 0.214 | 0.158 | 0.065 | 0.154 | 0.079 | -0.002 | -0.074 | 0.006 | -0.068 |
| 2000 | 0.189 | 0.119 | 0.071 | 0.163 | 0.117 | -0.023 | -0.114 | 0.021 | -0.093 |

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

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 $\ln QMPK_{j,t}$ is always between $-0.54$ and $-0.77$. Clearly, prices are partially correcting the cross-sectional dispersion in the physical MPK, and countries with high $QMPK$s 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 countermovement of prices with $\ln QMPK$ can easily overturn by itself the dispersion in $\ln VMPK$ (i.e., the contribution of $2cov\left[\ln QMPK, \ln P^Y_{j,t}/P^K_{j,t}\right]/var\left[\ln VMPK\right]$ 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 $\ln QMPK$. As a matter of fact, the values for both the physical $\ln QMPK$ and $\ln VMPK$ 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 $MPKs$, these prices are far from eliminating cross-country dispersion (in any point in time) and are not driving the downward trend in dispersion observed between 1970 and 2005. Even after controlling for the countries' differences in their capital intensity in production and in their observed relative prices of physical capital, there remains a nonnegligible dispersion in the marginal product of physical capital across countries. The overall message from our results is that, despite a downward trend from the early 1970$s$, there are still significant and persistent distortions in the allocation of capital.

## 4.2 Relation to Observable Policies

This section briefly explores whether the implied distortions can be related to directly observable measures of policy distortions. To this end, we use 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 country satisfies all five criteria, SW call it open and set the indicator to 1.

Otherwise, the indicator takes the value of 0.

While originally SW aimed to design their indicator to classify countries as being open or closed to international trade, the inclusion of criteria (iii) and (iv) allows them to capture forms of government intervention that clearly extend much further beyond restrictions on international trade. Several authors have argued that this indicator is better interpreted as an overall measure toward market friendly versus 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 versus government interventionist policies. As do 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, the black market premium is always joined by many other forms of financial market distortions. Moreover, a socialist government or a government that monopolizes major exports is most likely also a good proxy for government rents that depress the accumulation and/or the effective use of human and physical capital in a country.

Obviously, a dichotomic indicator is at best a stark one and 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 policy regimes. The main advantage of the SW indicator is the provision of a simple indicator that is available for most of the country-years in our panel. Richer indicators, are available only for a reduced sample of countries, a cross-section, or only a handful of recent years.

Table 4 compares the MPK of closed and open countries. It compares the averages of both $QMPK$ and $VMPK$ for open and closed countries, splitting the sample in 5-year intervals. The table also presents the t-statistic of a simple test that the average $QMPK$ 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 Table 4. First, the marginal product of capital in closed countries is always higher than in open countries. These differences are quantitatively very large and 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 that for open countries remains relatively flat (at lower levels). Third, the number of open countries drastically increases from 1981 onward. The lower $MPK$ of open countries and a higher fraction of them drive the overall downward trend in the average marginal product of capital.[25] Finally, we would

[25] It is worth indicating that essentially the same findings hold if the analysis is done in logarithms as opposed to levels.

Table 4: The MPK of Open and Closed Economies: 5-Year Averages (1970-2000)

| Year | $QMPK_{j,t}$ | | | $VMPK_{j,t}$ | | | 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, FAOSTAT, and Sachs and Warner (1995).

Table 5: Factor Shares, Output-to-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, FAOSTAT, and Sachs and Warner (1995).

also like to emphasize that the fact that our $MPK$ are strongly related to the SW indicator, a good proxy for market-oriented policies (Rodriguez and Rodrik, 2000; Hall and Jones, 1999; Buera et al., 2011), is reassuring of the low extent of measurement error of our $MPK$ measures.

Table 5 further explores the drivers of the differences between open and closed countries. It lists the averages of capital income shares, $\phi^K_{j,t}$, the average output-to-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 into open and closed categories. The table also shows the t-statistic for the test of equality of means for each component. Our results are highly suggestive of how market-oriented countries differ from closed, state interventionist countries. Closed, interventionist countries have much higher output-to-capital ratios than open, market-oriented countries, and these differences are statistically significant. On the other hand, the relative cost of capital is higher in closed countries than in open countries, suggesting that some of the interventionist policies probably 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, especially 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 from efficient physical capital reallocation in Section 5.1. We study how global misallocation moves with market-oriented policies in Section 5.2. We analyze the gains of capital reallocation for an extended sample in Section 5.3. Then, we explore winners and losers from efficient reallocation in Section 5.4. Finally, we discuss differences in the degree of global misallocation across methodologies to estimate the output share of natural resources in Section 5.5.

## 5.1 Global Output Gains of Physical Capital Reallocation

To focus on the allocation of physical capital, 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-sectional distributions of these production factors—and their behavior over time—are what they are, and there is nothing to evaluate. We also take as given and fixed the allocation of human capital, $H_{j,t}$ in each country and the measured output shares. 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 embeds TFP $(A_{j,t})$ and the output contribution of natural resources.

### 5.1.1 The Two Benchmarks

Our first measure of global misallocation compares the observed world output with the one resulting from the maximization of global output with perfectly tradeable output and capital:

$$Y^{K^*}_{W,t} = \max_{\{K_{j,t}\}} \sum_{j=1}^{J} Z_{j,t} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})} \left(H_{j,t}\right)^{\theta_{j,t}}, \tag{15}$$

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

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

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

Naturally, this maximization requires that the quantity marginal product of physical capital across all countries

$$QMPK_{j,t} = \gamma_{j,t}\left(1-\theta_{j,t}\right) Z_{j,t}(H_{j,t})^{\theta_{j,t}} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})-1}. \tag{16}$$

be equal to a common world cost of use of capital $r_t^K$. In particular, countries with higher TFP and/or natural resources, $Z_{j,t}$, a higher supply of human capital, $H_{j,t}$, and a 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 $\theta_{j,t} = \bar{\theta}_t$; when the cross-country heterogeneity in factor shares disappears.[26] Although there is not closed-form solution using the heterogeneous 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 $\ln\left[Y_{W,t}^{K^*}/Y_{W,t}^{O}\right]$—that is, the percentage difference between the maximized global output and $Y_{W,t}^{O}$, the sum of the country outputs observed in the data.

To incorporate price differences $\left\{P_{j,t}^Y, P_{j,t}^K\right\}$ from the data, and to use comparable benchmark to the one above, we interpret $P_{j,t}^K/P_{j,t}^Y$ as the cost of investing one unit of capital in country $j$ in terms of units of the output in the country. Then, the cost of the observed capital $K_{j,t}^O$ in each country $j$ in period $t$ in international dollars, is given by $\left(P_{j,t}^K/P_{j,t}^Y\right) K_{j,t}^O$. Then, our second benchmark for global misallocation observed world output relative to the maximized world's output (15), but subject to the using the same overall global investment, i.e.,

$$\sum_{j=1}^{J} \frac{P_{j,t}^K}{P_{j,t}^Y} K_{j,t} \leq K_{W,t}^N. \tag{17}$$

where $K_{W,t}^N \equiv \sum_{j=1}^{J} \frac{P_{j,t}^K}{P_{j,t}^Y} K_{j,t}^O$.

This maximization requires the equalization of the $VMPK$s price-corrected marginal product of physical capital, that is,

$$VMPK_{j,t} = \frac{P_{j,t}^Y}{P_{j,t}^K} \gamma_{j,t}\left(1-\theta_{j,t}\right) Z_{j,t}(H_{j,t})^{\theta_{j,t}} \left(K_{j,t}\right)^{\gamma_{j,t}(1-\theta_{j,t})-1}$$

must be equal to a global cost of capital $R_t^K$. Under this benchmark, prices also determine the allocation of capital for each country. The higher (lower) the relative price of output (capital) in

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

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

a country, $P^Y_{j,t}/P^K_{j,t}$, the more (less) physical capital should be allocated to it.[27]

### 5.1.2 Results

Our results are summarized in Figure 5, which presents the evolution of quantity and value global gains from 1970 to 2005. We find that global misallocation is large with output gains roughly between 5 and 2 percent for entire sample period. Note that 2 percent global output gains are quantitatively important. For instance, in this period the total output in South America is around 5 percent and in Africa is around 2 percent of global output value; that is, if the full 2 percent global gains (i.e., roughly our minimum) were geared toward Africa, its output size would double. In terms of accuracy, we find that the global gains we obtain are significantly different from zero; see the bootstrapped confidence intervals in Table 6.[28]

In terms of the evolution of global misallocation, there is an unambiguous movement toward more efficiency over time. The equalization of quantity MPK yields gains that start at 5.18 percent in 1970 and decrease to 2.43 percent in 1985 (see Table 6). Since the early 1990s, quantity global gains have also declined but at a slower pace: from 2.51 percent in 1990 to 2.29 in 2005. The equalization of value MPK shows a similar trend pattern, starting with gains that average 3.20 percent during the 1970s and decrease to roughly 2 percent in 2005. Not surprisingly, the value global gains are always somewhat lower—by an average of 20 percent—than the quantity global gains, indicating the role of prices in accounting for income differences across countries.[29] In addition, for any particular year, quantity and value gains are highly correlated at the country level.[30] We discard the notion that these patterns are driven by measurement error. Instead, as we now discuss, the global movement toward efficiency is strongly associated with the worldwide movement towards market-oriented policy regimes as observed since the early 1980s (see also Appendix C).

[27] Under the assumption of identical factor shares across countries, $Y^{K^*}_{W,t}$ is given by:

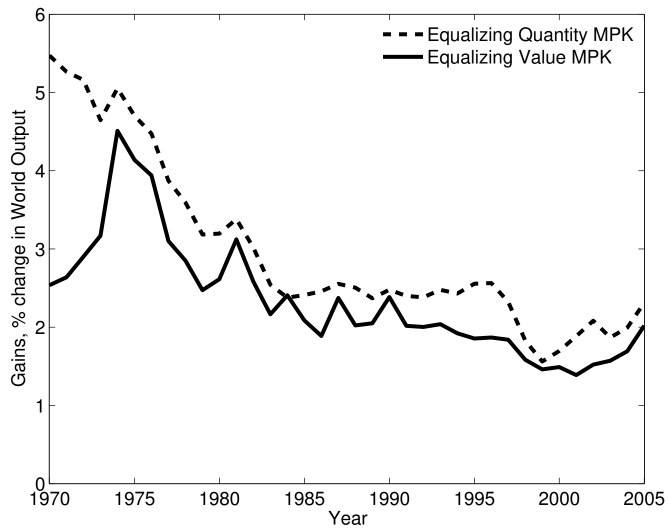
$$Y^{K^*}_{W,t} = \left[ \sum_{j=1}^{J} \left[ A_{j,t} T_{j,t}^{(1-\bar{\gamma}_t)\left(1-\bar{\theta}_t\right)} (H_{j,t})^{\bar{\theta}_t} \left( \frac{P^Y_{i,t}}{P^K_{i,t}} \right)^{\bar{\gamma}_t\left(1-\bar{\theta}_t\right)} \right]^{\frac{1}{1-\gamma\left(1-\bar{\theta}_t\right)}} \right]^{1-\bar{\gamma}_t\left(1-\bar{\theta}_t\right)}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

[28] China and India are key players in the world economy and the assessment of global misallocation can greatly vary depending on whether these countries are included or not. However, as already reported in Appendix Table 8, moving from the sample of CF sample (which does not include Chin and India) to our benchmark sample which includes China and India, only changes the estimated global losses from 2.32% to 2.51%. Finally, to directly and decisively address this issue we computed the results using our benchmark sample and with the sample of excluding China, India or both. We find that neither China nor India move the results in significant amounts, nor their exclusion change the main conclusions about the movement towards efficiency, with the persistence of a significant amount of misallocation.

[29] Excluding the year 1970, for which the differences between value and quantity gains are the largest, the gap between value and quantity gains slightly drops to 15 percent.

[30] Running a regression of country-specific value gains on quantity gains by year, we find an intercept that remains very close to 0 and a significant slope coefficient that oscillates between 0.6 and 0.8.

Figure 5: Global Output Gains of Physical Capital Reallocation




Notes: Our results are based on our measures of MPKs computed using natural resources rents, factor shares, capital, output, and prices as described in section 3. The global output gains are defined as the log difference between the efficient global output implied by the quantity and value models posed in Section 2 and the actual global output.

Table 6: Global Output Gains of Physical Capital Reallocation: Bootstrap Estimates

| | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 |
|---|---|---|---|---|---|---|---|---|
| QMPK | 5.18 | 4.55 | 3.13 | 2.43 | 2.51 | 2.47 | 1.66 | 2.29 |
| | [3.35,8.27] | [2.87,6.52] | [2.04,4.52] | [1.52,3.58] | [1.59,3.78] | [1.44,4.00] | [0.98,2.44] | [1.34,3.46] |
| VMPK | 2.38 | 4.01 | 2.56 | 2.10 | 2.35 | 1.79 | 1.46 | 1.99 |
| | [1.45,3.73] | [2.20,6.30] | [1.57,3.74] | [1.24,3.23] | [1.38,3.76] | [1.06,2.91] | [0.88,2.16] | [1.22,3.00] |

Notes: The global output gains refer to the median value of 1,000 bootstrap simulations with 100 percent replacement. The confidence intervals (in brackets) refer to the 10th and 90th bootstrapped percentiles.

## 5.2 Global Policy Movements and Misallocation

Figure 6 shows the fraction of open countries—that is, those with market-oriented policy regimes (right scale) and the median of the implied wedges for physical capital (left scale) in market-oriented countries (blue) and heavily interventionist countries (red.) These wedges were computed as follows: For every year, we compute the allocation of capital resulting from the quantity and value marginal product of capital and obtain the efficient worldwide $MPK_t^*$. Then, we construct country-specific wedges as: $\Delta_{j,t} = \frac{MPK_{j,t}^o}{MPK_t^*}$, where $MPK_{j,t}^o$ is the observed MPK for country $j$ in period $t$ according to the quantity and value definitions. The patterns for the averages are very similar to those for the medians.

Panel (a) in Figure 6 shows very clearly that, along the sample period, the world moved toward openness and market orientation. On the one hand, the number of open countries almost doubled, from just about 50% of the countries in our sample during the 1970s, and the fraction of market-oriented countries reached 92.5% by the end of the sample. The most dramatic increment in the share of market-oriented countries take place during the 1980s. On the other hand, the gap between the implied wedges of market-oriented and government interventionist countries also declined substantially during the 1970s. During the 1980s, the gap completely disappears according to the quantity benchmark, and becomes negative under the value 1. Such a gap becomes positive for both cases for the later part of the sample period, but at that point it applies to only a handful of countries.

Thus, both margins, the number of open countries and the gap in the wedges between closed and open countries, seem relevant for the global movement toward efficiency. To explore further how the global movement in policies may drive changes in global misallocation, we perform a counterfactual simulating how much reallocation would be reduced if all interventionist countries had adopted market-oriented policies. In particular, panel (b) in Figure 6 compares our estimated global misallocation with those when all closed countries are assumed to have the median wedge of market-oriented countries.[31] Three main conclusions arise: First, the degree of the degree of misallocation would have been significantly lower for all years. Second, practically all misallocation would disappear by the end of the sample period. Third, the above conclusions hold for both the quantity and value benchmarks.

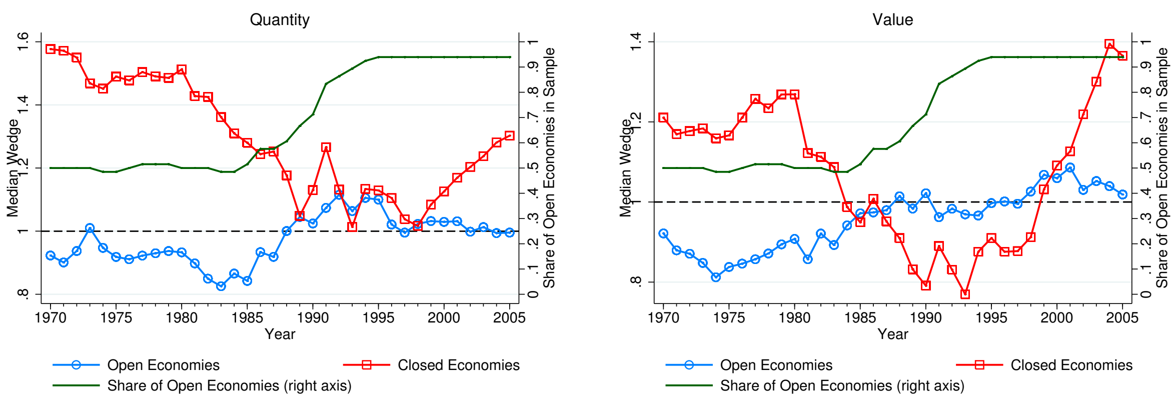
## 5.3 Results Extending the Sample of Countries

So far, we focused on a sample of 76 countries for which we were able to consistently retrieve information on rents of natural resources, factor shares, physical capital, human capital, and output from 1970 to 2005. With improvement on data collection with time, as well as the emergence of new countries in the 1990s (for example, after the fall of communism in Eastern Europe), data for more countries are available in the present than in the past. In this section, we extend our benchmark sample to the set of 107 countries for which we can retrieve all necessary

[31]Note that the gains in Figure 6 are slightly different from those in 5 because our sample of countries is reduced to 67 countries with information on the SW variable.

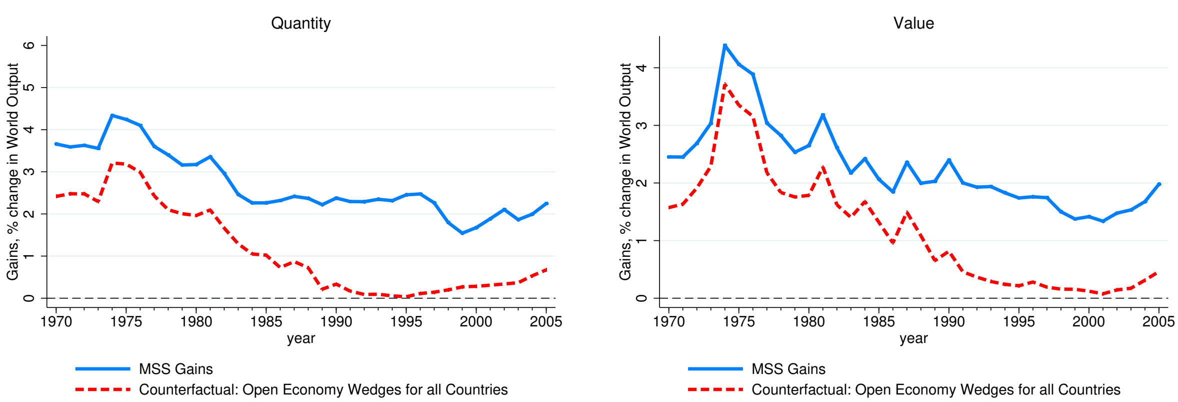
Figure 6: Market-Oriented Policy and Global Misallocation

(a) Wedges and Number of Market-Oriented and Interventionist Countries



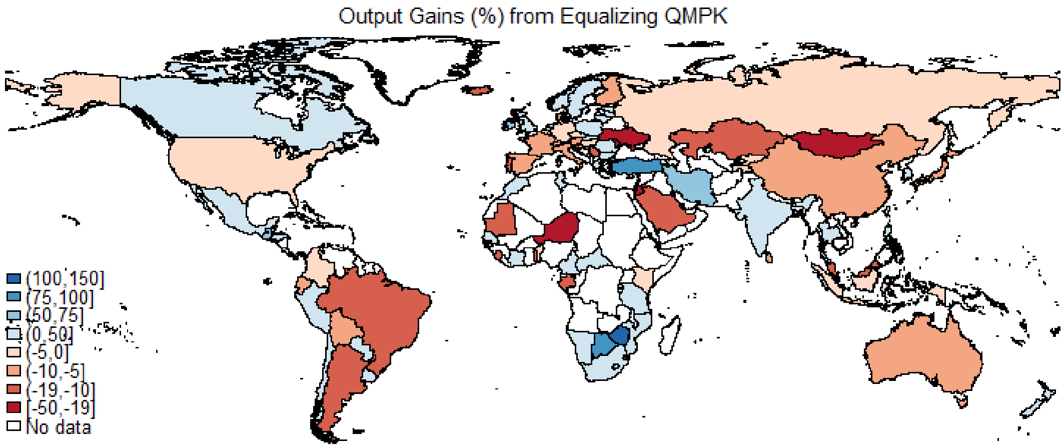

$QMPK$ $VMPK$

(b) Counterfactual Gains in a Market-Oriented World




$QMPK$ $VMPK$

Figure 7: Winners and Losers of Reallocation with the Extended Sample




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

information to perform our analysis for the year 2005. Thus, we explore the robustness of our main results to the increased sample size.

We compare the global output gains between our benchmark sample and the extended sample in Table 7. We find minor differences across samples or, if at all, our benchmark sample tends to underestimate the global gains or reallocation compared with the extended sample. If we equalize only the quantity $MPKs$, our benchmark sample implies global gains of 2.31% of output in 2005, while these gains are 3.56% for the extended sample. In value terms the gains of equalizing $MPKs$ is 2.02% for the benchmark sample and 3.78% for the extended sample in 2005.

Table 7: Comparing Gains (%) in Output in 2005

| | Quantity | | Value | |
|---|---|---|---|---|
| | Benchmark | Extended Sample | Benchmark | Extended Sample |
| Equalizing MPK | 2.31 | 3.56 | 2.02 | 3.78 |
| Number of countries | 76 | 107 | 76 | 107 |

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

With the extended sample, we use maps in Figure 7 to describe winners and losers of reallocation. The reallocation of physical capital (top panel) is from large countries (red in the map) such as Australia, Brazil, China, Russia, the United States, and Southern European countries, toward several African countries, India, Eastern and Northern Europe, Canada, and Mexico, among others (blue in the map).

### 5.4 Distributional Patterns: Regions and Income Levels

Interestingly, the global patterns are quite similar under both quantity and value exercises. In both gains of capital reallocation vary greatly across countries. Panel (a) in Figure 8 shows the distribution of quantity and value gains from 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 10th-90th percentile range, and the lightest region the 5th-95th percentile range. The distribution of gains is asymmetric: the percentiles 5th, 10th and 25th are relatively close to the median and percentile 75th, 90th and 95th are further away. For instance, in 1970 the median quantity gains are around 20 percent, the 5th percentile of gains is around minus 20 percent, and the 95th percentile of gains is more than 80 percent. The median quantity gains decrease from about 20 percent in 1970 to around 0 in 2005. The pattern for value gains is similar, but the median gains increase again at the end of the 1990s.

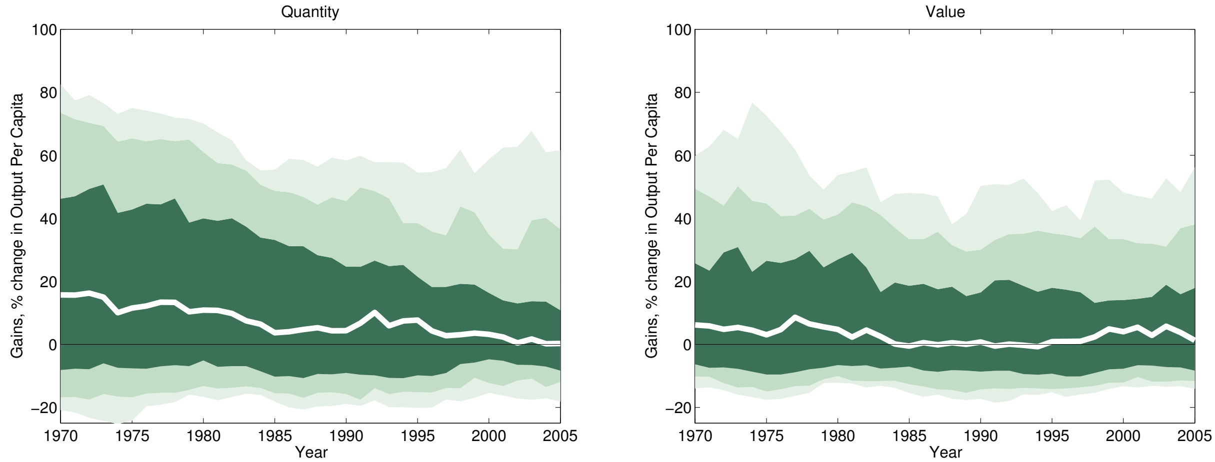
To characterize the global output gains further, we compute the gains by regions (panel (b), Figure 8). Regional differences are striking. First, using the counterfactuals based on QMPK, output gains in Africa would have been roughly 30 percent in 1970, fallen to 10 by the mid-1990s, and then climbed to 20 percent in 2005, even when the global gains are in the 2 percent range. For Latin American and the Caribbean countries (LAC), the gains would also be quite large: 30 percent in 1970, around 20 percent for most of the years between 1980 and 2000, falling to 10 percent at the end of the period. Asian countries (excluding Japan) would initially have much larger gains, around 40 percent in the early 1970s, which is consistent with the findings of Ohanian et al. (2013); then the gains for the Asian countries would consistently fall down to 10 percent in 2005, a reflection of the rapid accumulation of capital observed for these countries. Using the counterfactual with VMPK (i.e. including price differences) would lead to very similar results for Asia and Latin America. The notable difference is that the gains would be much smaller for Africa, driven by the relatively high cost of installing capital in those countries. For 2005, both counterfactuals lead to very similar numbers for almost all regions.

As for developed countries, we find that overall, regardless of using the quantity or value counterfactuals, developed countries (the US, Canada, Europe, and Oceania) will export capital and reduce their domestic production, mostly around 10 percent. The notable exception to this pattern is Japan, which during most years between 1970 and the early 1990s would be a net recipient of capital. These high MPK values for Japan reflect the fast growth experienced by the country during the first 25 years in our sample. Then, from the early 1990s onward, the stagnation of Japan's economy, and perhaps the aging of its population, made the country exhibit a behavior similar of the other developed countries.

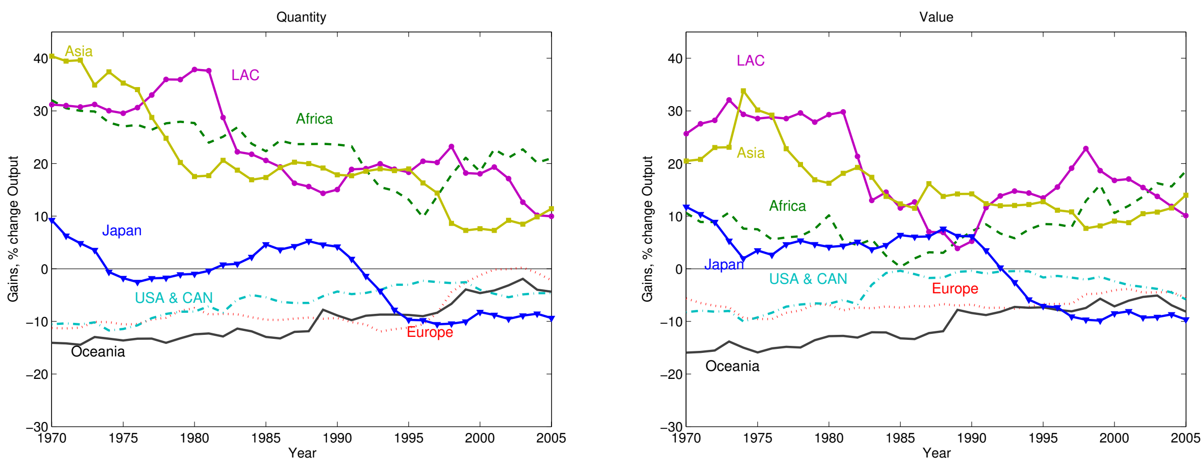
A complementary look at the distributional implications of the barriers and distortions to physical capital allocations is shown in panel (c) of Figure 8, in which the set of countries is divided into per capita income quartiles (1st quartile composed by the poorest countries; 4th quartile by the richest ones). As before, the vertical axes indicate the counterfactual gains (in percent) for each group of countries and the horizontal axis the year; the left panel shows the results for QMPK and the right one for VMPK. Four patterns are very clear from these figures. First, as hypothesized by Lucas (1990), some capital would flow out of the rich countries to be allocated to the rest. Second, this pattern of reallocation does not depend on whether we use

Figure 8: Distributional Patterns of Global Output Gains

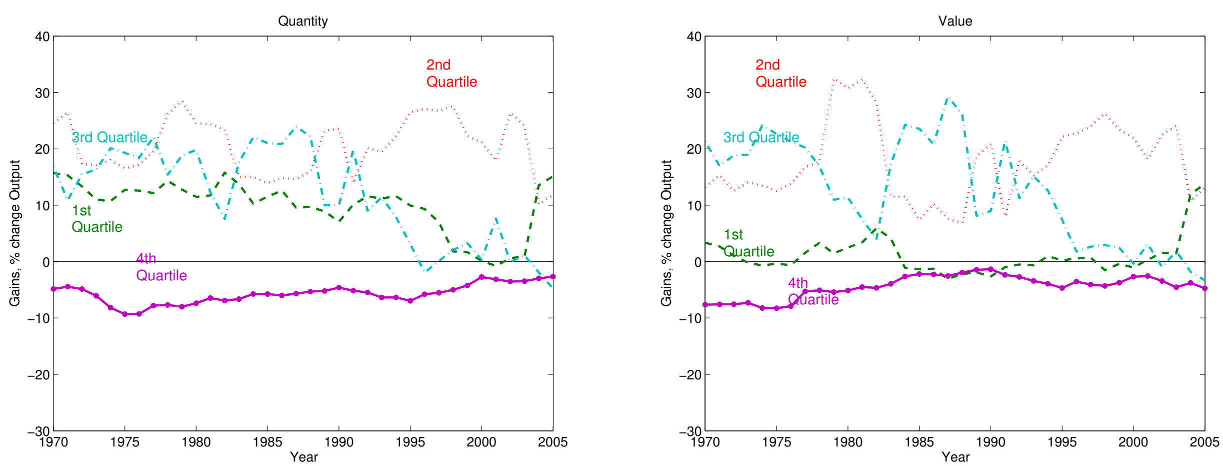
(a) Winners and Losers: Distribution of Output Gains of Physical Capital Reallocation




(b) Regional Gains of Physical Capital Reallocation




(c) Gains of Physical Capital Reallocation across Income Quartiles




Notes: Results of equalizing QMPK (left panels) and VMPK (right panels) across countries, 1975-2005. In the top panel (a), the white line represents the median, and gradually from dark to light blue shades (i.e., as we move away from the median) we show the interquartile (25-75 percentile) range, the 10-90 percentile range, and the 5-95 percentile range. For a list of countries in each region in the center panel (b), see Appendix A.
Source: Authors' calculations based on PWT 8.0, WB, and FAOSTAT.

prices or not. Third, the amount of capital that would be reallocated from developed countries declines over time in both counterfactuals, consistent with movement toward efficiency. Finally, and most interestingly, the gains are not monotonic in income. For most periods, the countries that would gain the most are in the middle, the second, and third income quartiles, and not the poorest countries.

## 5.5 Comparison with Caselli and Feyrer (2007)

We conduct two exercises to compare the magnitude of global misallocation obtained using our benchmark environment with estimates of output shares of natural resources based on *rent flows* that we label as MSS (Section 3.1.1) and the environment proposed by CF where output share estimates are based on *natural* capital *stocks* (Section 3.1.2).

First, we show a discrepancy between the results in MSS and CF in a direct manner by comparing the global output gains in both environments. Figure 9 shows the global output gains for both environments, MSS and CF, separately for quantity and value units from 1970 to 1996.[32,33] The CF environment simply replicates the global gains obtained in Caselli and Feyrer (2007) based on their data and sample size, while the MSS environment shows the global gains from our benchmark based on our data and sample size as described in Section 3. A clear message emerges: The global gains in MSS are roughly five times larger than those in CF. We emphasize that these differences between MSS and CF are not only large but also statistically significant. In terms of the evolution of global misallocation across time, the dynamics between the MSS and CF environments also differ dramatically. While we find a clear movement toward efficiency from global gains of roughly 5 percent in the 1970s to roughly 2 percent in the 2000s under the MSS environment, there is no evidence of a trend toward efficiency over time under the CF environment.

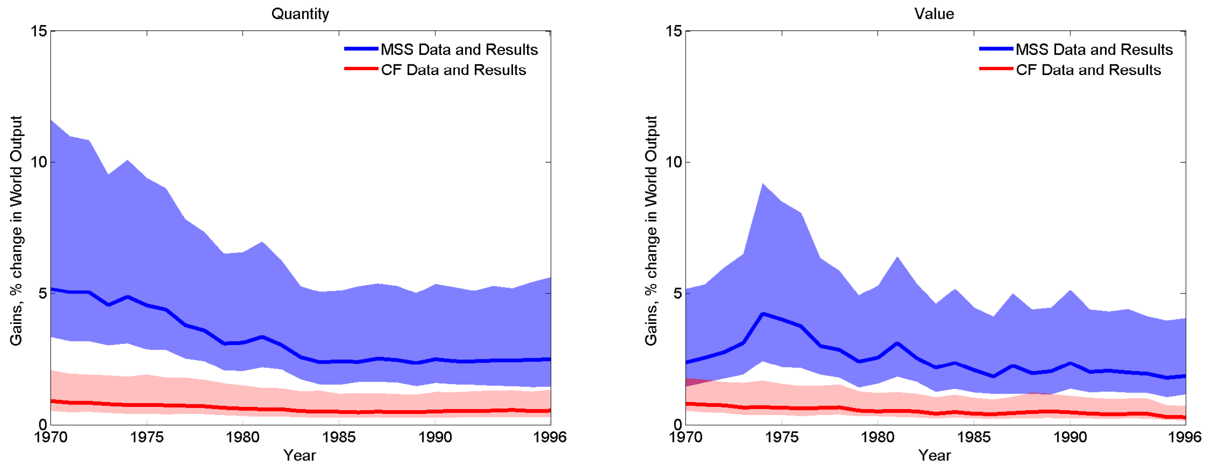
Second, to explore in detail the sources of our discrepancy with CF, Table 8 presents the global output gains of physical capital reallocation from alternative combinations of data sources (either from MSS or CF), and associated country-sample sizes for the year 1996 ( i.e., the base year in Caselli and Feyrer (2007)). We start by restricting the comparison for the 47 countries available in both the CF and MSS data sets, which we label as the CF sample.[34] The first row of Table 8 reproduces CF's results for these 47 countries and for which we find median gains of 0.52 percent. In the second and third rows, we gradually impose the MSS labor share and capital and output on the CF environment. We find that adding the MSS labor share increases the global gains to roughly one percent, and the MSS capital and output data barely change these

[32] The sample is restricted to 1996—i.e., that is up to the year for which CF data (PWT 6.1) are available.

[33] As in Caselli and Feyrer (2007), we assume that the labor share constructed by Bernanke and Gurkaynak (2001) circa 1996 remains constant across all years for the CF environment. We find that using series of time-varying labor shares from the PWT does not alter their results.

[34] This restriction binds mostly for the availability of labor share data from Bernanke and Gurkaynak (2001). Note that while the CF environment in Figure 9 has 51 countries, in Table 8 we use 47 countries. This is due to the fact that in MSS (i.e., PWT8.0) we do not have labor share data in 1996 for the Democratic Republic of Congo, El Salvador, and Zambia. Further, in MSS we do not have $\phi^R$ for Burundi, while CF does. However, we find that the presence of these four countries makes no quantitative difference for the CF results.

Figure 9: Global Output Gains of Physical Capital Reallocation: MSS versus CF




Notes: The CF environment reproduces the global gains in Caselli and Feyrer (2007) from the equalization of $MPKs$ computed from *natural* capital *stocks* and their data sources for factor shares, capital, output, and prices available for 51 countries (mainly PWT 6.1, WB, and Bernanke and Gurkaynak (2001)). The MSS environment refers to the global gains from our benchmark equalization of $MPKs$ computed from *rent flows* from natural resources. To compute global output gains for MSS we use available data for factor shares, capital, output, and prices for 76 countries, as described in Section 3. The global output gains are defined as the ratio between the efficient global output implied by the quantity and value models posed in Section 2 and the actual global output. The left panel refers to the $QMPK$ model and the right figure to the $VMPK$ model. In both environments, CF and MSS, we report the median global gains and their associated $10th$ and $90th$ confidence intervals from 1,000 bootstrap simulations with 100 percent replacement.
Source: Authors' calculations based on PWT 6.1 and 8.0, Bernanke and Gurkaynak (2001), WB, and FAOSTAT.

gains to 0.98 percent. Note that up to this point, the global gains are not significantly different from the CF benchmark. In the fourth row, we add our output shares of natural resources, $\phi^R$, based on *natural rents* (Section 3.1.1) as opposed to the corresponding shares based on *natural stocks* in the original CF benchmark (Section 3.1.2). We find that the global gains substantially rise to 2.32 percent. Therefore, the larger gains from efficiently reallocating capital in the MSS environment compared with the CF environment are largely driven by the difference in the estimates for $\phi^R$. Precisely 1-(0.98-0.52)/(2.32-0.52)=74.4% of the increase in output gains in the MSS environment compared with the CF environment is driven by the different estimates of the output share of natural resources. This result strictly arises from the overestimation of the output share of natural resources by the CF methodology (Section 3.1.3) that makes the $MPKs$ of poor countries artificially closer to those of the rich countries implying a degree of global misallocation artificially low in the CF environment.[35] Finally, in the fifth and sixth rows, we

[35] In Appendix B we show how the differences in the estimated output shares of natural resources discussed in Section 3.1.3 translate into large differences in the implied $MPKs$ between the MSS and CF environments.

Table 8: Comparing Alternative Data Sources and Samples: MSS versus CF (1996)

| Sample | Data Source $\phi^R_{j,t}$ | (K,Y) | $\theta$ | Gains [CI] | Sample Size |
|---|---|---|---|---|---|
| CF: | CF | CF | CF | 0.52% | 47 |
| | | | | [0.29,0.95] | |
| | CF | CF | MSS | 1.01% | 47 |
| | | | | [0.48,2.05] | |
| | CF | MSS | MSS | 0.98% | 47 |
| | | | | [0.51,1.87] | |
| | MSS | MSS | MSS | 2.32% | 47 |
| | | | | [0.90,5.31] | |
| MSS, Benchmark: | MSS | MSS | MSS | 2.51% | 76 |
| | | | | [1.45,4.17] | |
| MSS, Extended: | MSS | MSS | MSS | 3.35% | 107 |
| | | | | [1.63,6.45] | |

Notes: CF refers to Caselli and Feyrer (2007) and their data, and MSS to this paper with data sources described in Section 3. Recall that $\phi^R$ refers to the output share of natural resources, $(K, Y)$ to the capital and output data, and $\theta$ to labor share data. Recall that our estimate of $\phi^R$ is based on *natural rents* (Section 3.1.1) as opposed to the corresponding shares based on *natural stocks* in the original CF benchmark (Section 3.1.2). The global output gains refer to the median value of of 1,000 bootstrap simulations with 100 percent replacement. The confidence intervals refer to the $10th$ and $90th$ bootstrapped percentiles.

respectively increase the sample size to our MSS benchmark of 76 countries and to our extension of 107 countries described in Appendix A. We find that increasing the sample size from 47 to 76 countries slightly increases the global gains to 2.51 percent and, at the same time, increases the accuracy of our estimated gains, making the MSS results significantly different from CF—that is, the confidence intervals between the MSS and CF benchmarks do not overlap. Finally, increasing the sample size to 107 countries further increases the global gains to 3.51 percent and also increases the significance in the differential global gains between MSS and CF.[36]

To sum up, our new estimates for the output share of natural resources based on *rent flows*, as opposed to the CF's estimates based on *natural* capital *stocks*, are the major component driving the large differential in global gains between MSS and CF. Moreover, the differential between MSS and CF gains becomes more accurate and significant as we increase the sample size.

[36]Note that our extension to 107 countries refers to the year 2005, not 1996. Nevertheless, under the MSS benchmark, the global gains are very similar for these two years: 2.51 percent in 1996 and 2.29 percent in 2005.

# 6 Examining the Reallocation of Capital, 1970-2005

A main finding in Section 5 is the improvement in the efficiency of the allocation of world physical capital over the sample period. Such a result might seem to contradict those in the literature, particularly the work of Gourinchas and Jeanne (2013) on 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 synthesize 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 9 shows 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 $QMPK$ as the measure for $MPK$.We report the results for the whole sample of countries and for a sample without the OECD countries, to be consistent with the focus of Gourinchas and Jeanne (2013) on developing countries.

The results in Table 9 strongly indicate that from 1970 to 2005, capital accumulation has been positively—and rather strongly—aligned with 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 use either values of $VMPK$ or $QMPK$ 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 accumulate faster when the $MPK$ is higher. The effects are quantitatively substantial and statistically significant.

Second, and even more importantly, capital accumulates 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, note that the growth in TFP ($\Delta \ln Z$),[37] 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 sometimes exhibits the wrong sign and is

[37] 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 $Z_{j,t} \equiv A_{j,t} T^{\phi^R_{j,t}} = Y_{j,t} / \left[ K_{j,t}^{\phi^K_{j,t}} H_{j,t}^{\theta_{j,t}} \right]$.

Table 9: 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) | - | - |
| $QMPK_{1970}$ | - | 6.729*** | - | - | 6.340*** | - |
| | - | (1.081) | - | - | (1.124) | - |
| $\left(\frac{Y}{K}\right)_{1970}$ | - | - | 2.610*** | - | - | 2.400*** |
| | - | - | (0.438) | - | - | (0.457) |
| Includes 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 are listed in parentheses. One asterisk means $p < 0.1$; two asterisks mean $p < 0.05$; and three asterisks mean $p < 0.01$.
Source: Authors' calculations based on PWT 8.0, WB, and FAO.

statistically insignificant. A positive and marginally significant coefficient is attained only in our least preferred specification, which includes only ($\Delta \ln Z$), ignore all other components that drive $MPK$, using only $Y/K$ in 1970 as a proxy for initial capital scarcity, and excluding all the OECD countries.

Third, 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, in our preferred specifications, columns (1) and (4), in which we regress growth of physical capital with initial $VMPK$ and the growth of the factors driving $VMPK$ growth, the regressors account for almost 90% of the variation in $\Delta \ln K$. Needless to say, the high goodness of fit of the regressions does not contradict our findings that important inefficiencies remain at the end of the sample period. The high goodness of fit simply indicates the correlation in the direction of capital accumulation with the drivers 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 changes in both capital intensities, $\Delta \ln \phi^K$, and 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 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 of whether the allocation of capital has improved or worsened during our sample period 1970 to 2005. In these counterfactual exercises, we compute the 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 in 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 exercise, we assume that the relative allocation of capital across countries remains fixed at the values observed in 1970, $\mu^K_{j,1970} \equiv K^O_{j,1970}/K_{W,1970}$, where $K_{W,1970} = \sum_j K^O_{j,1970}$ is the world's total physical capital as of 1970. Then, we construct a counterfactual sequence of capital stock for each country $j$ as

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

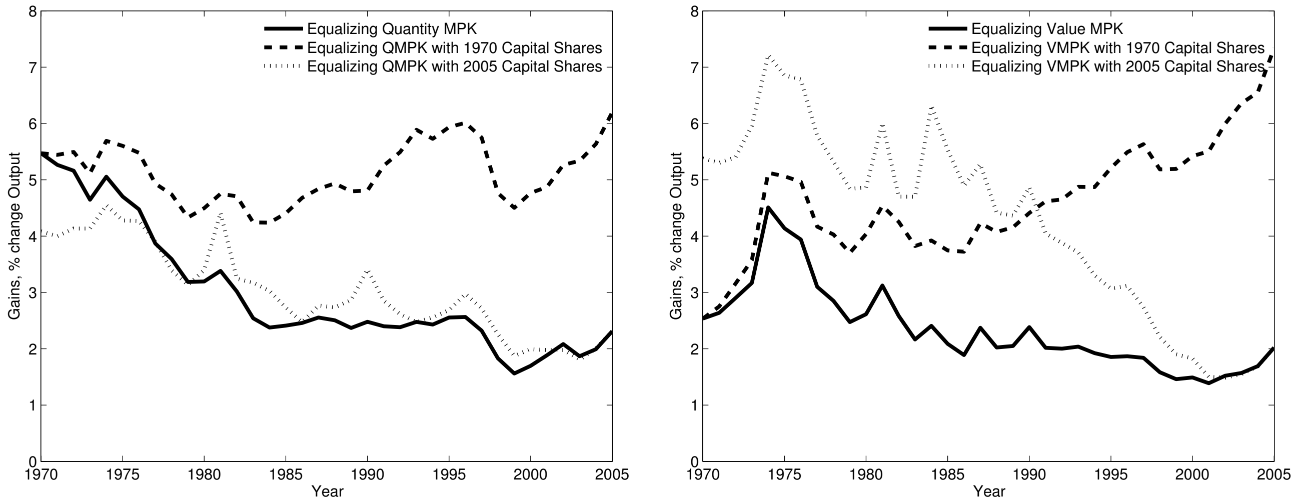
With the series $\left\{\tilde{K}^{1970}_{j,t}\right\}$, we compute the counterfactual levels of output $\{\tilde{Y}^{1970}_{j,t}\}$ for each country and the implied world's total $\tilde{Y}^{1970}_{W,t}$, assuming that everything in the world economy—that is, the technologies $\{Z_{j,t}, \phi^K_{j,t}, \theta_{j,t}\}$ and labor inputs $H_{j,t}$ for all countries—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 can 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 value benchmarks as defined in Section 2, 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 counterfactual exercises is 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

Figure 10: Comparing Gains of Counterfactual Allocations




Equalizing QMPK Equalizing VMPK

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

efficiency loss $\ln\left[Y_{W,t}^{K^*}/\tilde{Y}_{W,t}^{2005}\right]$. These second set of countefactuals complements the first ones by indicating how efficient the current distribution of capital would have been for the first years in our sample.

Figure 10 displays the results for the counterfactuals based on physical and value marginal products of capital, $QMPKs$ and $VMPK$. In each panel, the solid lines represent the global efficiency losses 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.

In terms of $QMPK$, the left panel of Figure 10 unambiguously shows that the global efficiency losses would have remained 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 losses by the end of the sample. Interestingly enough, if the allocation of capital over the sample period 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 of Figure 10, the counterfactuals based on the value marginal products of capital, $VMPK$, convey an only slightly different message. As with $QMPK$, this counterfactual shows that keeping the relative capital allocations constant as in 1970 would have led 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 a much more inefficient for any of the years prior to 2000. Overall, both counterfactual exercises coincide in their verdict that the reallocation caused by capital accumulation between 1970 and 2005 was conducive to higher efficiency.

# 7 External Flows Versus Domestic Accumulation

For physical capital, Sections 5 and 6 documented a strong trend toward global efficiency in the allocation of physical capital. In this final section, we explore the role of external flows in shaping up these findings.

We first show that domestic savings drive the movement toward efficiency in the allocation of physical capital from 1970 to 2005. In essence, the countries whose $MPK$ grows the faster were also the ones saving the most. Then, rather than contradicting, our findings reinforce and transcend the negative results of Gourinchas and Jeanne (2013) on the role of 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 compute this for the initial year and for the final year in a given period.[38] 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 $\{XK_{j,s}\}_{s=1982}^{2000}$—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 derived from 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.[39] We depreciate the capital flows at $\delta = 4.64\%$, the depreciation rate for the US in PWT 8.0.

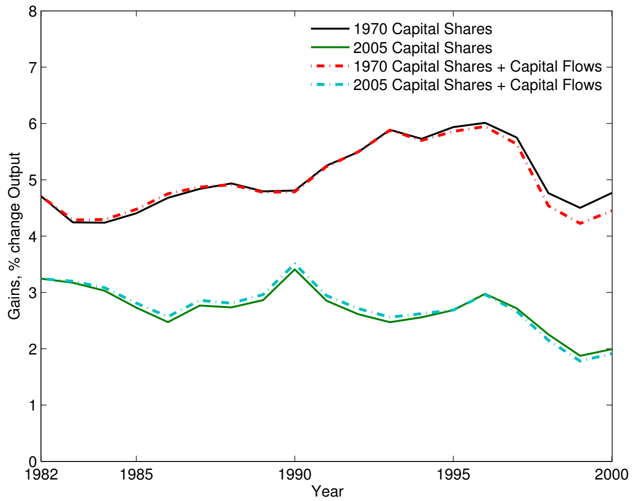
Figures 11 reports the results for the exercises based on $QMPK$ and $VMPK$, respectively. In each graph, the exercises with 1982 shares are in darker lines and lighter ones for 2000. Dashed lines are used for the counterfactuals with the observed $XK_{j,s}$. The finer, solid lines are the cases when $XK_{j,s} = 0$.

The most striking result 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 indistinguishable dashed and solid lines in both graphs. If anything, the magnitude of the external flows is so small that, effectively, it does not really

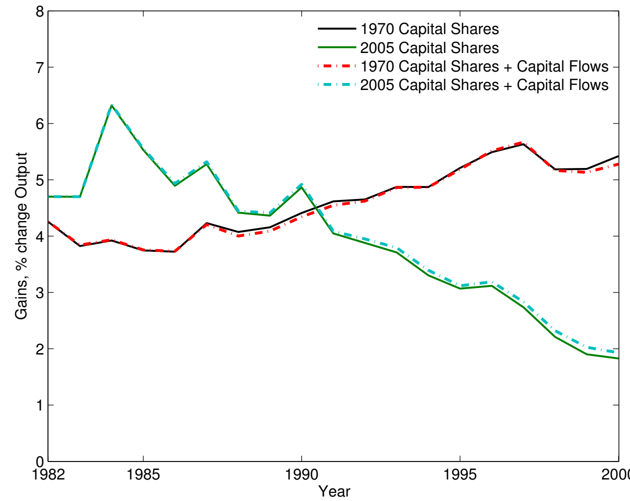
[38] Data limitations, in particular the desire to include China, restricts us to the period $1982-2000$ and only 69 countries. We checked that removing China and India does not alter our insights.

[39] The USD figures from the IMF are converted to PPP units using $P^K_{j,t}$ and $P^K_{j,t}$ from the PWT 8.0. 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 adds up to 0. Very similar results are attained using the current account deficits to measure $XK_{j,s}$, but the required adjustment for global balance is much larger in that case.

Figure 11: Comparing Gains of Counterfactual Allocations: Role of Capital Flows




Equalizing QMPK




Equalizing VMPK

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

matter whether they are misallocated or not.

# 8 Conclusions

We introduced a new methodology to estimate output shares of natural resources. With this new methodology we constructed estimates of these shares for a large panel of countries for the past 35 years. These estimates are useful for uncovering a number of patterns on the global allocation of resources. First, while the substantial global misallocation of physical capital persists over time, we found a clear indication that the global allocation of physical capital has improved over time. Specifically, global output losses were around 6% in the 1970s, while these losses were on the order of 2% in 2005. These figures are substantially larger than previous work with output share estimates based on *natural stocks* (Caselli and Feyrer, 2007) and easily comparable with the estimates from other forms of international relationship such as the gains of trade and FDI.

A second important finding is that disparities in the MPK are associated with observed policies. Countries with more interventionist policies, which a priori inhibit and distort the accumulation of capital, exhibit larger and more dispersed marginal products. Our results suggest that the trends toward global efficiency are clearly aligned to the observed worldwide trend toward market orientation. A third key result is that during the sample period the movement toward global efficiency is accounted for by the strong association between the accumulation of capital and the changes in the MPK. Initial MPK and changes in the factor shares, TFP-cum-natural resources and relative prices explain almost 90% of the accumulation of capital. This movement is driven by domestic capital accumulation, not external flows.

As the world has moved towards allocating physical capital efficiently, key pressing issues remain for the allocation of human capital. As we show in (Monge-Naranjo et al., 2018), reallocating both workers and capital would lead to much higher efficiency gains, and more interestingly, may revert the direction of the allocation, as it would often prescribe moving capital and workers towards some of the rich countries. Reallocating workers, nonetheless, involves many other issues that deserve being the central focus of the research.

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# A Data: Details and Extensions

In this appendix we explain additional aspects of our data. We also report our results under an alternative pricing of crops that uses local producer prices as opposed to international prices. Last, we extend our sample of countries to 107 in the most recent years.

## A.1 List of Countries

We compute the share of natural resources of output for a benchmark set of 79 countries for which data are available for every year from 1970 to 2005. We organize these countries by regions: **Africa:** Burkina Faso, Côte d'Ivoire, Cameroon, Kenya, Morocco, Mozambique, Niger, Nigeria, Senegal, Tunisia, Tanzania, South Africa, and Zimbabwe. **Asia:** Bahrain, China, Hong Kong, Indonesia, India, Iran, Israel, Jordan, Republic of Korea, Kuwait, Sri Lanka, Malaysia, Oman, Philippines, Qatar, Saudi Arabia, Singapore, Thailand, Turkey, and Taiwan. **Europe:** Austria, Belgium, Bulgaria, Switzerland, Cyprus, Germany, Denmark, Spain, Finland, France, the United Kingdom, Greece, Hungary, Ireland, Iceland, Italy, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, and Sweden. **Latin America and the Caribbean:** Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Ecuador, Costa Rica, Dominican Republic, Guatemala, Honduras, Jamaica, Mexico, Panama, Peru, Paraguay, Trinidad & Tobago, and Uruguay. **Oceania: Australia and New Zealand**. Japan and the United States, and Canada were left separated for their substantial role in the world economy.

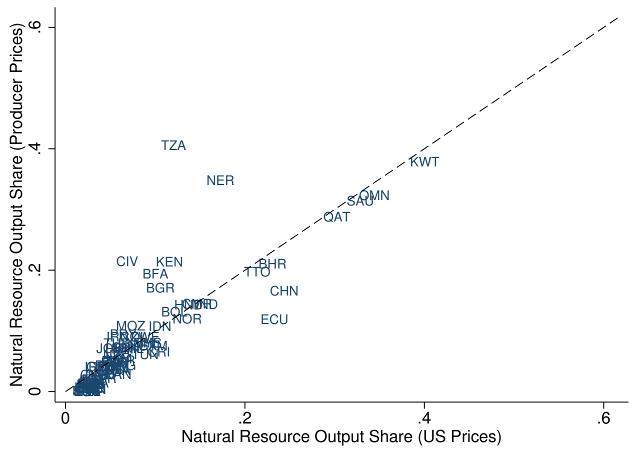
We exclude Burkina Faso, Nigeria, and Oman from our reallocation exercises because these countries do not have data on human capital. This implies a total of 76 countries for our benchmark sample. In Section 5.3 we expand our analysis to countries for which we can retrieve information on rents of natural resources, factor shares, physical capital, human capital, and output for the year 2005. The improvement on data collection and sources over time and the presence of new countries since the early 1990s (e.g., from Eastern Europe), implies more countries for which the required data are available. This new set of countries includes Armenia, Benin, Botswana, Central African Republic, Croatia, Czech Republic, Estonia, Fiji, Gabon, Kazakhstan, Kyrgyzstan, Latvia, Lesotho, Lithuania, Macao, Mauritania, Mauritius, Moldova, Mongolia, Namibia, Romania, Russia, Rwanda, Serbia, Sierra Leone, Slovak Republic, Slovenia, Swaziland, Tajikistan, Togo, and Ukraine. This yields a total sample of 107 countries for the year 2005.

## A.2 Valuation of Crops at Producer Prices

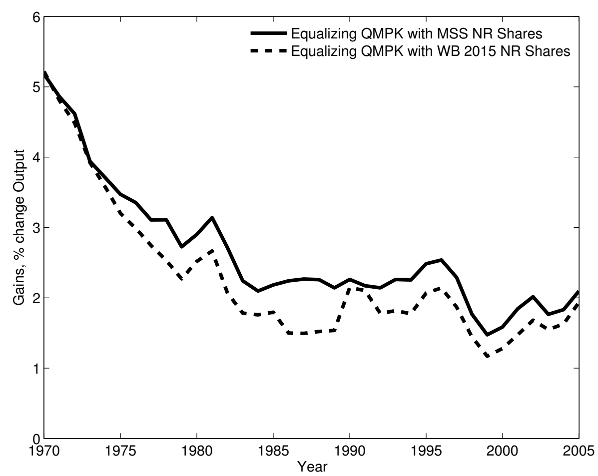
As discussed in Section 3, we extend previous estimates of natural resources rents from the World Bank (henceforth, WB) to an annual basis and for a larger sample period starting in 1970. *The Wealth of Nations* database data were available only at a quinquennial frequency and only since 1990. Currently, *The Wealth of Nation* (forthcoming 2015) is working on an expansion of previous database to an annual frequency and starting 1970.

Figure A-1: Benchmark at US Prices versus World Bank (Unpublished Data, 2015) at Producer Prices

(A) Natural Resources Shares of Output




(B) Global Gains of Physical Capital Reallocation




Source: In panel (A), the definition of natural resources share of output that uses US prices to value agricultural production refers to our benchmark, while the definition that uses producer prices to value agricultural production corresponds to the most updated World Bank measurement (unpublished data, 2015). In panel (B), these two measures of natural resources are used to compute global output gains from a physical capital reallocation exercise where equalizing QMPK with MSS shares refers to our benchmark with US prices, while equalizing QMPK with WB 2015 data refers to the producer prices analog.

The Wealth of Nations group at the WB has kindly shared their new (but still unpublished) data with us. In expanding their data, the WB has also introduced a new relevant feature in the valuation of natural resource rents in terms of crop pricing. While in previous versions the WB used export unit values to value agricultural output, they are currently using producer prices to conduct these valuations. 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 recently, FAOSTAT has started to provide regular coverage of producer prices/gross value of production, and the newest version of *The Wealth of Nations* (forthcoming 2015) values crop production using the newly available producer prices, which tend to be lower than export values. This implies that the WB estimates for cropland rents will tend to be lower than their previous estimates. This also affects the rents from pastureland that are assumed to be a fraction of those from cropland rents (see Section 3) by the WB. The rents from natural resources, other than crop and pastureland, remain unchanged in the new version.

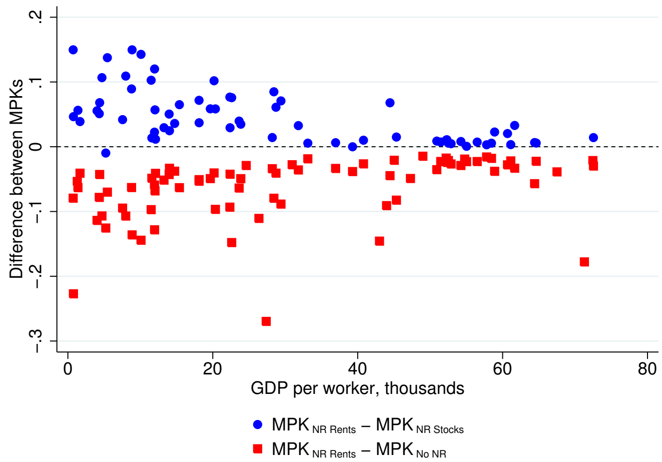
Here, we compare our benchmark estimates of natural resources shares of output in which cropland rents are computed using US prices as a proxy for international prices (see our Section 3) with the new estimated WB data in which cropland rents use producer prices instead of export unit values. By large, both natural resources shares are very similar, see panel (A) in Figure A-1, which scatters plots these shares for our benchmark (US prices) against the new WB benchmark (producer prices). The implied global gains of physical capital reallocation are also very similar across both pricing schemes. Our benchmark output gains are slightly above those from the gains obtained using producer prices (see panel (B) in Figure A-1).

# B Additional Comparison with Caselli and Feyrer (2007)

Here we investigate further differences between our methodology based on *rent flows* and that of CF based on *natural stocks*. Not surprisingly, the differences in the estimated output shares of natural resources discussed in Section 3.1 translate into large differences in the implied $MPK_{j,t}$. As depicted in Figure B-1, the differential of $MPK$s computed with *rent flows* with respect to those proxied with *natural stocks* (i.e.,as in CF) 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). Figure B-1 also shows that our implied measures of $MPK$ are 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 that ignores the correction for natural resources.

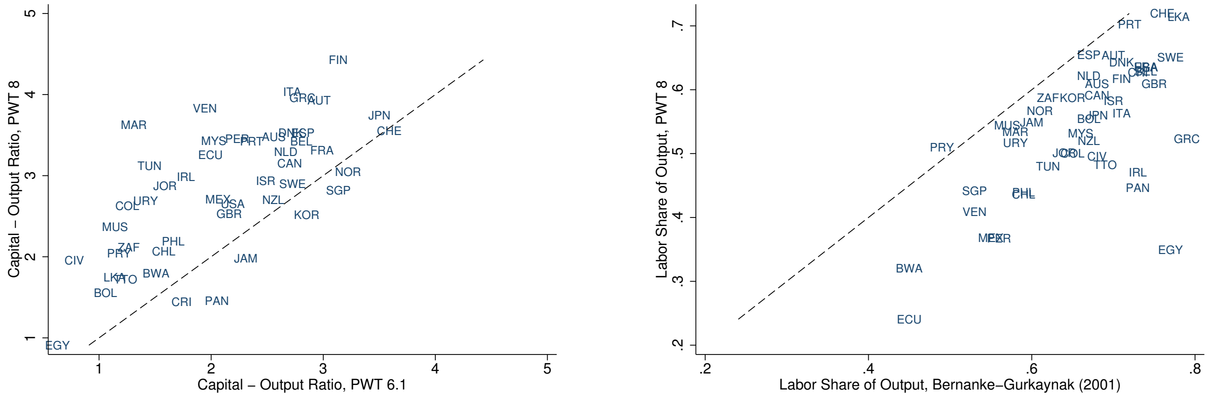
There are other potential reasons for the difference between our $MPKs$ and those obtained by CF. These are the data sources for physical capital, output, and labor shares. While we use PWT 8.0, CF use data on physical capital and output from PWT 6.1 and on labor shares from Bernanke and Gurkaynak (2001). Figure B-2 shows there are differences between those sources. The most obvious patterns are (i) the $K/Y$ ratios are higher in PWT

Figure B-1: Marginal Product of Physical Capital: MSS versus CF




8.0 than in PWT 6.1 and (ii) the labor shares are larger in PWT 8.0 than in Bernanke and Gurkaynak (2001). While each of these items has implications for the size of global misallocation, the main discrepancy between the global gains attained in CF and those we find in our benchmark scenario are in its major part driven by the differences in the measurement of the output share of natural resources, as we discuss in Section 5.5.

Figure B-2: Differences in$K/Y$ and $\theta$

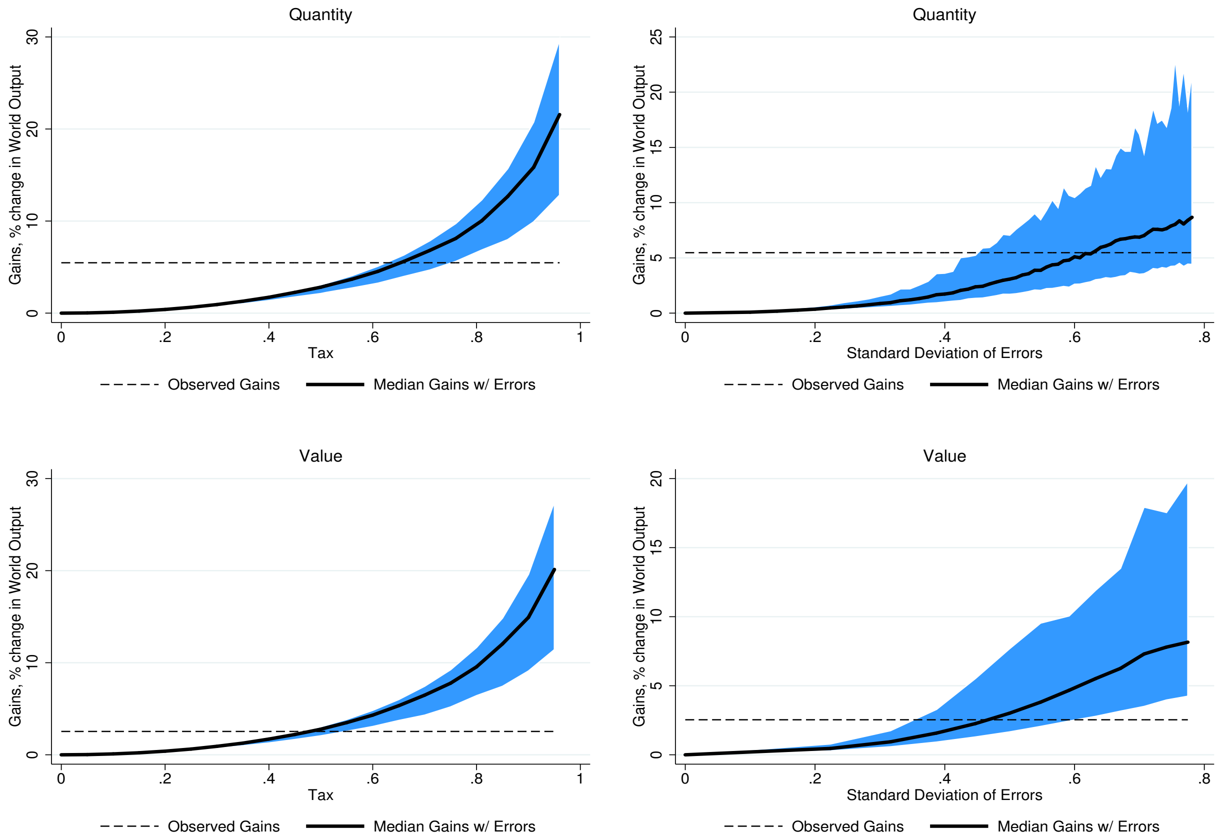



# C Misallocation versus Measurement Error

In this section, we explore the potential role of measurement errors in driving our results. We consider the hypothesis that the world is fully efficient and that our measured misallocation is driven entirely by measurement error. Since measurement error seems a more daunting possibility at the beginning of the sample, here we assume that each country has the efficient allocation of capital in 1970, $K^*$, but we actually observe a noise measure $K = (1+\epsilon)K^*$, where $\epsilon$ is a country-specific measurement error. We explore the results for two different forms of $\epsilon$ : (a) an i.i.d normally distributed measurement error term $\epsilon \sim N(0, \sigma)$. Alternatively, (b) we consider the case of a tax/subsidy rate that with probability $\frac{1}{2}$ is positive (tax) and with probability $\frac{1}{2}$ is a subsidy. This second representation follows Restuccia and Rogerson (2008). We generate the stocks of capital for each country as $K = (1+\epsilon)K^*$ and then compute the gains in terms of global output of reallocating capital.

Figure C-1 show the results. The dashed line represents the gains obtained in our benchmark reallocation exercise, which are above 5%. The x-axis represents the size of the standard deviation of $\epsilon$ in the first exercise, and the size of the $\epsilon$ (the tax) in the second case. The black line represents the median size of the gains for the different values on the x-axis (the blue area represents the standard errors bands). When the black line crosses the dashed line, that is the value on the x- axis that would generate gains as in our benchmark exercise. The results show that to account for the gains obtained in 1970, measurement error would have to be very large, between 50 and 60 percent of the capital stock.

Figure C-1: Measurement Errors




# D Multilateral versus Unilateral Counterfactuals

In this section, we show that, for all but the largest countries, the counterfactual output gains of removing barriers unilaterally would be very similar to that in our benchmark, multilateral counterfactuals. Interestingly, this is different than trade and FDI liberalization exercises, more commonly found in the literature.

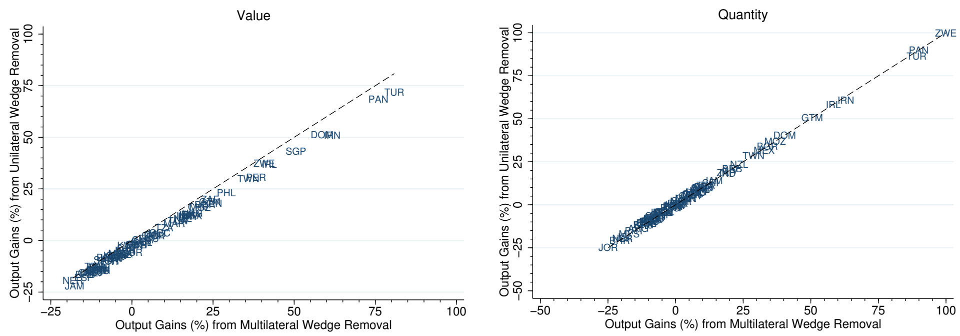
For a given year, by removing the barriers to the allocation of capital capital we obtain an efficient marginal product of capital, $MPK_t^*$. Given this efficient return to capital, we can construct country-specific wedges as:

$$\Delta_{j,t} = \frac{MPK_{j,t}^o}{MPK_t^*},$$

where $MPK_{j,t}^o$ is the observed MPK.

The graphs below show the gains in output from this counterfactual exercise in which we remove one wedge at a time as compared to our benchmark results, in which all wedges removed at the same time. Strikingly, the gains for most of countries are of similar magnitude in both exercises.

Figure D-1: Unilateral versus Multilateral Gains




# E External Flows and Counterfactual Allocations

Here we explain the construction of the counterfactual series of physical capital based on external net flows of physical capital. Data on net exports are from the International Monetary Fund International Financial Statistics (IFS). We exclude 7 countries (Belgium, Greece, Hong Kong, Luxembourg, Qatar, Taiwan, and Zimbabwe) from our sample because of data limitations. The sum of net exports across countries in our sample does not add up to zero; this is not surprising as we include only a subset of global capital flows. We address this issue 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 $\lambda_t$ 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 the quantity marginal product of physical capital using the adjusted flows are similar to those shown in Figure 9,

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