

Natural Resources and Global Misallocation[†]

By ALEXANDER MONGE-NARANJO, JUAN M. SÁNCHEZ,
AND RAÜL SANTAULÀLIA-LLOPIS*

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 E22, E23, O13, Q21, Q31, Q32)

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, Monge-Naranjo, and Primiceri 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

*Monge-Naranjo: Federal Reserve Bank of St. Louis, One Federal Reserve Bank Plaza Broadway and Locust Street, St. Louis, MO 63102, and Washington University in St. Louis (email: Alexander.MongeNaranjo@stls.frb.org); Sánchez: Federal Reserve Bank of St. Louis, One Federal Reserve Bank Plaza Broadway and Locust Street, St. Louis, MO 63102, and Washington University in St. Louis (email: juan.m.sanchez78@gmail.com). Santaulàlia-Llopis: MOVE-UAB and Barcelona GSE, Plaça Cívica s/n, Bellaterra, Barcelona 08193, Spain (email: rauls@movebarcelona.eu). Virgiliu Midrigan was coeditor for this article. Santaulàlia-Llopis thanks the ERC AdG-GA324048 Asset Prices and Macro Policy when Agents Learn (APMPAL) and the Spanish Ministry of Economy and Competitiveness through the Severo Ochoa Programme for Centers of Excellence in R&D (SEV-2015-0563) for financial support. 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 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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¹See Caselli (2005), Klenow and Rodríguez-Clare (1997), and references therein.

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—henceforth, 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, $\phi_{j,t}^R$, 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 (World bank). To extend the estimates for the years from 1970 to 2005, we apply the same methodology used by the World bank 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 percent 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 percent. 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 percent, while it is only 0.58 percent 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 (PWT 8.0) to compute capital shares of income, $\phi_{j,t}^K = 1 - \phi_{j,t}^R - \theta_{j,t}$, 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 apply 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, $P_{j,t}^Y/P_{j,t}^K$, 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 $QMPK_{j,t} = \phi_{j,t}^K Y_{j,t} / K_{j,t}$ and $VMPK_{j,t} = QMPK_{j,t} P_{j,t}^Y / P_{j,t}^K$, 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 of 1970–2005. It is particularly noteworthy that the global upward trend in the capital income shares, $\phi_{j,t}^K$, 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 percent of global output in the early 1970s to a rather stable level around 2 percent 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 percent 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 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 percent, the average country would lose between 1 percent and 2 percent of real income. For foreign

²This 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).

³This is consistent with the global labor share decline documented in Karabarbounis and Neiman (2014) and Aum, Koh, and Santaulàlia-Llopis (2018).

⁴Specifically, our *MPKs* are strongly related to the observable policies (see Section IIB). 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 C).

direct investment (FDI), Burstein and Monge-Naranjo (2009) obtain global gains of 1.1 percent 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, Monge-Naranjo, and Primiceri 2011). Specifically, we show that according to an extended Sachs and Warner (1995) indicator, the countries with more interventionist policies (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, Restrepo-Echavarria, and Wright (2018), 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 consider human and physical capital. As shown in our sequel work Monge-Naranjo, Sánchez, and Santaaulàlia-Llopis (2018), the complementarity between physical and human capital would lead these two factors toward 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 United States and Puerto Rico and the European Community on one side with NAFTA on the other).

The paper is organized as follows. The next section presents our organizing model framework. Section II describes our measurement of rents for natural resources comparing our methodology to that of CF. Section III describes the behavior of *MPKs*

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

across countries and policy regimes over time. Sections IV and V examine the global allocation of physical capital. Section VI shows that domestic accumulation and not internal flows account for the observed trends. The conclusion follows. The appendices contain numerous extensions, comparisons, and additional details.

I. 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.

A. Efficiency Benchmarks

Consider a world economy populated by an arbitrary number J of countries, indexed by $j = 1, 2, \dots, J$. Given our data, we index the (yearly) time periods by $t = 1970, 1971, \dots, 2005$. 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

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

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 λ_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

$$(2) \quad \max_{\{C_j, K_{j,t}\}} \sum_{j=1}^J \lambda_j u(C_{j,t})$$

subject to

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

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

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 toward maximizing total world output. Denote by π_t^C the Lagrange multiplier associated to the adding-up constraint on consumption and π_t^K the multiplier associated with the adding up constraint of world capital. For the efficient allocation, π_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

$$\pi_t^C = \lambda_j u'_j(C_{j,t}).$$

Similarly, π_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 ,

$$(5) \quad QMPK_{j,t} = \frac{\partial F_{j,t}}{\partial K_{j,t}} = \frac{\partial F_{i,t}}{\partial K_{i,t}} = QMPK_{i,t}.$$

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 equation (2) subject to

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

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

Instead of just restricting global consumption to not exceed total world output, with non-tradability 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 $\pi_{j,t}^C$ is the shadow price of consumption in country j , which now should be allocated according to

$$\pi_{j,t}^C = \lambda_j u'(C_{j,t}).$$

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

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

In principle, the efficient allocation of capital can be quite different because it is now closely linked to the valuation of consumption $\pi_{j,t}^C$ and the differential cost of investment $\pi_{j,t}^K$ 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 ,

$$(8) \quad VMPK_{j,t} = \frac{\pi_{j,t}^C}{\pi_{j,t}^K} \frac{\partial F_{j,t}}{\partial K_{j,t}} = \frac{\pi_{i,t}^C}{\pi_{i,t}^K} \frac{\partial F_{i,t}}{\partial K_{i,t}} = VMPK_{i,t}.$$

In sum, different assumptions about the tradability 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.

B. Distortions versus 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 distinguish 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

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

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 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 countries 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

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

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

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

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 $VMPKs$ as distortions in the allocation of capital. As we show in Section IIIB, 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 $P_{j,t}^K/P_{j,t}^Y$.

II. 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.

A. 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. 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* that we also describe.

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 World Bank's project *Where is the Wealth of Nations?* (World Bank 2006) and its sequel, *The Changing Wealth of Nations* (World 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.

⁶The World Bank includes non-timber forest resources and protected areas in the calculation of the estimated countries' stock of natural wealth (World Bank 2006, 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.

For each different natural resource, the World Bank provides direct estimates of the rate of return using a set of benchmark countries. With these benchmark estimates the World Bank extrapolates the rents for each natural resource for an extended sample of countries.⁷ We further extend the sample of countries using data from the United Nations' FAOSTAT database.⁸ Our estimates cover all years from 1970 to 2005. The final objective of the World Bank's project is to estimate the *stocks of wealth* of countries. In our calculations *we only use their rent flow estimates*, and not their wealth stocks estimates. Indeed, as we show extensively in Appendix B, factor share 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 World Bank estimates. Second, the rents for (b) timber were also taken directly from the World Bank.⁹

Third, we construct our own estimates for the rents for items (c) and (d), crop and pasture lands, respectively. For croplands (which includes apples, bananas, coffee, grapes, maize, oranges, rice, soybeans, wheat, and many others), we follow the World Bank's (2006) methodology: For each crop, the World Bank estimates the average rate of return to the land for a set of countries that are major producers of that crop. The 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 US 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** percent of the total value of output from FAOSTAT accrues as rents to land.¹¹ Last, we follow the World Bank

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/>.

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 the 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 percent for soybeans (from China, Brazil, Argentina), 8 percent for coffee (from Nicaragua, Peru, Vietnam, Costa Rica), 42 percent 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 World Bank used export unit values to value agricultural output. **While export values might be poor predictors of output value when the country's markets are not well connected to the world market, 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 World Bank 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 Appendix A. We find very similar quantitative results.

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

(2006) and Caselli and Feyrer (2007) and estimate that the rents of (e) *urban land* are equal to 24 percent 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

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:

$$NRR_{j,t} = \sum_q rents_{q,j,t},$$

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

$$(12) \quad \phi_{j,t}^R \equiv \frac{NRR_{j,t}}{Y_{j,t}},$$

where $Y_{j,t}$ is the country's GDP. To compute $\phi_{j,t}^R$, and for all other purposes, we use the variable *cgdpo* production-side real GDP at current PPPs (in millions of 2005 US dollars) from the PWT 8.0.¹³ Our benchmark final sample consists of 79 countries (see Appendix AA1) with consistently 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 $\phi_{j,t}^R$ 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

¹² The value of the share of urban land, 24 percent, 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 percent, 12 percent, 24 percent (our benchmark), and 36 percent. Quantitatively, we find that reducing the amount of rents accrued to urban land would increase the implied degree of misallocation and would imply a steeper trend toward efficiency between 1970 and mid-1980s. Our assessment is that the rent of 24 percent 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 percent, 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.

¹⁴ Section IVC presents a further analysis for a larger sample of countries with consistent data for 2005.

TABLE 1—OUTPUT SHARE OF NATURAL RESOURCES (PERCENT, 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
Observations	79	79	79	79

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

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 for an average of 5.44 percent of output, with oil and natural gas the major components, representing 4.03 percent and 1.21 percent of output, respectively. The second major component of natural resources is cropland with a share of output of 2.26 percent. Pasture land rents and rents from timber forest account for lower shares, respectively, 0.36 percent and 0.13 percent 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 percent (i.e., close to 3 percent of its mean value), while the median share of cropland rents drops to 1.06 percent (i.e., about 53 percent 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 percent on average, with subsoil rents being 1.25 percent 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. Panel A singles out the oil-exporting countries (marked in red), which we define as those with subsoil shares of output above 10 percent.¹⁶ Oil-exporting countries have much higher $\phi_{j,t}^R$, averaging 36.80 percent, versus 4.51 percent of their non-oil-exporting

¹⁵ We find similar patterns with a larger sample of 122 countries for which $\phi_{j,t}^R$ 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.

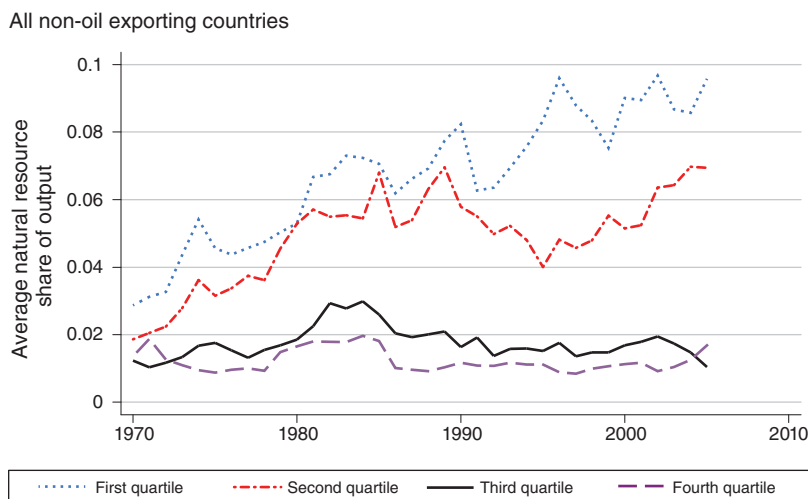


FIGURE 2. AVERAGE OUTPUT SHARE OF NATURAL RESOURCES: BY INCOME QUANTILES (NON-OIL-EXPORTING COUNTRIES)

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

developing countries (third quartile), the output share of natural resources is low and relatively constant, around 1 percent over the sample years. However, the share is significantly higher for the other half of the countries in the sample (quartiles one and two). This is particularly stronger by the end of the sample, when natural resources consistently accounted for more than 8 percent of the income of the countries in the poorest quartile.

A Methodology Based on Natural Stocks (Caselli and Feyrer 2007).—In their seminal paper, Caselli and Feyrer (2007—henceforth, CF), use the World Bank'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 $q \in \{a, b, c, d\}$ (detailed in Section II), the World Bank computes natural stocks, $N_{q,j,1995}$, for each country j , in their sample. The World Bank obtains these estimates by multiplying their data on the flow of rents $rents_{q,j,1995}$ by a present value term $PVF_{j,q}$:

$$N_{q,j,1995} = rents_{q,j,1995} \times PVF_{j,q},$$

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

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

TABLE 2—WORLD BANK’S PRESENT VALUE FACTORS, $PVF_{j,q}$

Resources	Developed countries			Developing countries		
	$G_{j,q} - 1$ (percent)	$T_{j,q}$	$PVF_{j,q}$	$G_{j,q} - 1$ (percent)	$T_{j,q}$	$PVF_{j,q}$
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

where r^* is the discount rate, $G_{j,q}$ is the growth rate in the rent flows, and $T_{j,q}$ is the terminal or exhaustion date of the resource. Unfortunately, the World Bank does not have direct measures of r^* , $G_{j,q}$, and $T_{j,q}$. Thus, computing the stocks requires making additional assumptions. The World Bank assumes that the discount rate r^* is the same across all countries, 4 percent. More importantly, they assume that the growth rate in the rent flows, $G_{j,q}$, and the terminal or exhaustion date of the resource $T_{j,q}$ 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 ($G_{developing,q} > G_{developed,q}$) and exhaust later ($T_{developing,q} > T_{developed,q}$) than for developed countries. Table 2 shows the implied values for $PVF_{j,q}$ for a range of values of $G_{j,q}$ and $T_{j,q}$ assumed by the World Bank.

Table 2 shows two important aspects of 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 resources rents are the same proportion of GDP.

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

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

The World Bank 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 to impute the fraction of non-labor income that should accrue to natural resource owners. In particular, if $r_{j,1995}^K$ and $r_{j,1995}^N$ 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

$$\phi_{j,1995}^R = \frac{r_{j,1995}^N N_{j,1995}}{r_{j,1995}^N N_{j,1995} + r_{j,1995}^K K_{j,1995}} \times [1 - labor\ share_{j,1995}].$$

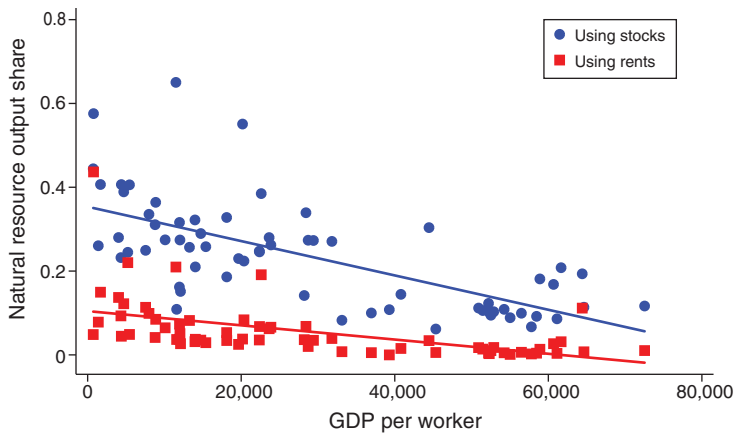


FIGURE 3. ESTIMATES OF OUTPUT SHARES OF NATURAL RESOURCES: MSS VERSUS CF

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 IIA.

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

However, the required cross-country data for $r_{j,1995}^K$ and $r_{j,1995}^N$ are simply not available. This gives rise to the second key assumption in CF's method: $r_{j,1995}^N = r_{j,1995}^K$ 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

$$(13) \quad \phi_{j,1995}^R = \frac{N_{j,1995}}{N_{j,1995} + K_{j,1995}} \times [1 - \text{labor share}_{j,1995}].$$

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.

Estimates of the Output Shares of Natural Resources $\phi_{j,t}^R$: MSS versus CF.— In Figure 3 we compare our measure $\phi_{j,t}^R$ 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 percent. The average using the measurement of CF is much higher, above 30 percent. 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 $\phi_{j,t}^R$ and those by the CF's methodology using natural capital stocks is around 15 percent 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 $\phi_{j,t}^R$ is better? We argue that our direct measure based on *rent flows* proposed in Section IIA 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 $\phi_{j,t}^R$ for poor countries will be biased upward compared with the estimates for rich countries in the CF's methodology. This artificial discrepancy in $\phi_{j,t}^R$ 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*.

B. 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

In the PWT, as explained in Feenstra, Inklaar, and Timmer (2015), the raw labor share, defined as the ratio of unambiguous compensation of employees (WN) to GDP, $\theta_{j,t} = \text{WN}/\text{GDP}$, 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

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

²¹ The PWT considers four different adjustments: (i) Add AMB to unambiguous labor compensation, resulting in $\theta_{j,t} = (\text{WN} + \text{AMB})/\text{GDP}$; (ii) Assume the labor share, $\theta_{j,t}$, is identical to the labor share of unambiguous output, $\theta_{j,t} = \text{WN}/(\text{GDP} - \text{AMB})$; (iii) If proxies for the number of employees (N) and self-employed (SE) are

discuss below, the resulting values for $\theta_{j,t}$ from the PWT 8.0 are lower than 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. In Section IV, we show that our choice of labor share is not the main driver of our results.

For the output share of physical capital, denoted here by $\phi_{j,t}^K$, 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

$$(14) \quad \phi_{j,t}^K = 1 - \theta_{j,t} - \phi_{j,t}^R.$$

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

III. 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 II, along with PWT 8.0 measures of output, physical capital measures, and the prices of output and capital goods.²²

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).²³ The number of workers in each country and year, $L_{j,t}$, is measured with the variable *emp* in PWT 8.0 for our measure of aggregate labor—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, $P_{j,t}^Y$, 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, $P_{j,t}^K$, 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, $P_{j,t}^C$, we

available, then assuming the same average wage for both leads to a labor share is $\theta_{j,t} = (WN/GDP) \times (N + SE)/N$; (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 Available online at <http://www.rug.nl/research/ggdc/data/penn-world-table>; see also Appendix.

²³ 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, Inklaar, and Timmer (2015), including a comparison with previous PWT datasets.

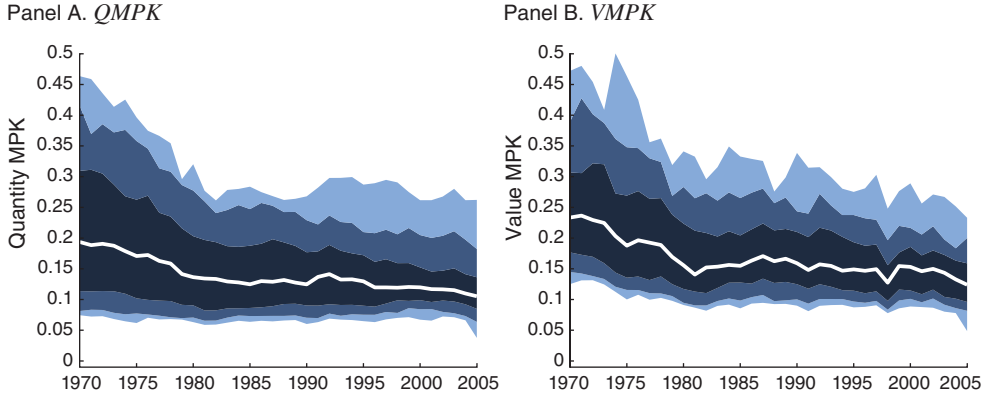


FIGURE 4. GLOBAL EVOLUTION OF MPKs

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 (twenty-fifth–seventy-fifth percentile) range, the tenth–ninetieth percentile range, and the fifth–ninety-fifth percentile range.

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

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.

A. Across Space and Across Time

The panels in Figure 4 present the distribution, across countries, of the quantity and value MPK s 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 MPK s has steadily decreased over the sample period. Third, the most dramatic declines in the median and dispersion of MPK s 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 MPK s, 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:

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

TABLE 3—DECOMPOSITION OF THE DISPERSION OF *QMPK* AND *VMPK*

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

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

and

$$\text{var}[\ln VMPK_{j,t}] = \text{var}[\ln QMPK_{j,t}] + \text{var}\left[\ln \frac{P_{j,t}^Y}{P_{j,t}^K}\right] + 2 \text{cov}\left[\ln QMPK_{j,t}, \ln \frac{P_{j,t}^Y}{P_{j,t}^K}\right].$$

The top panel of Table 3 shows the variances of the different objects, and the bottom panel shows 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 $\log \phi_{j,t}^K$ and $\log Y_{j,t}/K_{j,t}$. With respect to the former, the contribution of $\text{var}[\ln(Y_{j,t}/K_{j,t})]$ to the variance of $\log QMPK_{j,t}$ increases from 61 percent in 1970 to 82 percent in 2000. With respect to the covariance of $\ln \phi_{j,t}^K$ and $\ln(Y_{j,t}/K_{j,t})$, we find that it changes sign between 1970 and 2000. Therefore, from a world in the 1970s where countries with a more capital intensive technology (i.e., high $\phi_{j,t}^K$) 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 percent. 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 $\phi_{j,t}^K$ has a positive but mildly declining contribution on the variance of $\log QMPK_{j,t}$. Its contribution lies in a range between 20 percent and 33 percent. 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, $P_{j,t}^Y/P_{j,t}^K$, 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, $\text{var}[\ln QMPK_{j,t}]$ is almost 2.5 times the value $\text{var}[\ln VMPK_{j,t}]$, 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 $\ln P_{j,t}^Y/P_{j,t}^K$ 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 $\ln P_{j,t}^Y/P_{j,t}^K$). 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 $2 \text{cov}[\ln QMPK, \ln P_{j,t}^Y/P_{j,t}^K] / \text{var}[\ln VMPK]$ is often 100 percent), this covariance is far from enough to offset the joint dispersion of prices $\ln P_{j,t}^Y/P_{j,t}^K$ 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 MPK s, 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 1970s, there are still significant and persistent distortions in the allocation of capital.

B. 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—henceforth, SW) openness $\{0, 1\}$ indicator. Specifically, SW require the following five criteria to classify a country as “open”: (i) The average tariff rate on imports is below 40 percent; (ii) Non-tariff barriers cover less than 40 percent 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 percent. 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, Monge-Naranjo, and Primiceri (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 United States 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 into five-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.²⁴ Finally, we would

²⁴ 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: FIVE-YEAR AVERAGES (1970–2000)

Year	$QMPK_{j,t}$			$VMPK_{j,t}$			Observations	
	Open	Closed	<i>t</i> -stat	Open	Closed	<i>t</i> -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: FIVE-YEAR AVERAGES (1970–2000)

	Year	Open	Closed	<i>t</i> -stat
$\phi_{j,t}^K$	1970–1975	0.308	0.342	4.11
	1976–1980	0.303	0.334	3.40
	1981–1985	0.302	0.318	1.83
	1986–1990	0.322	0.318	−0.47
	1991–1995	0.331	0.324	−0.59
	1996–2000	0.333	0.335	0.17
$\frac{Y_{j,t}}{K_{j,t}}$	1970–1975	0.484	0.699	7.84
	1976–1980	0.420	0.609	7.84
	1981–1985	0.383	0.559	6.42
	1986–1990	0.421	0.562	4.92
	1991–1995	0.420	0.609	5.06
	1996–2000	0.407	0.766	5.80
$\frac{P_{j,t}^Y}{P_{j,t}^K}$	1970–1975	1.484	1.236	−5.41
	1976–1980	1.401	1.139	−8.27
	1981–1985	1.409	1.102	−8.92
	1986–1990	1.399	1.084	−8.91
	1991–1995	1.272	1.064	−3.92
	1996–2000	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, Monge-Naranjo, and Primiceri 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, $\phi_{j,t}^K$, the average output-to-capital ratio, $Y_{j,t}/K_{j,t}$, and the average output-to-capital price ratio, $P_{j,t}^Y/P_{j,t}^K$, 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, Ravikumar, and Sposi 2014). Interestingly, the capital intensity differences, $\phi_{j,t}^K$, 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.

IV. Assessing Global Misallocation

In this section, we present the global output gains from efficient physical capital reallocation in Section IVA. We study how global misallocation moves with market-oriented policies in Section IVB. We analyze the gains of capital reallocation for an extended sample in Section IVC. Then, we explore winners and losers from efficient reallocation in Section IVD. Finally, we discuss differences in the degree of global misallocation across methodologies to estimate the output share of natural resources in Section IVE.

A. 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.

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:

$$(15) \quad Y_{W,t}^{K^*} = \max_{\{K_{j,t}\}} \sum_{j=1}^J Z_{j,t} (K_{j,t})^{\gamma_{j,t}(1-\theta_{j,t})} (H_{j,t})^{\theta_{j,t}},$$

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

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

Here, $K_{W,t} \equiv \sum_{j=1}^J K_{j,t}^O$, where $K_{j,t}^O$ 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,

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

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, $\gamma_{j,t}(1 - \theta_{j,t})$, 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.²⁵ Although there is not a 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 $\ln[Y_{W,t}^{K*}/Y_{W,t}^O]$ —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 $\{P_{j,t}^Y, P_{j,t}^K\}$ 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 $(P_{j,t}^K/P_{j,t}^Y) K_{j,t}^O$. 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.,

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

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

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

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

²⁵ In more detail, if factor shares are identical across countries, then the maximized output is equal to

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

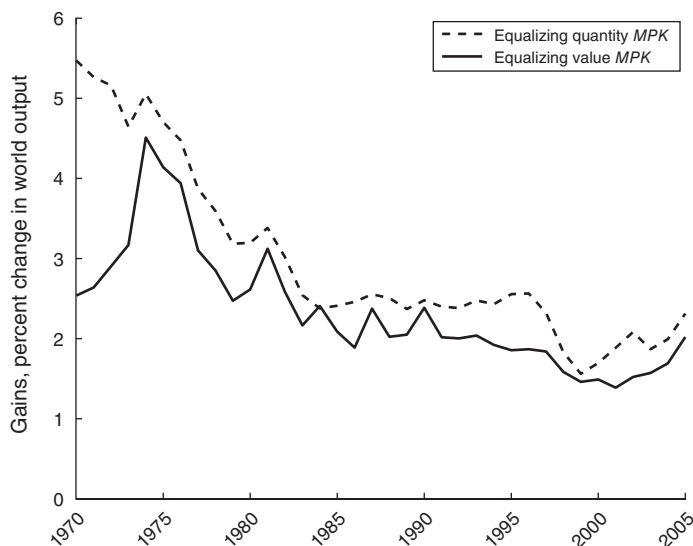


FIGURE 5. GLOBAL OUTPUT GAINS OF PHYSICAL CAPITAL REALLOCATION

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 II. 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 I and the actual global output.

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 a country, $P_{j,t}^Y/P_{j,t}^K$, the more (less) physical capital should be allocated to it.²⁶

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 the 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 6.²⁷

²⁶ Under the assumption of identical factor shares across countries, $Y_{W,t}^{K^*}$ is given by

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

²⁷ 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 online Appendix

TABLE 6—GLOBAL OUTPUT GAINS OF PHYSICAL CAPITAL REALLOCATION: BOOTSTRAP ESTIMATES

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

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.²⁸ In addition, for any particular year, quantity and value gains are highly correlated at the country level.²⁹ 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).

B. Global Policy Movements and Misallocation

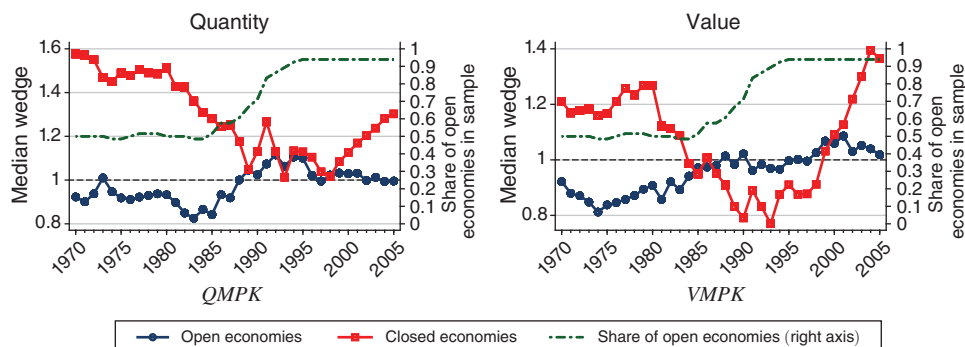
Figure 6 shows the fraction of open countries—that is, those with market-oriented policy regimes (right scale) and the median of the implied wedges for physical capital (left scale) in market-oriented countries (blue) and heavily interventionist countries (red). These wedges were computed as follows. 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: $\Delta_{j,t} = MPK_{j,t}^O / MPK_t^*$, 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.

Table 8, moving from the sample of CF sample, which does not include China and India, to our benchmark sample, which includes China and India, only changes the estimated global losses from 2.32 percent to 2.51 percent. 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 does their exclusion change the main conclusions about the movement toward efficiency, with the persistence of a significant amount of misallocation.

²⁸ 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.

²⁹ 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.

Panel A. Wedges and number of market-oriented and interventionist countries



Panel B. Counterfactual gains in a market-oriented world

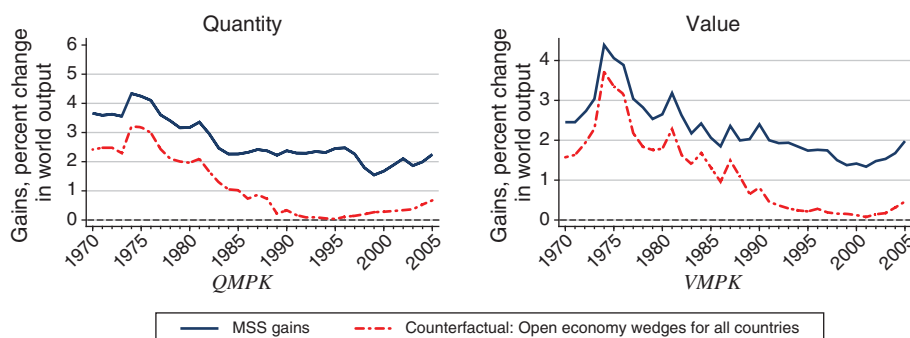


FIGURE 6. MARKET-ORIENTED POLICY AND GLOBAL MISALLOCATION

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 percent of the countries in our sample during the 1970s, and the fraction of market-oriented countries reached 92.5 percent by the end of the sample. The most dramatic increment in the share of market-oriented countries takes 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.³⁰ Three main conclusions arise. First, 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.

C. 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 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 percent of output in 2005, while these gains are 3.56 percent for the extended sample. In value terms the gains of equalizing *MPKs* is 2.02 percent for the benchmark sample and 3.78 percent for the extended sample in 2005.

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).

D. 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 tenth to the ninetieth percentile range, and the lightest region the fifth to the ninety-fifth percentile range. The distribution of gains is asymmetric: the percentiles fifth, tenth, and twenty-fifth are relatively close to the median and percentile seventy-fifth, ninetieth, and ninety-fifth are further away. For instance, in 1970, the median quantity gains are around 20 percent, the fifth percentile of gains is around minus 20 percent, and the ninety-fifth percentile of gains is more than

³⁰ Note that the gains in Figure 6 are slightly different from those in Figure 5 because our sample of countries is reduced to 67 countries with information on the SW variable.

TABLE 7—COMPARING GAINS (PERCENT) IN OUTPUT IN 2005

	Quantity		Value	
	Benchmark	Extended sample	Benchmark	Extended sample
Equalizing <i>MPK</i>	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.

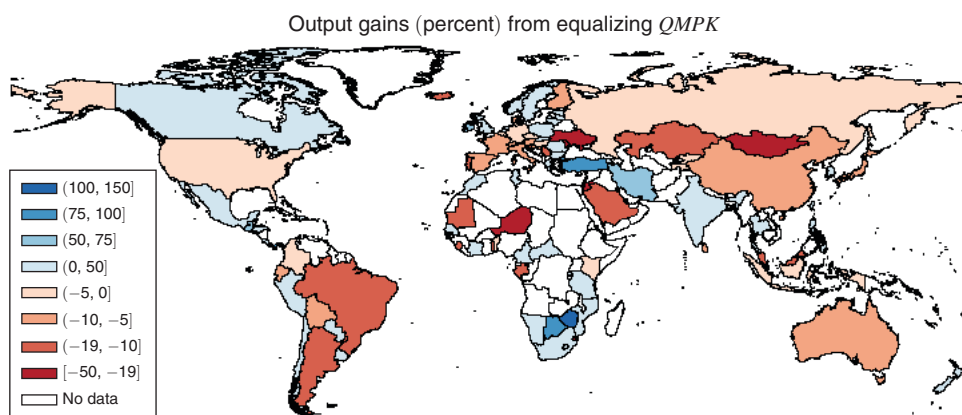


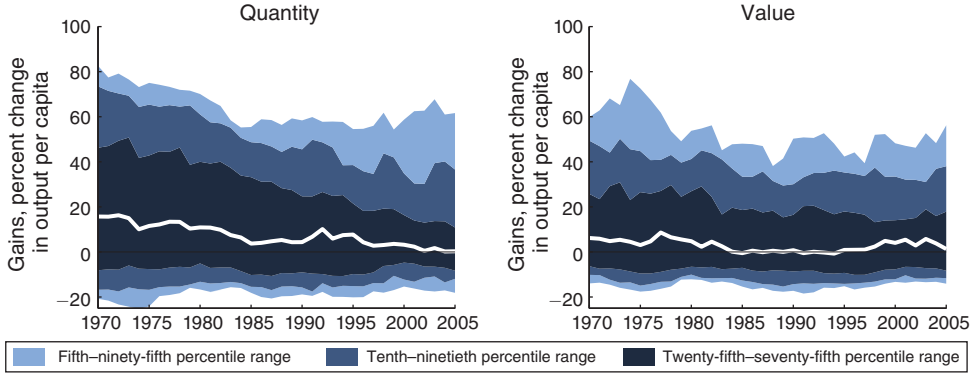
FIGURE 7. WINNERS AND LOSERS OF REALLOCATION WITH THE EXTENDED SAMPLE

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

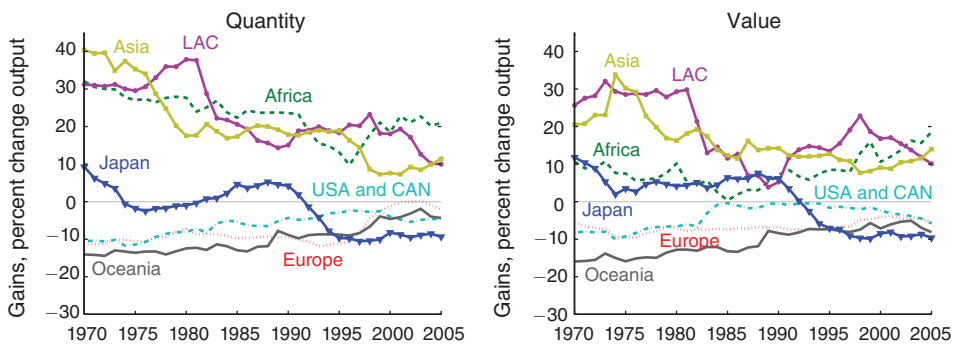
80 percent. The median quantity gains decrease from about 20 percent in 1970 to around 0 in 2005. The pattern for value gains is similar, but the median gains increase again at the end of the 1990s.

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, Restrepo-Echavarria, and Wright (2018); 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.

Panel A. Winners and losers: Distribution of output gains of physical capital reallocation



Panel B. Regional gains of physical capital reallocation



Panel C. Gains of physical capital reallocation across income quartiles

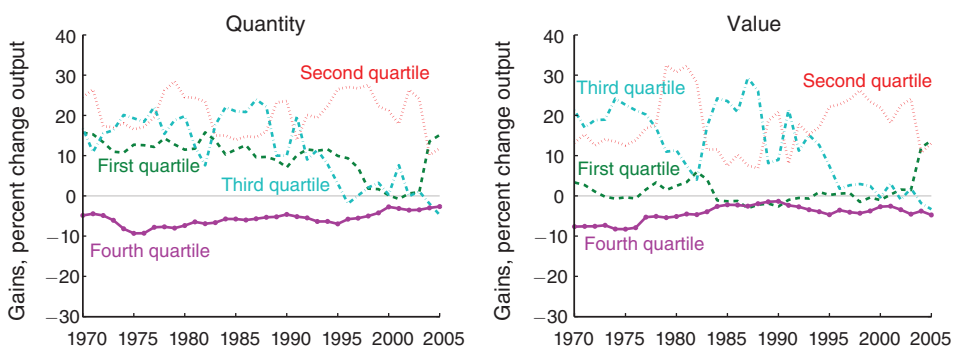


FIGURE 8. DISTRIBUTIONAL PATTERNS OF GLOBAL OUTPUT GAINS

Notes: Results of equalizing *QMPK* (left panels) and *VMPK* (right panels) across countries, 1975–2005. In 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 (twenty-fifth–seventy-fifth percentile) range, the tenth–ninetieth percentile range, and the fifth–ninety-fifth percentile range. For a list of countries in each region in panel B, see Appendix A.

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

As for developed countries, we find that overall, regardless of using the quantity or value counterfactuals, developed countries (the United States, 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 (first quartile composed by the poorest countries; fourth 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 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.

E. 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 IIA) and the environment proposed by CF where output share estimates are based on *natural capital stocks* (Section IIA).

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.^{31,32} 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 II. 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

³¹ The sample is restricted to 1996—i.e., that is, up to the year for which CF data (PWT 6.1) are available.

³² 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.

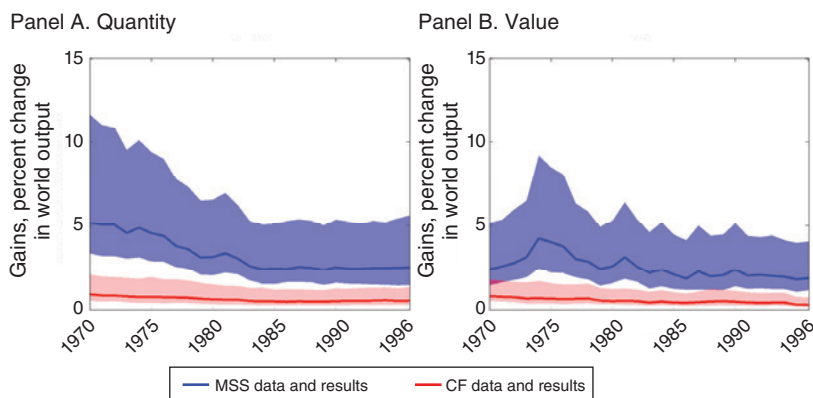


FIGURE 9. GLOBAL OUTPUT GAINS OF PHYSICAL CAPITAL REALLOCATION: MSS VERSUS CF

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 II. The global output gains are defined as the ratio between the efficient global output implied by the quantity and value models posed in Section I and the actual global output. Panel A refers to the *QMPK* model and panel B to the *VMPK* model. In both environments, CF and MSS, we report the median global gains and their associated tenth and ninetieth 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.

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 datasets, which we label as the CF sample.³³ 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 1 percent, and the MSS capital and output data barely change these gains to 0.98 percent. Note

³³ 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 ϕ^R for Burundi, while CF does. However, we find that the presence of these four countries makes no quantitative difference for the CF results.

TABLE 8—COMPARING ALTERNATIVE DATA SOURCES AND SAMPLES: MSS VERSUS CF (1996)

Sample	Data Source			Gains [CI]	Sample Size
	$\phi_{j,t}^R$	(K, Y)	θ		
CF	CF	CF	CF	0.52% [0.29, 0.95]	47
	CF	CF	MSS	1.01% [0.48, 2.05]	47
	CF	MSS	MSS	0.98% [0.51, 1.87]	47
	MSS	MSS	MSS	2.32% [0.90, 5.31]	47
MSS, benchmark	MSS	MSS	MSS	2.51% [1.45, 4.17]	76
MSS, extended	MSS	MSS	MSS	3.35% [1.63, 6.45]	107

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

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, ϕ^R , based on *natural rents* (Section IIA) as opposed to the corresponding shares based on *natural stocks* in the original CF benchmark (Section IIA). 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 ϕ^R . Precisely $1 - (0.98 - 0.52)/(2.32 - 0.52) = 74.4$ percent 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 IIA) 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.³⁴ Finally, in the fifth and sixth rows, we 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

³⁴ In Appendix B, we show how the differences in the estimated output shares of natural resources discussed in Section IIA translate into large differences in the implied *MPKs* between the MSS and CF environments.

gains to 3.51 percent and also increases the significance in the differential global gains between MSS and CF.³⁵

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.

V. Examining the Reallocation of Capital, 1970–2005

A main finding in Section IV 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.

A. 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

³⁵ 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 2 years: 2.51 percent in 1996 and 2.29 percent in 2005.

TABLE 9—POPULATION-WEIGHTED OLS REGRESSION, $\Delta \ln K$ (1970–2005)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln Z$	0.425 (0.095)	0.750 (0.164)	0.358 (0.094)	0.504 (0.092)	0.817 (0.157)	0.428 (0.104)
$\Delta \ln H$	−0.024 (0.144)	−0.034 (0.224)	0.074 (0.181)	0.185 (0.126)	0.300 (0.253)	0.371 (0.203)
$\Delta \ln \phi^K$	1.270 (0.269)	1.631 (0.458)	—	1.348 (0.266)	1.597 (0.442)	—
$\Delta \ln \frac{P_Y}{P_K}$	1.687 (0.124)	—	—	1.665 (0.110)	—	—
$VMPK_{1970}$	2.188 (0.804)	—	—	2.055 (0.786)	—	—
$QMPK_{1970}$	—	6.729 (1.081)	—	—	6.340 (1.124)	—
$\left(\frac{Y}{K}\right)_{1970}$	—	—	2.610 (0.438)	—	—	2.400 (0.457)
Includes OECD	Yes	Yes	Yes	No	No	No
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.

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

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 ($\Delta \ln Z$),³⁶ 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 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

³⁶ Recall the definition $Z_{j,t} \equiv A_{j,t} T^{\phi_{j,t}^R}$. Here, using our values of $\theta_{j,t}$ and $\phi_{j,t}^K = 1 - \theta_{j,t} - \phi_{j,t}^R$, we impute the value of these TFP -like terms as $Z_{j,t} \equiv A_{j,t} T^{\phi_{j,t}^R} = Y_{j,t} / [K_{j,t}^{\phi_{j,t}^K} H_{j,t}^{\theta_{j,t}}]$.

account for almost 90 percent 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-à-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.

B. 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, $\mu_{j,1970}^K \equiv K_{j,1970}^O/K_{W,1970}$, where $K_{W,1970} = \sum_j K_{j,1970}^O$ is the world's total physical capital as of 1970. Then, we construct a counterfactual sequence of capital stock for each country j as

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

With the series $\{\tilde{K}_{j,t}^{1970}\}$, we compute the counterfactual levels of output $\{\tilde{Y}_{j,t}^{1970}\}$ for each country and the implied world's total $\tilde{Y}_{W,t}^{1970}$, assuming that everything in the world economy—that is the technologies $\{Z_{j,t}, \phi_{j,t}^K, \theta_{j,t}\}$ 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, $\ln[Y_{W,t}^{K^*}/Y_{W,t}]$ with those from

the counterfactual allocation $\ln[Y_{W,t}^{K^*}/\tilde{Y}_{W,t}^{1970}]$, 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 I, where the shares are defined as $\mu_{j,t}^K \equiv (P_{j,t}^K/P_{j,t}^Y) K_{j,t}/K_{W,t}^N$ and $K_{W,1970}^N = \sum_j (P_{j,t}^K/P_{j,t}^Y) K_{j,t}$.

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

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

and follow the same steps to compute the world outputs $\tilde{Y}_{W,t}^{2005}$ and the counterfactual global efficiency loss $\ln[Y_{W,t}^{K^*}/\tilde{Y}_{W,t}^{2005}]$. These second set of counterfactuals 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 *VMPKs*. 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 losses from an allocation that keeps constant the shares as of 1970 and 2005.

In terms of *QMPK*, panel A of Figure 10 unambiguously shows that the global efficiency losses would have remained approximately flat over time, around 5.5 percent 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 panel B 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.

VI. External Flows versus Domestic Accumulation

In this final section, we explore the role of external flows in shaping up the strong trend toward global efficiency in the allocation of physical capital documented in the previous sections. 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

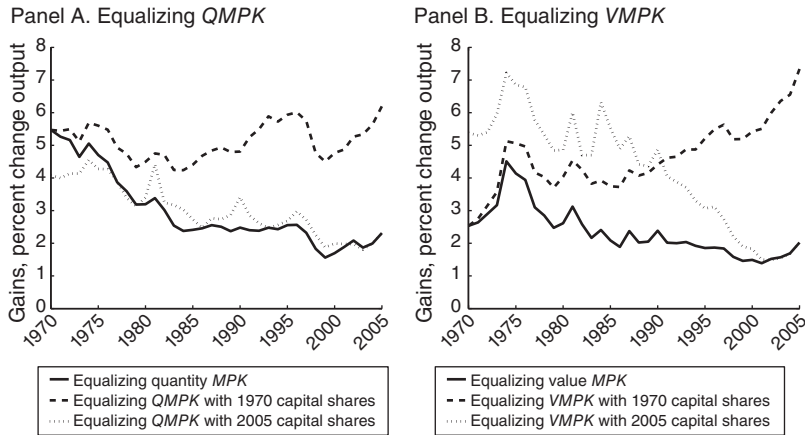


FIGURE 10. COMPARING GAINS OF COUNTERFACTUAL ALLOCATIONS

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

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.³⁷ For the former, the shares $\mu_{j,1982}^K = K_{j,1982}/K_{W,1982}$ 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

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

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

For $XK_{j,s}$, we use the negative of the trade balance of the countries.³⁸ We depreciate the capital flows at $\delta = 4.64$ percent, the depreciation rate for the United States in PWT 8.0.

³⁷ 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.

³⁸ The USD figures from the IMF are converted to PPP units using $P_{j,t}^C$ and $P_{j,t}^K$ 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.

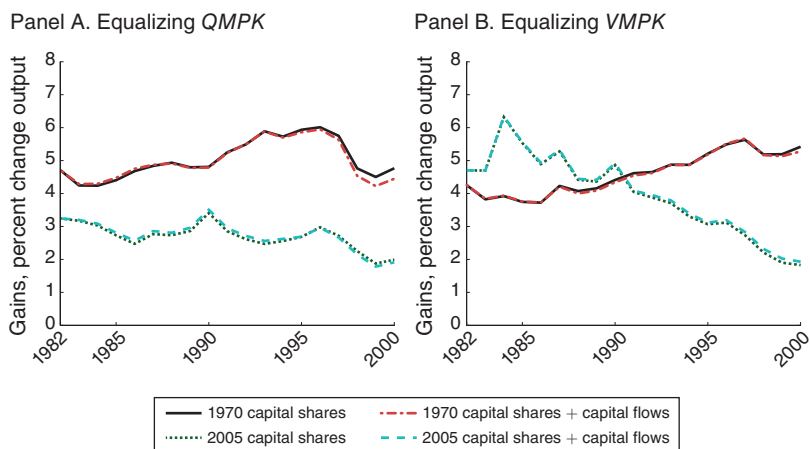


FIGURE 11. COMPARING GAINS OF COUNTERFACTUAL ALLOCATIONS: ROLE OF CAPITAL FLOWS

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

Figure 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 matter whether they are misallocated or not.

VII. 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 percent in the 1970s, while these losses were on the order of 2 percent 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 percent 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, Sánchez, and Santaefulàlia-Llopis (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.

APPENDIX 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.

A1. 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 and 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 IVC 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.

A2. Valuation of Crops at Producer Prices

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

The Wealth of Nations group at the World bank has kindly shared their new (but still unpublished) data with us. In expanding their data, the World Bank has also introduced a new relevant feature in the valuation of natural resource rents in terms of crop pricing. While in previous versions the World Bank 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* (2015) values crop production using the newly available producer prices, which tend to be lower than export values. This implies that the World Bank 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 II) by the World bank. 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 II) with the new estimated World Bank 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 A1, which scatters plots these shares for our benchmark (US prices) against the new World bank 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 A1).

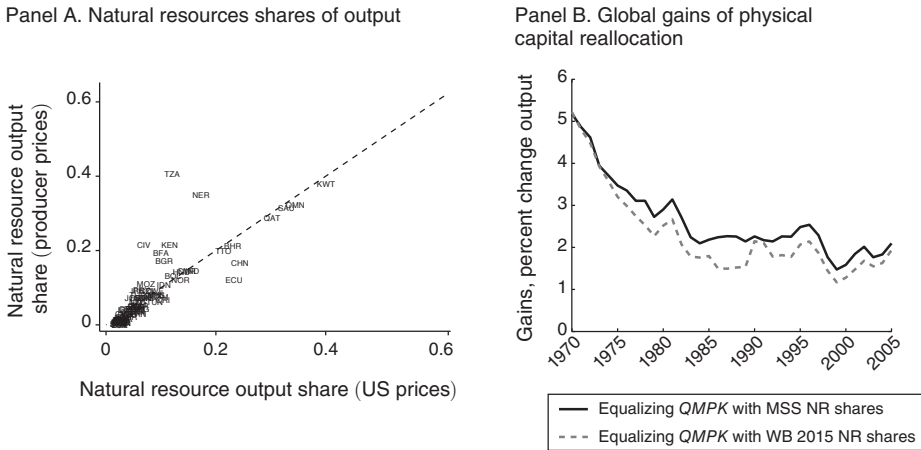


FIGURE A1. BENCHMARK AT US PRICES VERSUS WORLD BANK (UNPUBLISHED DATA, 2015) AT PRODUCER PRICES

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.

APPENDIX B. ADDITIONAL COMPARISON WITH CASELLI AND FEYER (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 IIA translate into large differences in the implied $MPK_{j,t}$. As depicted in Figure B1, 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 B1 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 MPK s 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 B2 shows there are differences between those sources. The most obvious patterns are (i) the K/Y ratios are higher in PWT 8.0 than in PWT 6.1 and (ii) the labor shares are larger in PWT 8.0 than in Bernanke and Gurkaynak (2001). 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 IVE.

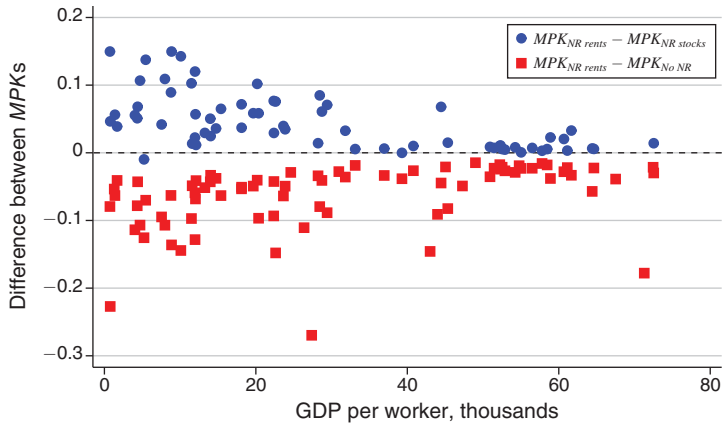


FIGURE B1. MARGINAL PRODUCT OF PHYSICAL CAPITAL: MSS VERSUS CF

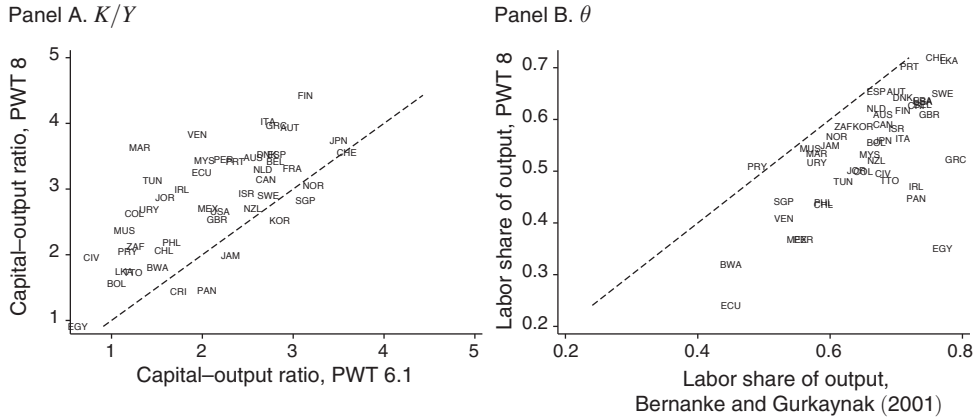
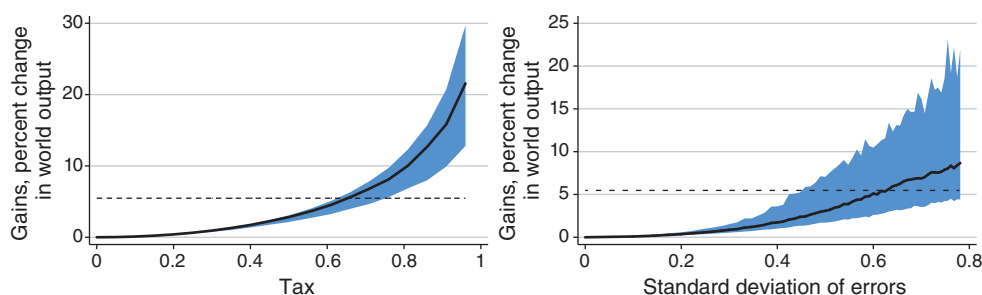


FIGURE B2. DIFFERENCES IN K/Y AND θ

APPENDIX 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 ϵ is a country-specific measurement error. We explore the results for two different forms of ϵ : (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 1/2 is positive (tax) and with probability 1/2 is a subsidy. This second representation follows Restuccia and Rogerson (2008). We generate the stocks of capital for each country

Panel A. Quantity



Panel B. Value

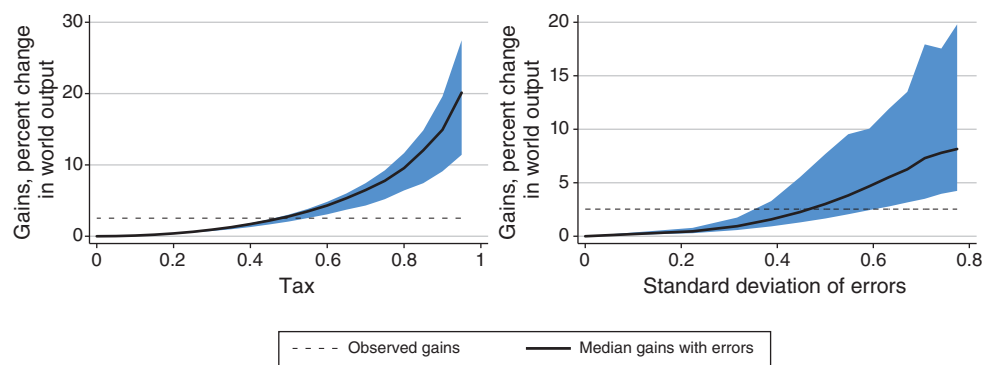


FIGURE C1. MEASUREMENT ERRORS

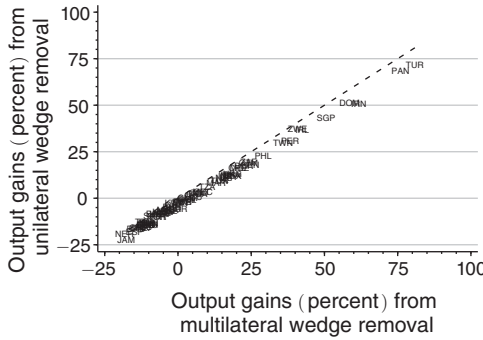
as $K = (1 + \epsilon)K^*$ and then compute the gains in terms of global output of reallocating capital.

Figure C1 show the results. The dashed line represents the gains obtained in our benchmark reallocation exercise, which are above 5 percent. The x -axis represents the size of the standard deviation of ϵ in the first exercise, and the size of the ϵ (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.

APPENDIX 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.

Panel A. Value



Panel B. Quantity

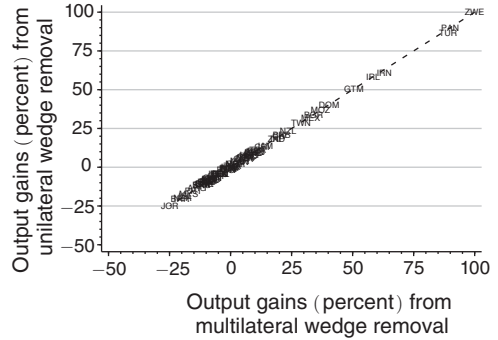


FIGURE D1. UNILATERAL VERSUS MULTILATERAL GAINS

For a given year, by removing the barriers to the allocation of 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.

APPENDIX 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 seven 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 λ_t and define the adjusted flows as $\hat{f}_{j,t}^K = \lambda_t \mathbf{1}_{f_{j,t} \geq 0} \cdot f_{j,t} + f_{j,t} \cdot \mathbf{1}_{f_{j,t} < 0}$. Results from equalizing the quantity marginal product of physical capital using the adjusted flows are similar to those shown in Figure 9, where

$$\lambda_t = \frac{\left| \sum_j^N \mathbf{1}_{f_{j,t} < 0} f_{j,t}^K \right|}{\sum_j^N \mathbf{1}_{f_{j,t} \geq 0} f_{j,t}^K}.$$

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