Natural Resources and Global Capital Misallocation*

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Abstract

In this paper, we use an extended version of the neoclassical multi-country growth model to explore the efficiency in the allocation of physical capital across countries. In our framework, the observed marginal product of capital (MPK) can differ across countries because of two different factors: (a) differences in the countries’ production functions, specifically output shares of mobile factors; and (b) differences in the distortions (wedges) in the use of capital across countries. We use the model to evaluate the importance of these two factors in accounting for the cross-country dispersion in the implied MPKs over the last 35 years and assess how efficiently capital is and has been allocated. Our findings indicate that in the last two decades the world has decidedly moved in the direction of efficiency. Moreover, we find that a realignment of capital to countries with higher TFP and capital-output shares accounts for a large fraction of the gains in efficiency. However, we find that even today, distortions (factor b) are still quantitatively significant and that the global output gains would be significant if those distortions were eliminated. We also find a large degree of heterogeneity. For example, we find significant output loses for countries which heavily distort international trade and for countries with weak financial markets. Finally, despite those distortions, we argue that there is no evidence of “allocation puzzle,” as the international capital flows are directed to countries with higher MPK.

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*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. PRELIMINARY AND INCOMPLETE.

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1 Introduction

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

To sustain those differences over time, either internal or external barriers must preclude the accumulation of capital in the countries where its marginal product (MPK) is the highest, in detriment, perhaps, of the countries with lower MPKs. If so, the removal of those barriers—such as the worldwide movement towards openness observed since 1980s—could drastically change the allocation of capital across countries and the resulting world income distribution. In this paper we use an extension of the multi-country neoclassical growth model to infer the differences in the MPKs across countries and evaluate the efficiency and distributional consequences of observed and counter-factual changes in the barriers to the accumulation of capital in a large number of countries for the years 1970 to 2005.

We argue that in order to infer the cross-country barriers and distortions for the allocation of capital, we should extend the standard one-sector growth model by allowing not only TFP differences but also by (i) introducing differences in the intensity of capital across countries, and by (ii) allowing for forms of capital that are not readily mobile across countries, i.e. natural resources. First, with (i), observing a country with a high capital-to output ratio ($K/Y$) does not necessary imply that the MPK of such a country is lower than the MPK of a country for which $K/Y$ is low. It might be the case that production in the former is more capital intensive than production in the latter. This simple consideration is going to play a crucial role in our

\textsuperscript{1}See the handbook chapter by Caselli (2005) and references therein.
Figure 1: Estimated cross-section distributions Capital-Output Ratios, $K/Y$

Notes: 79 observations. Same restrictions that benchmark results.

analysis since, as shown by Figure 1, there data shows a wide range of $K/Y$ ratios across countries, with some of these differences being highly persistent over time. Second, with (ii) it is not enough to use the standard practice of inferring capital income shares from the labor income shares. Following Caselli and Feyerer (2007), some of the non-labor income of countries accrue to factors that are very different from the standard notion of physical capital. They show that correcting for the non-labor but not-physical capital income shares, the resulting MPKs can be quite different from those inferred using the standard model, especially if the share of rents of natural resources is significant and higher for less developed countries than for developed ones.

In this paper, we extend and revisit the corrections made by Caselli and Feyerer (2007). Like those authors, our estimates of the rents to natural resources in each country are based on the benchmark-countries’ estimates of the World-Bank (2006, 2011). Using data from the FAOSTAT, we applied the same methodology of the World Bank, and extended the estimates
to include the natural resource rents for a large set of countries for 1970 to 2005. Thus, we are able to extend the analysis of Caselli and Feyerer (2007), which is only for 1995-1996, and to a larger set of countries and over time. More importantly, our estimates are substantially different from theirs. We argue that those authors’s greatly overestimated the importance of natural resources, and by doing so, their conclusion that the MPKs are equalized across countries need not hold. The source of the overstatement lies in the (present value) calculations to infer the wealth stocks in natural resources from the rent estimates done by the World Bank, and also by the implicit assumption of equal rates of returns between physical (reproducible) and natural (non-reproducible capital).

Our estimates of factor shares are based solely on the flow of rents. We are not required to take a stand of the relevant growth and discount rates or the relevant horizon for the estimation of wealth stocks in the different forms of natural resources — and their rates of return— across the different countries and years. Indeed, our results differ drastically from those of Caselli and Feyerer (2007). Figure 2 illustrates this using Japan and Costa Rica in 1996. The former is a developed country with a notably high $K/Y$, almost 4, while the latter is a developing country with a surprising low $K/Y$, barely 1.4. The standard model and calibration, the red curve, would lead to the conclusion that Costa Rica heavily taxes or blocks capital in the country and/or that Japan subsidizes capital rather heavily too. Whatever is the case, if those distortions were lifted, physical capital would flow from Japan to Costa Rica. The calculations of Caselli and Feyerer (2007), the magenta curve, lead to very different conclusions: If anything, the capital should be flowing from Costa Rica, a country in which capital seem to be of little use, to Japan, where the physical abundance does not translate in economic abundance. Our estimates lead to quite a different conclusion. As indicated by the corrected MPK curve, capital intensity differences do not lead to equalization of MPKs. As for Costa Rica, we find that barriers to capital allocation to developing countries are quantitatively important, even if not all the way as in the standard model. In Section 5, we provide a detailed discussion of our measurement results, including a description of the different data sources.
Figure 2: The MPK of Japan and Costa Rica, 1996

Notes: In red we denote the assumptions by Lucas 1990, i.e., ignoring technology differences, and in magenta we denote the assumptions in Caselli and Feyerer (2007) that overestimate capital intensity differences.
We then use our estimates of the physical capital output shares in conjunction with data on income, capital and price data from the Penn World Table (PWT 8) to compute the evolution of the MPKs across countries and over time, since 1970 until 2005. We report the results for two different notions of MPK. The first one, which we call real MPK (hereafter RMPK), is the standard one. Given that the PWT reports the output and capital of all countries in comparable international prices, the RMPK corresponds to the increment in quantity of units of output in each country associated to a marginal increment in the physical units of capital in each country. The second notion of MPK, which we call nominal MPK (hereafter NMPK), corresponds to the increment in the value of output in each country associated to marginal increments in the value of capital in each country. This second notion recognizes the fact that the output and capital prices differ across countries. Both of these notions of MPKs can be associated to a different efficiency benchmark, which we explain in Section . Comparing the patterns that emerge from the two different notions of MPKs, we can also ascertain the role of cross-country output and capital differences for the behavior of investment across countries, as advocated by Hsieh and Klenow (2007) and others.

We find a significant dispersion in the MPKs across countries has persisted over time. Thus, despite the fact that countries with low $K/Y$ also tend to have low capital income shares, the data suggests that some form of barriers may be distorting the allocation of capital across countries. This finding holds for both, RMPK and NMPK, so relative price corrections alone cannot explain cross-country differences in the return to capital. Indeed, for the early years in our sample, the dispersion in NMPKs is higher than the dispersion in RMPKs, while the opposite is true at the end of the period. While prices play a substantial role in the evaluation of the MPKs of countries, it is not the case that prices alone drive the trends.

Our results also indicate interesting trends in the world economy from 1970 to the 2000s. Specifically, we show that the dispersion in both notions of MPKs went down decisively between 1970 and the mid 1980s. Such trend would be expected from the worldwide movement towards liberalization and openness observed during that period, e.g. Buera et al. (2011). However, our
findings suggests that barriers are still relevant, even at the end of the sample. While lower and flat, the dispersion in MPKs remains significant, and, as discussed in Section 5, the implied individual country and world output loses can be large. Another interesting trend is that we find that the median MPK has trended down over time, consistent with the global labor share decline documented in Karabarbounis and Neiman (2014). While the capital income share has increased over time for many of the countries in our sample, the capital-output ratios across countries have outpaced the movements in the factor shares.

Our result that barriers have affected the allocation of capital across countries is supported by the relationship of our inferred MPKs with observable measures of policy distortions. In principle, the accumulation of capital in a country can be distorted by internal and external policies. Internal policies such as macro instability, financial repression, taxes and other forms of regulations, can reduce or enhance, domestic savings and investment, e.g. Greenwood et al. (2010, 2013). On the other hand, external policies such as barriers to trade and foreign investment, currency convertibility and the extend of government monopolies can easily block the inflow of foreign capital to a country, e.g. Sachs and Warner (1995). At any rate, to the extent that those distortions reduce capital formation inside a country they should be reflected in a higher MPK. We find that indeed, countries that are financially repressed (indicated by either a low deposits-to-income ratios or a high lending-to-borrowing interest rates) and/or not open to international trade and investment (as indicated by the Sachs-Warner indicator) exhibit higher (and also more dispersed) MPKs. Those policies help explaining the trends in the distribution of MPKs as stated above. The mass of countries that were not open and financial repressed was much higher in the 1970s. Interestingly, we also find that by the end of the sample, the MPK of not open countries tend to behave more like open countries. This might be a reflection that countries like China and India, which since late 1980s have released some of their most severe restrictions to capital inflows, but are still classified as non open.

The dispersion of MPKs is far from being a sufficient statistic for the global and individual country’s costs of barriers to capital mobility. This is because countries’ sizes and whether a
high MPK is driven by low $K/Y$ or a high share of capital – the curvature of the production function – matters for the potential gains from eliminating barriers. We use two different simple counterfactual exercises to assess the economic significance of removing the barriers to capital mobility. The first one consist in eliminating all the barriers to capital allocation, but keeping in place the trade frictions and possibly other distortions that are entirely captured by the different output and capital prices across countries. Under this counterfactual exercise, global output maximization requires the equalization of the NMPKs across countries, which is the same equilibrium condition of an investor that maximizes the returns of a financial portfolio. The second counterfactual is when all the trade frictions and other distortions are eliminated along with a perfect mobility of capital across countries. This counterfactual exercise leads to the standard equalization of RMPKs across countries.

Our findings suggest that the economic significance of the existing barriers have been – and still are – significant. Eliminating all frictions, distortions and barriers would have lead to an increase of 5.5% in global output in 1970. These implied gains have declined consistently over the sample period, but they are still 3% of global output in 2005. Eliminating only the barriers to capital allocation but keeping those in the prices, would have led to smaller gains, peaking at around 4.4% in 1974, and otherwise flat around 3% over the sample period. Interestingly, the both counterfactuals lead to similar figures for the end of the sample, perhaps suggestive that price differences have declined substantially in the latter years.

Behind those global gains lie a great deal of heterogeneity across countries. Our results indicate that liberalization of capital flows would lead to output reduction of developed countries, as they export their capital to emerging markets and developing countries. More interestingly, some groups of developing countries, such as South America in the late 1990s and early 2000s, would also end up exporting their capital and contracting their internal output. Most notably, African countries would greatly gain if the barriers to global capital were to be removed. Indeed, we find that their output would have double in 1970, and would be 50% higher in 2005. Needless to say, those numbers must be taken with caution, but their sheer magnitude deserve
attention.

We then use our measured MPKs to revisit the allocation puzzle of international capital flows (Gourinchas and Jeanne, 2013), namely the proposition that international capital flows have not been directed to the countries where the return to capital is the highest. According to calculations based on TFP growth, these authors argue that capital has flown from high-MPKs countries to low-MPKs countries, hence the puzzle. Instead of relying on TFP, we directly examine the relationship between our measure of NMPKs with capital inflows. We find that the puzzle disappears. Countries with high NMPK tend to receive capital while those with low NMPK tend to export capital. We argue that the reversal of the puzzle is fairly robust to different time periods and subgroups of countries. To be sure, we are not saying that capital flows are fully efficient. If anything we have argued in this paper is that some important frictions and barriers have been present in the world economy. What we argue is that the frictions might have distorted the magnitudes, but have not been strong enough so as revert the direction of the international capital flows.

The reminder of the paper is as follows. In the next section, we describe our version of the multicountry neoclassical growth model. In Section 3, we discuss in detail our measurement of rents for natural resources and the implied output share of physical capital. In Section 4, we describe the implied numbers of MPKs across countries and over time. We also examine the relationship of our implied MPKs with observed policy distortions. In Section 5 we define our counterfactual policies and explain the global and country level gains. In Section 6 we examine the allocation of capital flows. Section 7 concludes.

2 The Model

2.1 The Environment

Consider a discrete time, infinite horizon world economy, populated by $J$ countries. Time periods and countries are indexed by $t = 0, 1, 2, ...$ and $j = 1, 2, ..., J$, respectively. Our baseline
model assumes that there is a single consumption/investment good. All countries produce output using physical capital, $K_{j,t}$, natural resources, $T_{j,t}$ and human capital-augmented labor, $h_{j,t}L_{j,t}$, according to a production function that is also augmented by the countries’ overall total-factor-productivity, $A_{j,t}$. Except for physical capital, all the other sequences are assumed to be exogenous and fixed in the respective countries—they cannot be reallocated to across countries. Production is in terms of a single good, which can be used for consumption or investment, and is tradeable across countries along the lines explained below.

Production of the good in country $j$ at time $t$ is according to the production function

$$Y_{j,t} = A_{j,t}(K_{j,t}^{\gamma_{j,t}}T_{j,t}^{1-\gamma_{j,t}})^{1-\theta_{j,t}}(h_{j,t}L_{j,t})^{\theta_{j,t}},$$

where $0 < \theta_{j,t} < 1$ is the labor share of output and $1 - \theta_{j,t}$ is the capital share of output. Out of the latter, a fraction $0 < \gamma_{j,t} < 1$ accrues to reproducible (and reallocateable) capital and $1 - \gamma_{j,t}$ to non-produced capital (natural resources and land). The amount of physical reproducible capital installed in country $j$ in period $t$ is $K_{j,t}$. Further, for the purpose of our exercise we isolate the production factors and productivities that are exogenously fixed in each country $j$ in each period $t$. To this end, note that we can rewrite (1) as,

$$Y_{j,t} = Z_{j,t}K_{j,t}^{(1-\theta_{j,t})\gamma_{j,t}},$$

where $Z_{j,t} \equiv A_{j,s}T_{j,s}^{(1-\gamma_{j,s})(1-\theta_{j,s})}(h_{j,s}L_{j,s})^{\theta_{j,s}}$ represents the entire set of factors and productivities that are not mobile across countries.\footnote{For the purposes in this paper, we do not separate the different components of $Z_{j,t}$—even if we could assess some of them directly from the data.} Therefore, to recover $Z_{j,t}$ we require information on output, $Y_{j,t}$, capital, $K_{j,t}$, the labor share, $\theta_{j,t}$ and the natural resources share of output per country and period, i.e., $\phi_{j,t} = (1-\theta_{j,t})(1-\gamma_{j,t})$. Physical capital is accumulated over time and can be reallocated across the $J$ countries in
the world. In any country \( j \), physical capital follows the law of motion

\[
K_{j,t+1} = (1 - \delta) K_{j,t} + I_{j,t},
\]

where \( \delta \) is the depreciation rate and \( I_{j,t} \) is gross investment.

We assume that the world allocation of capital is possibly distorted by the presence of installment costs and, possibly, policy distortions, \( \iota_{j,t} \). In particular, we assume that installed physical capital in country \( j \) entails \( \iota_{j,t} \) units in terms of world’s consumption goods. Notice that this implies that the cost of capital goods installed in country \( j \) in terms of consumption goods is

\[
\iota_{j,t} = \frac{P_{j,t}^K}{P_{j,t}^Y}.
\]

Before explaining how we measure \( \{\theta_{j,t}, \gamma_{j,t}, Y_{j,t}, K_{j,t}, Z_{j,t}, P_{j,t}^Y, P_{j,t}^K\} \) to compute the \( RMPK_{j,t} \) and \( NMPK_{j,t} \) across countries and periods, we now discuss a number of benchmarks which we use in our counterfactuals discussed in Section 5.

### 2.2 Observed Allocations and Efficiency Benchmarks

Using the standard model described above we can infer the implied marginal product of physical capital (\( MPK_{j,t} \)) across countries from observable data. We now explain how we use those measures and alternative benchmarks derived from the model, to assess the efficiency in the allocation of capital across countries. Finally, we can use the model to perform counterfactual exercises to evaluate the potential output gains attainable from fully efficient allocations.

Using the production function (2), the standard measure of the marginal production of physical/reproducible capital observed in country \( j \) in period \( t \) is given by

\[
RMPK_{j,t} = (1 - \theta_{j,t}) \gamma_{j,t} \frac{Y_{j,t}}{K_{j,t}}.
\]

\(^3\)Note that the installment costs of capital are destination country specific and independent of the country in which the goods were produced.
The letter “R” emphasizes that this is a purely real return, the number of units of output generated by the marginal unit of physical capital in the country. As a fraction of the output-to-capital ratio, $RMPK_{j,t}$ is the fraction $\gamma_{j,t}$ of the non-labor income share $1 - \theta_{j,t}$ that accrues to the capital that is mobile. The equalization of $RMPK_{j,t}$ would maximize world output $\sum_{j=1}^{J} Y_{j,t}$ in a world free of frictions and barriers in the trade of consumption and investment goods.

An alternative concept of MPK is in nominal terms, i.e.

$$NMPK_{j,t} = (1 - \theta_{j,t}) \gamma_{j,t} \frac{P_{j,t}^{Y} Y_{j,t}}{P_{j,t}^{K} K_{j,t}}. \quad (4)$$

The NMPK measures the return that an investor attains in units of dollars (or any numeraire) from investing resources in country $j$ during period $t$. The letter “N” highlights the fact that different countries lead to different numbers of machines per dollar invested, $1/P_{j,t}^{K}$ and that the value $P_{j,t}^{Y}$ of the same units of output can be different across countries. In a world in which investors can freely adjust their portfolios, on average, they would seek to equate the $NMPK_{j,t}$. Given $\{P_{j,t}^{Y}, P_{j,t}^{K}\}$, the equalization of $NMPK_{j,t}$ would maximize world output $\sum_{j=1}^{J} Y_{j,t}$ subject to the value of the global investment portfolio, $\sum_{j=1}^{J} \frac{P_{j,t}^{K} K_{j,t}}{P_{j,t}^{Y}}$ is the same that the observed in the data.

3  Measurement

In this section we first describe the series of output, capital, prices and labor share that we use in our analysis. Then, we discuss in detail the construction of the shares of output attributed to natural capital using measures of actual rents from natural resources.\footnote{The raw data and do-files that replicate all our computations is publicly available in here.}
3.1 Output, Capital, Prices and Labor Share

Our data for output, capital and prices is retrieved from the most recent version of the Penn World Tables (PWT 8.0).\textsuperscript{5} For real output values, $Y_{j,t}$, we use the variable $cgdpo$, production-side real GDP at current PPPs (in million 2005USD).\textsuperscript{6} The capital stocks in each country/year, $K_{j,t}$, are taken as the variable $ck$, capital stocks at current PPPs (also in million 2005 USD). For each country, these aggregate stocks are computed applying the perpetual inventory method (PIM) separately for different types of investment that include structures (residential and non-residential), equipment (separately for transportation, computers and communication), software, and other machinery and assets.\textsuperscript{7} The application of the PIM to each type of capital implies that the aggregate capital stock not only differs across time and space because of differences in investment flows but also because of investment prices and depreciation rates.\textsuperscript{8} For the price of output, $P_{Y_{j,t}}$, we use the GDP deflator $pl_{gdpo}$, i.e. the price level of cgdpo (PPP/XR, normalized so that price level of USA GDP in 2005 = 1); similarly, the price level of capital, $P_{K_{j,t}}$, is taken to be $pl_{k}$, the price level of the capital stock (normalized so that the price for USA in 2005 is 1). Throughout our analysis is conducted we use variables in per worker terms with the employment variable $emp$ in PWT for our measure of aggregate labor, $L_{j,t}$, i.e., the number of persons, in millions, engaged in production. What is most relevant for our analysis

\textsuperscript{5}Available online at http://www.rug.nl/research/ggdc/data/penn-world-table; see also Appendix A.

\textsuperscript{6}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. Note that incorporating the US inflation to all countries, i.e., $rgdpo$, yields identical reallocation results.

\textsuperscript{7}Recently, national accounts such those of Australia, Canada, the U.K. and the U.S. have started to capitalize Intelectual Property Products (IPP) in SNA 2008 by the United Nations. IPP capital includes software, Research and Development (R&D) and Entertainment. The PWT 8.0 incorporates software for some (but not all) countries.

\textsuperscript{8}That is, the aggregate price of investment and the aggregate depreciation rate capture potential differences in the composition of the aggregate capital stock. For example, in regard with depreciation rates these are assumed to be identical across time and space for each type of capital. The depreciation rate for structures is 2%, for equipment 18.9%, computers 31.5%, Communication equipment 11.5%, Software 31.5%, and other machinery and assets 12.6%. Hence, a higher intensity in equipment and software capital in rich countries implies higher depreciation rates of the aggregate capital stock in rich countries. Finally, the initial capital stock in 1950 is assumed to be common across time and space (as opposed to standard steady-state assumptions) with a capital-output ratio that is 2.2 for structures, .1 for transport equipment, .3 for other machinery and assets and zero for the rest of assets (mainly), that is, the common aggregate capital-output ratio is 2.6 in 1950; see a detailed comparison and discussion in Feenstra et al. (2013).
is that this measure of capital from the PWT does not include natural capital, a dimension that we explicitly incorporate in Section 3.2.

For the labor share of output, $\theta_{j,t}$, we use the PWT variable $labsh$. This measure of the labor share corrects 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.\footnote{The issue on how to attribute ambiguous income to capital and labor is not trivial, in particular, for poor countries with a large population of household-farms in the rural/agricultural sector (Gollin (2002)).} As explained in Feenstra et al. (2013), four different adjustments to the labor share of income are considered: \footnote{The unadjusted labor share uses the unambiguous labor income, i.e., the compensation of employees (WN), as the only source of labor income. Hence, the unadjusted labor share is $\theta = WN/GDP$.} (1) add ambiguous income (AMB) to unambiguous labor compensation (WN), i.e., the labor share is $\theta = (WN+AMB)/GDP$; (2) assume the labor share, $\theta$, is identical to the labor share of unambiguous output, $\theta_u = WN/(GDP-AMB)$; \footnote{That is, labor share is $\theta = (WN + \theta_u AMB)/GDP= \theta_u$ where the last equality is the assumption.} (3) assume the same average wage for the self-employed as for the employees (W), i.e., the labor share is $\theta = (WN+WS)/GDP$, where $N$ and $S$ are, respectively, the number of employees and self-employed; \footnote{Note that we can also write this third adjustment as $\theta = (WN/GDP)\cdot(N+S)/N$.} and (4) add value added in agriculture (AGRI) to unambiguous labor income, i.e., $\theta = (WN+AGRI)/GDP$.

The authors of PWT 8.0 construct their ‘best estimate’ of the labor share using the following procedure: If the unadjusted share is larger than 0.7, no adjustments are used, as the share never excess 0.66 when ambiguous income data are available in national accounts statistics.\footnote{Note that all adjustments discussed previously imply an increase in the labor share.} If the unadjusted share is smaller than 0.7, then: if the the ambiguous income data is available, they use adjustment 2, because adjustment 1 seems to extreme; otherwise, if the ambiguous income data is not available, then use the minimum of the resulting shares of adjustments 3 and 4.
3.2 Natural Resources Share of Output

In this section we first discuss our measurement of the share of output attributed to natural resources, a key dimension of our empirical analysis and for which we rely on the use of natural rents. Second, we discuss the differences between our measure of natural shares and previous estimates that rely on the use of natural stocks.

3.2.1 Natural Rents and their Share of Output

Our main source of data is the set of rents for the different natural resources from the World Bank’s project on ‘The Changing Wealth of Nations’, see World-Bank (2011).\textsuperscript{14} We further use the United Nation’s Food and Agriculture Organization database (FAOSTAT) to extend the analysis of crop and pasture land rents for a larger sample period.\textsuperscript{15}

We follow the World Bank’s grouping of the natural resources into: (a) timber, (b) subsoil resources, (c) crop lands, and (d) pasture lands. First, the rents of timber and subsoil resources (i.e., oil, natural gas, coal nickel, lead bauxite, copper, phosphate, tin, zinc, silver, iron and gold), were taken directly from the World Bank estimates.\textsuperscript{16} Second, for the rents associated to crop lands (apples, bananas, coffee, grapes, maize, oranges, rice, soybeans, wheat and all others), we follow the method in World Bank (2006). For each crop, we measure total rents as the product of estimated rates of return and total values of production for each different crop. The total values of production of each crop are then computed for each country and each year using quantities reported in FAOSTAT for each country. We use the U.S. price of the crop, as a proxy of the international price of the crop. Then, we compute total rents using the estimated rates of return from the World Bank (2006) for the land used in producing this crop, as a fraction of total value of production. Those rates of return are estimated by the World Bank

\textsuperscript{14}The Wealth of Nations dataset provides country level data on comprehensive wealth and natural capital rents (i.e., non-renewable resources) for over 150 countries. We thank Glenn-Marie Lange and Esther Naikal in “The Changing Wealth of Nations” group at the World Bank for insights on the use of these data.
\textsuperscript{15}Both datasets are available online at http://data.worldbank.org/data-catalog/wealth-of-nations and http://faostat.fao.org/, respectively.
\textsuperscript{16}Available at http://data.worldbank.org/sites/default/files/subsoil_and_forest _rents.xls.
from information on a set of benchmark countries that are major producers of that crop. We compute the overall countries’s rental rates for croplands as the average rate weighted by area used for each crop.\textsuperscript{17} Third, for the rents of pasture lands (e.g., beef, lamb, milk and wool) we follow the World Bank (2005) estimating 45\% of total value of output from FAOSTAT. Finally, we follow World Bank (2006) and Caselli and Feyerer (2007) and assume that the rents of urban land are equal to 24\% of the total rents of physical capital.\textsuperscript{18}

The sum of these natural rents across natural capital types in country $j$ and year $t$ is total rent accrued to natural or fixed capital for that country and year,

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

where $q = \{\text{timber, subsoil, crop land, pasture land}\}$ are the natural capital types. Since these rents are computed in current PPPs (in million 2005USD), then natural resources share of output for country $j$ in period $t$ is

$$\psi_{j,t} = (1 - \gamma_{j,t}) (1 - \theta_{j,t}) = \frac{NR_{j,t}}{Y_{j,t}}.$$ \hfill (5)

Our benchmark final sample size is of 79 countries for which we can define both total factor productivity $Z_{j,t}$ from (2) and the share of natural resources in output $\phi^R_{j,t}$ from (5) with consistently available information throughout the entire sample period from 1970 to 2005.\textsuperscript{19}

The natural resources shares of output by type of natural capital are described in Table 1 for the year 2000. Across countries, natural resources account for an average of 8.19\% of total output. The largest component of rents generated from natural capital are subsoil resources

\textsuperscript{17}For example, rental rates estimated for some benchmark countries are: 27\% for soybeans (from China, Brazil, Argentina), 8\% for coffee (from Nicaragua, Peru, Vietnam, Costa Rica), 42\% for bananas (from Brazil, Colombia, Costa Rica, d’Ivoire, Ecuador, Martinique, Suriname, Yemen), etc.

\textsuperscript{18}We exclude other (non-timber) forest rents. The World Bank (2006) correctly includes them in the calculation of the countries’ stock of wealth. However, they are not included in the standard computation of countries’ GDP, and as such, we opt for excluding them from the computation of the GDP share of natural resources.

\textsuperscript{19}We conduct further analysis for a larger sample of 122 countries for which $Z_{j,t}$ and $\phi^R_{j,t}$ are available when we restrict the analysis from 1990 to 2005. See Appendix A.3.
Table 1: Natural Resources Shares of Output (%), Year 2000

<table>
<thead>
<tr>
<th>Natural Resources:</th>
<th>Mean</th>
<th>Md.</th>
<th>CV</th>
<th>( \rho_{x,y} )</th>
<th>Non-Oil Countries</th>
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<tr>
<td></td>
<td>Mean</td>
<td>Md.</td>
<td>CV</td>
<td>( \rho_{x,y} )</td>
<td>Mean</td>
</tr>
<tr>
<td>Natural Resources:</td>
<td>8.19</td>
<td>4.00</td>
<td>17.07</td>
<td>-0.08</td>
<td>4.51</td>
</tr>
<tr>
<td>( \triangleright ) Timber</td>
<td>.12</td>
<td>.00</td>
<td>1.86</td>
<td>-0.28</td>
<td>.13</td>
</tr>
<tr>
<td>( \triangleright ) Subsoil:</td>
<td>5.09</td>
<td>.50</td>
<td>24.26</td>
<td>.16</td>
<td>1.41</td>
</tr>
<tr>
<td>Oil</td>
<td>3.72</td>
<td>.04</td>
<td>23.85</td>
<td>.15</td>
<td>.69</td>
</tr>
<tr>
<td>Gas</td>
<td>1.11</td>
<td>.02</td>
<td>7.28</td>
<td>.18</td>
<td>.44</td>
</tr>
<tr>
<td>Other</td>
<td>.25</td>
<td>.00</td>
<td>2.19</td>
<td>-0.20</td>
<td>.29</td>
</tr>
<tr>
<td>( \triangleright ) Cropland</td>
<td>2.62</td>
<td>1.00</td>
<td>5.11</td>
<td>-0.66</td>
<td>2.59</td>
</tr>
<tr>
<td>( \triangleright ) Pasture</td>
<td>.35</td>
<td>.17</td>
<td>.84</td>
<td>-0.28</td>
<td>.34</td>
</tr>
<tr>
<td>Nat. R. w/ Urban Land</td>
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<td>12.56</td>
<td>7.82</td>
<td>-0.09</td>
<td>12.44</td>
</tr>
<tr>
<td>Obs.</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>70</td>
</tr>
</tbody>
</table>

Notes: This table reports the mean, the median (Md.), and the coefficient of variation (CV) of the natural resources shares of output across countries and for the year 2000. It also reports the correlation of these natural shares and output per worker. This is conducted by type of natural resource with a last item that adds urban land to natural resources. The first set of statistics are computed for our benchmark sample of 79 countries, and the second set for the set of non-oil countries, i.e., 70 countries. Oil countries are defined as those with oil rents that account for more than 10% of total output.

that account for 5.09% of output. Within subsoil the oil and natural gas account for the vast majority of rents, respectively, 3.72% and 1.11% of output. The second major component of natural resources is cropland with a share of output of 2.62%. Pasture rents and rents from timber forest account for lesser shares, respectively, 0.35% and 0.12% of output. Further, the inclusion of urban land boosts the share of natural resources to 15.89%. Focusing on the two largest single components, oil and cropland rents, the median share of oil rents in terms of output dramatically drops to 0.04% (i.e., close to 1% of its mean value) while the median share of cropland rents drops to 1.00%, i.e., about 38% of its mean value. This suggest a large dispersion in oil shares across countries which is confirmed by a large coefficient of variation in oil, 4.5 times larger than that of cropland shares. Abstracting from oil countries, which we define as those with oil shares of output above 10%, \(^{20}\) drops substantially the average contribution of natural resources to output to 4.51%. In this case, the largest natural share of output is accounted by cropland rents, 2.59%. The oil share plays a much lesser role, 0.69% and hence

\(^{20}\)This way we exclude seven countries from our benchmark sample: Qatar, Kuwait, Saudi Arabia, Oman, Norway, Ecuador, Nigeria, Trinidad and Tobago, and Bahrain.
subsoil rents as well, 1.41%. This has implications for the dispersion of natural resources. The median share of natural resources in output is now close to mean with a mean-to-median ratio of 1.41, while this ratio is 2.04 when oil countries are included, and a coefficient of variation is 5.06, while this was 17.07 when oil countries are included.\textsuperscript{21} Finally, all natural resources shares of output co-move negatively with output, except for oil and natural gas, see Table 1. The correlation of the natural resources share of output and output is -.08 for the benchmark sample, and -.67 for the sample that excludes oil countries. From the disaggregation of natural resources further, we find that income per worker is negatively related to the share of output attributed to timber forest with a correlation coefficient of -.28, subsoil resources other than oil and gas, -.20, pasture, -.20, and, in particular, cropland, -.66.\textsuperscript{22}

The mechanics of the relationship between the total natural resource share of output and output per worker are highlighted in Figure 3. Panel (a) of Figure 3 shows that oil countries have the highest natural resources shares of output, on average 36.80%, versus 4.51 of their non-oil counterparts. Oil countries are also relatively richer than their non-oil counterparts.\textsuperscript{23} We find that the correlation between the natural resources share and output is still negative within oil countries, -.11, but significantly smaller than within non-oil countries, -.67. Focusing on non-oil countries, panel (b) of Figure 3 displays this clear negative relationship between the natural resources share and output. On average, for non-oil countries with income per worker above $40,000, the natural resources share of output is 1.13%, while this share is 6.90% for countries below $40,000 and 9.62% for countries below $10,000. In other terms, the bottom 20% poorest countries in income per worker have a natural resources share of their output that is 8.81 times larger than the natural share of the top 20% richest countries in income per worker.\textsuperscript{24}

\textsuperscript{21}We find similar insights with a larger sample of 122 countries for which $Z_{j,t}$ and $\phi^{R}_{j,t}$ are available from 1990 to 2005. See Appendix A.3.
\textsuperscript{22}See Appendix A.3 for further analysis of these subitems.
\textsuperscript{23}The income per worker of oil countries averages $51,888, while that of non-oil countries is $4,963. That is, the non-oil countries include a relatively larger share of poor countries.
\textsuperscript{24}Including oil countries this factor drops to 1.63.
Figure 3: Natural Resources Shares of Output (%), Year 2000

(a) Natural Resources Shares

(b) Natural Resources Shares, Non-Oil Countries

Notes: The natural resources shares of output are computed using rents from natural resources as described in Section 3.2.1. Oil countries are defined with oil shares that contribute more than 10% to total output. Panel (a) includes oil and non-oil countries, i.e., 79 observations, and panel (b) includes non-oil countries, i.e., 70 observations.
To summarize, natural resources are an important input for production that accounts for a sizable 9.50% of total output per worker across countries with the largest components being oil rents and cropland rents. Further, the quantitative role of natural resources differs largely by country and, perhaps, more importantly it decreases with income per worker. Poor countries rely substantially more on natural resources than rich countries.

3.2.2 Proxying the Natural Resources Share of Output with Natural Stocks

The WB also measures natural capital stocks. To do so the WB converts natural rent flows into natural stocks. To see this, define wealth of each country $j$, in natural resource $q$, in a given year, say 1995

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

where the present value factor $PVF$ is,

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

Then, country’s total natural wealth stock:

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

Note that to compute these stocks one needs to assume paths for the growth rates of each stock-type rents, and the world bank does so separately for developed and developing countries, $G_{j,q}$, as well for the life-time that each of these natural stocks is supposed to last $T_{j,q}$. Table 2 shows the implications of these assumptions.

It is these natural stocks that have been used previously to proxy for natural rents, see Caselli and Feyerer (2007), and hence to compute shares of non-natural resources as follows:

$$\phi_j^R = [1 - \theta_j] \gamma_j = \frac{r_j^K K_j}{r_j^N N_j + r_j^K K_j} \times [1 - \text{labor share}_j]$$
Table 2: World Bank’s Present Value Factors, $PVF_{j,q}$

<table>
<thead>
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<th>Resources</th>
<th>Developed Countries</th>
<th></th>
<th>Developing Countries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$G_{j,q} - 1$</td>
<td>$T_{j,q}$</td>
<td>$PVF_{j,q}$</td>
<td>$G_{j,q} - 1$</td>
</tr>
<tr>
<td>Subsoil Res.</td>
<td>0 (%)</td>
<td>13 (%)</td>
<td>10.5 (%)</td>
<td>0 (%)</td>
</tr>
<tr>
<td>Timber</td>
<td>0 (%)</td>
<td>25 (%)</td>
<td>16.3 (%)</td>
<td>0 (%)</td>
</tr>
<tr>
<td>Croplands</td>
<td>0.97 (%)</td>
<td>25 (%)</td>
<td>17.9 (%)</td>
<td>1.94 (%)</td>
</tr>
<tr>
<td>Pasturelands</td>
<td>0.89 (%)</td>
<td>25 (%)</td>
<td>17.8 (%)</td>
<td>2.95 (%)</td>
</tr>
</tbody>
</table>

Assume $r_j^N = r_j^K$. Then

$$\phi_j^R = [1 - \theta_j] \gamma_j = \frac{K_j}{N_j + K_j} \times [1 - \text{ labor share}_j]$$

(6)

Note that our preferred measure in (5, as opposed to (6), uses solely World Bank rents. That is, our measure of natural resources shares does not need to assume neither $r_j^N = r_j^K$ nor assumptions on $r$, $T_{j,q}$ and $G_{j,q}$.

The total natural resources shares in 2000 for our measure that uses rents versus the measure that uses solely stocks is in Figure 4. The results are striking. Using stocks to proxy for rents overestimates the share of natural resources, in particular, for poor countries. For countries below 15,000, the average share using stocks is roughly 30% , while for our preferred measure that uses rents and does not imposes assumptions on the return to natural capital is close to 7%.

Figure 5 shows that the share of non-natural resources is underestimated using stocks with respect to the share of non-natural resources that uses rents. This is problem is perverse in particular for the poorest countries, under 20,000 the underestimation is on average about 15% of GDP. This translates into large differences in the MPK of non-natural resources as depicted in Figure 6. The differential of MPKs computed with rents with respect to those proxied with stocks (i.e., Caselli and Feyerer (2007) is positive and largest for the poorest countries, while the differential of MPKs computed with rents compared with the assumption of no differentials
Notes: 67 observations.

(i.e., Lucas (1990)) is negative and less sizable.

Finally, using an entirely different methodology, we find that our measures of natural capital shares in aggregate output based on World Bank and FAOSTATS are consistent, in particular in terms of cropland, i.e., the major component of natural capital, with land share values imputed under entirely different methodologies. Valentinyi and Herrendorf (2008), using an entirely different methodology than ours based on the matrix of input output tables in the BEA for the U.S., compute factor shares for different sectors in the U.S. Further, using representative micro data from Integrated Surveys of Agriculture for Malawi, Uganda and Tanzania, Cheoran, Restuccia and Santaeulalia-Llopis (2014) find that at the household-farm level the land rental payments to output production are on average 19% for Malawi, 13% for Uganda and 11% for Tanzania.
Figure 5: Reproducible Capital Shares of Output (%): From Rents vs. Stocks, Year 1996

Notes: 67 observations.

Figure 6: Measuring Real and Nominal MPK Differentials: Rents vs. Stocks, Year 1996

(a) Real MPK

(b) Nominal MPK

Notes: 67 observations.
4 The Marginal Product of Capital

We present the real and nominal MPK in Figure 7. The left panel displays the evolution of the real MPK, or RMPK. The white line represents the median, the darkest blue region is the interquartile range, the lighter blue region is the 10-90 percentile, and the lightest blue is the 5-95 percentile range. The right panel displays the statistics but for the nominal MPK, or NMPK.

The first important finding is that both panels of Figure 7 show similar patterns. In both the level and the dispersion of MPK decrease from 1970 to 2005. In particular, they decrease between 1970 and 1985. The fact that the real and the nominal MPK is important. In that respect, adjusting by the relative price of capital to consumption goods is not crucial. The levels are different, though. While the median RMPK is about 20 percent in 1970, the NMPK for that year is about 25 percent.

To describe the MPK further, in Figure 8 we compare the distributions for a given year across countries with different policies.\textsuperscript{25} The top left panel, (a), shows the role of openness.

\textsuperscript{25}We use either the year 1985 or 1995 to maximize the number of observation and the dispersion of policies.
For this we use the index developed by Sachs and Warner (1995) (and later refinements and extensions). A country is open if tariffs are low, there are low non-tariff trade barriers, low black-market premium, the country is no socialist and there is no state monopoly of exports. Notice that, as expected, the dispersion is larger and the right tale fatter for closed countries (blue line). Open countries have lower and quite similar real MPK. The top right panel, (b), countries with more totalitarian government also have higher and more disperse MPK. The bottom left panel, (c), shows that a country’s degree of capital account openness, as measured by Chinn and Ito (2008), is less important in accounting for the differences in MPK. Finally, the right bottom panel (d) shows the same exercise but for countries with developed financial systems and not. A similar pattern emerge: Countries with more developed financial systems have lower and less dispersed MPK. This is what one would expect if financial development affect the economy in the form described by Greenwood et al. (2010, 2013).

5 Gains of Capital Reallocation

To evaluate how well is capital allocated across countries, we now compute what would be the gains of capital reallocation.

There are (at least) two exercises that are relevant. The first reallocation exercises eliminates all the barriers; those that prevent capital from flowing across countries and also those that generate differences in relative prices of capital and consumption goods. Notice that this implies the equalization of real MPK across countries. The second counterfactual exercise allows for reallocation of capital across countries but does not affect the prices of capital and consumption goods. These case implies the equalization of nominal MPK across countries.

In particular, the problem in the case removing all barriers (including those driving $P_{j,t}^Y$, $P_{j,t}^K$) is

$$\max_{\{K_{j,t}\}} \sum_{j=1}^{J} Y_{j,t} \quad \text{s.t.:} \quad \sum_{j=1}^{J} K_{j,t} = \sum_{j=1}^{J} K_{j,t}^Q,$$

(7)
Figure 8: Differences across Observable Policies

(a) (b) (c) (d)

Notes: (a) Use the variable Sachs and Warner (1995) for the year 1985. There are 29 economies classified as opened and 31 as closed. (b) Use the variable “polity” from the Polity IV Project, available here, for the year 1985. There are 30 observations in each group. (c) Use the Chinn and Ito (2008)’s index (KAOPEN) measuring a country’s degree of capital account openness, available here, for the year 1995. There are 38 countries classified as open and 39 as closed. (d) Use the Beck et al. (1999)’s measure of net interest rate margin. There are 21 countries classified as financially developed and 22 as non-financially developed.
were \( K_{j,t}^O \) represents the observed capital stocks. First order conditions (FOCs) of this problem imply equalization of real MPKs.

Similarly, the problem in the case of removing barriers to capital reallocation but keeping those generating differences in \( P_{j,t}^Y, P_{j,t}^K \) is

\[
\max_{\{K_{j,t}\}} \sum_{j=1}^J Y_{j,t} \quad \text{s.t.:} \quad \sum_{j=1}^J \frac{P_{j,t}^K}{P_{j,t}^Y} K_{j,t} = \sum_{j=1}^J \frac{P_{j,t}^K}{P_{j,t}^Y} K_{j,t}^O. \tag{8}
\]

The FOCs of this problem imply equalization of nominal MPKs, as defined above.

Figure 9 presents the evolution of real and nominal gains of capital reallocation. They are both large, between 2 and 6 percent for entire period between 1970 and 2005. Notice that 2 percent gains are very large. For instance, in this period the total output in South America is around 5 percent and in Africa is around 2 percent of the world total output. The equalization of real MPK yields gains that start at 6 percent and decrease steadily until 2.5 in the 2000s. The equalization of nominal MPK yields smaller gains (they start at around 4 percent and decrease to 2 percent) but the trend is similar. In addition, for any particular year, nominal and real gains are very correlated at the country level. If we run a regression of nominal gains on real gains, the intercept is very close to zero and the slope coefficient is between 0.6 and 0.8.

Gains of capital reallocation vary greatly. Figure 10 shows the distribution of real and nominal gains for each year since 1970 to 2005. In general, the figures are quite similar. The white line represents the median, the dark green region the interquartile range, the lighter green region the 10-90 percentile range, and the lightest region the 5-95 percentile range. The distribution of gains are asymmetric: the percentiles 5, 10 and 25 are relatively close to the median and percentile 75, 90 and 95 are further away. For instance, in 1970 the median real gains are around 20 percent, the percentile 5 of gains is around -20 percent and the percentile 95 of gains is more than 80 percent. The median real gains decrease from about 20 percent in 1970 to around zero in 2005. The pattern for nominal gains is similar, but the median gains increase again at the end of the 90s and beginning of the 2000s.
Figure 9: World Output Gains of Capital Reallocation

Notes: The “real” gains are gains in term of real output that obtained equalizing RMPK while “nominal” gains are gains in terms of real output that are obtained equalizing NMPK. There are 79 observations for each year.

Figure 10: Gains of Capital Reallocation, distribution

Notes: This figures shows the percentiles 5, 10, 25, 50, 75, 90, and 95 for each year. The “real” gains are gains in term of real output that obtained equalizing RMPK while “nominal” gains are gains in terms of real output that are obtained equalizing NMPK. There are 79 observations for each year.
Notes: In our sample of 79 countries, there are 13 countries from Africa, 21 from Asia, 23 from Europe, 11 from North and Central America, 9 from South America, and 2 from Oceania.

To characterize the real gains further, we compute the gains by regions—see Figure 11. The differences are striking. Gains in Africa range between 60 percent in 1970 and 20 percent in 2005. In North America, Oceania, and Europe gains are negative in 1970 but very close to zero toward the end of the sample. This happens because in the reallocation capital flows away from this region. Asia and South America have large gains, around 25 percent, in the 70s and early 80s. Gains in South America decrease in the 90s and 2000s and eventually become negative. Gains in Asia decrease but remain positive; they are around 10 percent in the 2000s.

6 On the Reallocation of Capital between 1970 and 2005

The trends in the dispersion of MPK and gains of reallocation suggest that the allocation of capital has improved over time. This may be the case because country save to accumulate capital, or because capital is flowing across capital to countries with higher MPK.
We analyze if capital increased as the simple theory described above prescribes by running regressions for the change in capital between 1970 and 2005. First, capital should have increased in the countries with higher initial NMPK. Thus, we include this variable to control for initial capital scarcity. Then, capital should have increased in countries where if it was not because the increase in capital, the NMPK would have increased. Notice that this occurs if any of the other components of the NMPK increase; i.e., $\phi^R$, TFP, employment, and $\frac{p_y}{p_k}$. Therefore, the changes between 1970 and 2005 for those variables are also included.

The results are presented in Table 3.

Table 3: OLS Regression, $\Delta \log K$

<table>
<thead>
<tr>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \log TFP$</td>
<td>0.314</td>
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<td>0.298</td>
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<tr>
<td></td>
<td>(0.098)</td>
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<td>(0.064)</td>
<td>(0.119)</td>
<td>(0.125)</td>
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<tr>
<td>$\Delta \log L$</td>
<td>0.205</td>
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<tr>
<td></td>
<td>(0.145)</td>
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<td>(0.192)</td>
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<td>$\Delta \log \phi^R$</td>
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<td>-</td>
<td>(0.327)</td>
<td>(0.351)</td>
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<td>$\Delta \log \frac{p_y}{p_k}$</td>
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<td>(0.119)</td>
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<td>$R^2$</td>
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<td>0.6097</td>
<td>0.2761</td>
<td>0.6449</td>
<td>0.5962</td>
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</tbody>
</table>

Notice that the findings above are apparently in contradiction with the findings Gourinchas and Jeanne (2013): “Capital flows [...] allocation across developing countries is the opposite of the predictions of standard textbook models: capital does not flow more to the countries that have a higher marginal product of capital. [...] We call it the allocation puzzle.”

There are at least three caveats. First, Gourinchas and Jeanne (2013) do not analyze changes in total capital, but instead the part of that accumulated externally. Second, no-
tice that there statement is conditional on initial capital scarcity, but they control by $\frac{Y}{K}$ instead of NMPK. As columns (3) and (6) in Table 3 shows, our results depend critically on controlling by the right measure for initial capital scarcity. Finally, Gourinchas and Jeanne (2013) emphasize the change in TFP but the same effect of an increase in TFP should be expect from that of $\phi^R$, employment, and $\frac{P_w}{P_k}$. Again, we show that controlling for those changes is important to get the coefficient in the change in TFP right.

7 Conclusions
References


