Online Appendix: "Natural Resources and Global Misallocation"

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In this Appendix we describe in detail our methodology to compute the *rent flows* from natural resources. We use to these *rent flows* to construct our measure of the output share of natural resources in the main text. The point of departure of our work with respect to Caselli and Feyrer (2007) (from now on, CF) is methodological. To compute the output share of natural resources we use *rent flows* data alone as opposed to the measure based on natural *capital stocks* implemented by CF. By using direct data on the *rent flows* we avoid two set of important assumptions embedded in CF:

(i) The equalization of the rate of return of natural and other physical capital, and

(ii) Assumptions on the values of the time-horizon for the extraction of rents T, the future path (growth) of rents g and the discount rates r used to capitalize rents into natural capital stocks. These are the stocks used by CF to equate returns in (i).

As emphasized in our main text, we find that our new estimates have large quantitative consequences for the original results in CF regarding the correction of MPKs and global misallocation. In particular, we find that the MPK equalization result in CF is no longer valid. That is, it all boils down to how new and improved is the our measure of output shares of natural resources compared to that of CF. In this context, our methodology based solely on current natural *rent flows* to compute the output share of natural resources not only renders the assumptions (i)-(ii) in CF unnecessary, but it also shows that the assumptions (i)-(ii) bias the results in the direction towards MPK equalization. See our main text for a detailed discussion.

We first discuss our methodology to construct natural resource *rent flows* in Section A. We show the full list of countries for which these data are available in Section B.

A Construction of Natural Resource *Rents Flows*

We estimate payment to rents accrued by natural resources for: (a) energy and mineral (subsoil) resources, (b) timber resources, (c) croplands, and (d) pasturelands. We follow the same classification as The WB's project *Where is the Wealth of Nations?* (World-Bank, 2006), and its sequel, *The Changing Wealth of Nations*. We adopt this grouping, but also follow Caselli and Feyrer (2007) by adding a category, (*e*) urban land, also as a non-relocatable resource across countries.

A.1 Energy and Mineral (Subsoil) Resources

For subsoil, the rent estimates were available directly from the World Bank. The available data on subsoil resources rents runs from 1970. The measurement is described in great detail in pages 27-36 of Kunte et al. (1998). To summarize it here, the WB computes the subsoil rents using the formula:

$$\text{Rent} = \text{Production Volume} \times (\text{International Market Price} - \text{Average Unit Production Cost})\,.$$

The International Market Price is taken from United Nations Conference on Trade and Development (UNCTAD, multiple years). Production volume data was taken from United Nations (UN) Energy Statistics database. The Average Unit Production Cost was obtained from multiple country studies, listed in Kunte et al. (1998). They have direct measure for 32 countries/regions. For these countries, they use their own measurement. For the others, they assign a surrogate country, based on proximity. This is done for each of the different subsoil products, e.g. oil, natural gas, metals, coal, etc. Table B-1 in Kunte et al. (1998) describes the surrogates used for each of the oil producing countries. For example, for Argentina, we use the Argentinian measurement itself. For Chile, the average cost of production is based on Argentinian estimates. For Colombia, the estimated cost is based on Venezuela. For Tajikistan the estimated cost is from Russia. And so on.

Again, the surrogate countries vary by product. For example, for Guatemala, the surrogate for oil is Mexico, but for natural gas is Venezuela. In any event, all of these aspects are discussed in great detail in Kunte et al. (1998) and their appendix B.

A.2 Timber Resources

Timber rents were also directly available from the World Bank. See, pages 36-38 of Kunte et al. (1998) for the methodology and data sources. Total volume of production of roundwood and fuelwood for the different countries and periods was taken from the FAO Forestry database, World Resources Institute. Not all countries and years are fully. Kunte et al. (1998) explain how they interpolate missing countries/years. The rental rate is estimated similarly to what we explained already for oil, they use different surrogate countries for the different regions. For example, for African countries, they used rental from studies on West African rainforest (30% rental rate) and Ghana (26%.) For Asian countries they use studies for Philippines, Thailand and Indonesia. For Latin America, they use studies from Brazil, Costa Rica and Ecuador.

Note that we do not require the valuation of standing wood. We do not have to make any valuation or distinction between available and non-available forest, as they are not included neither in the GDP of the country nor in the estimated timber rents. This is one additional advantage of only requiring rents flow data and not valuation of wealth stocks.

A.3 Cropland Resources

First, we describe the list of country-products rental rate for which we have data and discuss the dispersion across country-pairs. Second, we explain our methodology for computing the rental rate for croplands for each country. Third, we show that our main results for the implied behavior of global misallocation is very robust, even to extreme variations in the rental rate of croplands.

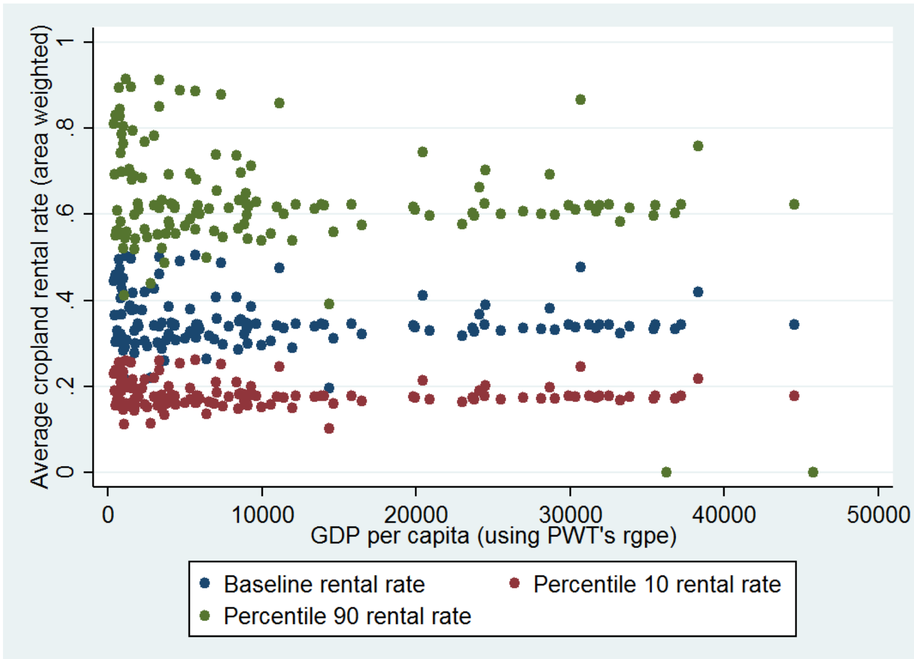
The available data on rental rates is presented in the next table. The table indicates, for each crop, the countries for which the World Bank had collected data (from individual country studies). The third column of the table indicates the average rental rate for each crop on the basis of the countries with data for each crop. There are multiple crops for which there is no data (mangos, berries, sorghum, etc.) Also, the number of countries available varies for each crop, from (8 countries for Bananas, 4 for coffee and wheat, 3 for soy, 1 for a few others, etc.) Notice also the large variation in the rental rates across these crops, ranging from 51% and 42% for rice and bananas, respectively, to 11% and 8% for tomatoes and coffee, respectively. Given the large variation and the sparsity in this data, we will conduct robustness exercises for the main results of the paper. Before we explain those, we now explain the construction of cropland rates.

Crop	Countries	Average Rental Rate (%, World Bank)
Bananas	Brazil, Colombia, Costa Rica, Cote d'Ivoire, Ecuador, Martinique, Suriname, Yemen	42
Wheat	Ecuador, Egypt, Colombia, Yemen	34
Coffee	Costa Rica, Nicaragua, Peru, Vietnam	8
Soybeans	Argential, Brazil, and China	27
Maize	China, Egypt and Yemen	29
Rice	Egypt, Indonesia, Lao	51
Oranges	Brazil, Egypt	26
Grapes	Argentina, Moldova	31
Broad Beans	Egypt	38
Cotton	Egypt	31
Long Berseen	Egypt	44
Short Berseen	Egypt	16
Potatoes	Egypt	12
Sugar Beets	Egypt	25
Sugar Cane	Egypt	47
Sunflower	Egypt	32
Tomatoes	Egypt	11

Our method to estimate the aggregate rents of croplands is based on first estimating an average cropland rental rate for each country, and then apply this average rate to the FAOSTAT series on the total value of crops for each country for all the years. The average cropland rate is based on a weighted average of rental rates for specific crops, where the weight of the averages is based on each countrys own share of crops.

To deal with the missing information about country-crop-year rental rates, our fixed country average cropland rental rate is computed in two stages. In the first stage, rental rates were computed for each of the different groups of crops (cereal, fruits, etc.).For example, the rental rate for cereals is the weighted average of the rental rates for wheat, maize and rice, using the countrys cultivated area of these three crops as the weight for the country. This rate is next applied to all cereals, a group that includes also barley, buckwheat, canary seeds, fonio, millet, mixed grains, oats, quinoa, rye, sorghum, triticale, and other cereals not elsewhere classified. The same procedure is done for all the different subcategories of crops, e.g. fruits, legumes, etc. Once a rental rate is computed for each group of products, a weighted average of all cropland products is computed using the cultivated area of each group as the weight.[1]

The blue dots in the next figure show the rental rate for croplands obtained for each of the countries in our sample for the year 2000. The average value is about 30 percent and the dispersion is quite limited, as most of the countries have rental rates between 25 and 50 percent.



We now report the results using extreme alternative assumptions of the rental rates for crop lands. These two extreme variations in the measurement of cropland rents consist in multiplying the cropland rents of all countries by a factor equal to the ratio between the percentiles 10 and 90 of the cropspecific rates of the distribution in the table above relative the world average of the cropland rates:

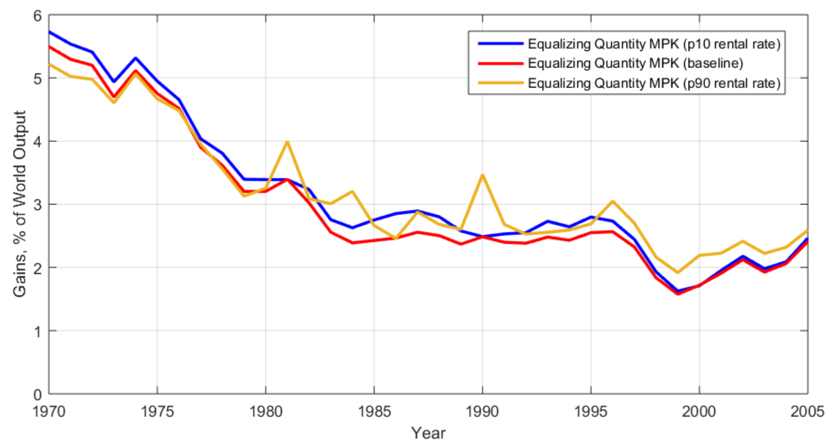
$$Crop\ Rent^{perc\ 10\ or\ 90}_{country,\ year} = \frac{Crop\ Rent^{observed}_{country,\ year} \times Crop\ Rate^{perc\ 10\ or\ 90}}{Crop\ Rate^{average}_{world,\ year}}$$

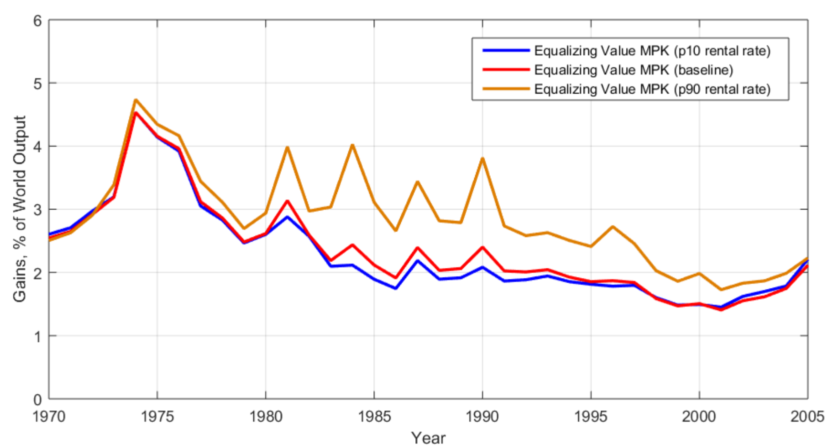
Scaling up or down the cropland rates in this way preserves the relative dispersion across the countries rents and the relationship of those rents with the countries GDP. The resulting counterfactual rates, for the year 2000, are shown in the Figure above using green and purple dots. The idea is to see how much our results change if we make these extreme assumptions about the rental rates of croplands. The same figure shows two other cases (green and purple dots.)

[1]The weights were constructed using cultivated areas of production but we checked that using production values did not change the results.

In particular, the green dots in the figure shows that evidently, scaling the cropland rates to be in the 90-th percentile of crop-specific rates would greatly enhance the potential role played by those rents for the results on the measurement of MPKs and of global misallocation of physical capital.

However, as the next two figures show, the main results of our paper are not altered in a substantial way, even under these two extreme assumptions. The left panel reproduces our global misallocation counterfactual exercises using the quantity MPK, while the right panel does that for the value MPK. In both graphs, the red line reproduces the one in our paper; the blue line is the case when we use the lower case, percentile 10% crop specific rental rate to scale down the aggregate cropland rates for the country, while the yellowish line does it for the upward extreme that uses the 90th percentile crop specific rate.





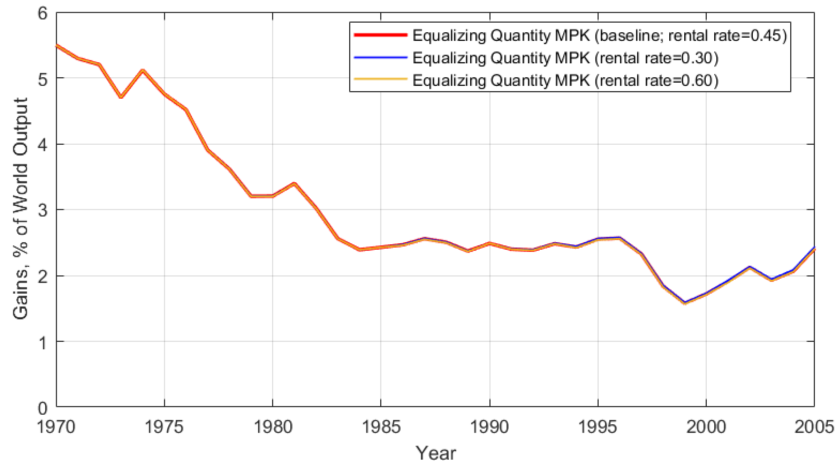
Both figures clearly show the three main patterns discussed in the paper are valid. Clearly, under both extremes (a) there is significant misallocation, around 2% of world output at the end of the sample, (b) there has been a clear trend towards efficiency from 1970 to 2000. Notice that both results are not driven by relative price differences across countries. We can also show that implications for the joint reallocation of physical and human capital in the paper are robust to these extreme variations in the rental rate of croplands.

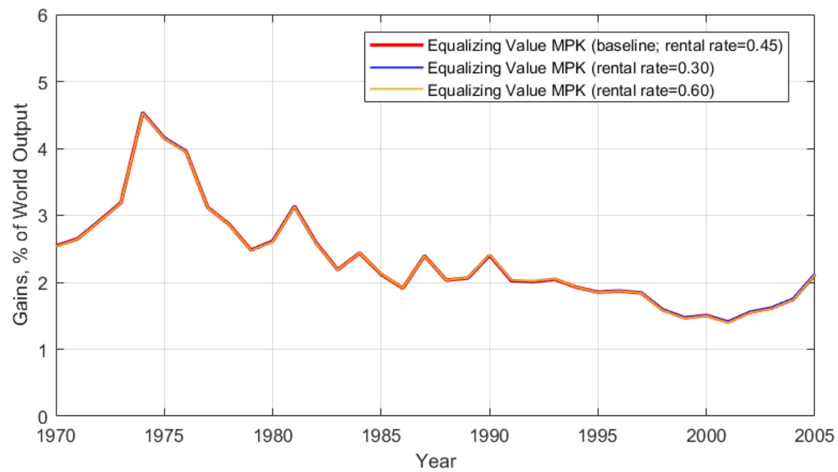
An entirely different approach to obtain cropland shares of output would be to use farm-level payments to rented in (or rented out) land from micro data. Unfortunately, farm surveys that incorporate rental payments of land are scarce. One notable exception are the Integrated Surveys of Agriculture (ISA) mentioned above which are available for few African countries, two of which overlap with our FAOSTAT sample data, Nigeria and Tanzania. With these ISA data we can compute rates of return as the ratio of land rental payments to cultivated rented land. This measurement is not free of caveats, as roughly only 15% of land is in the market for rents in these countries (Restuccia and Santaeulàlia-Llopis, 2017). This implies that we need to use the renting sample to impute rents to the farmers that do not rent. With this caveat in mind, simply by assuming that the average return from the renting sample is the same across all farms, we obtain a value of cropland share for Nigeria of 2.00% and for Tanzania of 8.53%.[2] Note that this implies that the micro-data pushes down even further the estimates based on FAOSTAT for which we find values of cropland shares for Nigeria of 6.78% and for Tanzania of 12.8%. It is very unfortunate that these type of ISA data are available for only a handful of African countries (DeMagalhaes and Santaeulàlia-Llopis, 2017). We added this discussion in the main text.

A.4 Pastureland Resources

For the rents of pasturelands (which include beef, lamb, milk, and wool) we follow the World-Bank (2006) by estimating that 45% of the total value of output from FAOSTAT accrues as rents to land. For values of 30% and 60% for the share of pasture land we find global misallocation results almost identical to our benchmark value of 45%. We seriously doubt that improving on the measurement of the rental rate of pasturelands would change our results. To see this, we computed the results using 30% and 60% as the rental rate for those lands. The next figures show those results along with the results in the paper, which uses the rate of 45% used by World Bank.

[2]The value of 2.00% for Nigeria is computed by multiplying the ratio of land rental payments to agricultural output from ISA data, 6.10%, with the agricultural share of value added from the WB, 32.75%. The same procedure is applied to Tanzania to obtain a value of cropland shares of 8.53 using a ratio of land rental payments to agricultural output computed from ISA data of 28.01% and an agricultural share of value added from the WB of 30.46%. Although not in our FAOSTAT data set, we can do the same exercise for Malawi using the ratio of land rental payments to agricultural output from ISA data 39.0% (Restuccia and Santaeulàlia-Llopis, 2017) and an agricultural share of value added from the WB of 37.10%





As is evident for the picture, the robustness of our results to variations in the rental rate of pasture lands is even stronger than for the rate on croplands. The figures dont even move! We briefly discuss this result in footnote 11, page 7 of our new version of the paper.

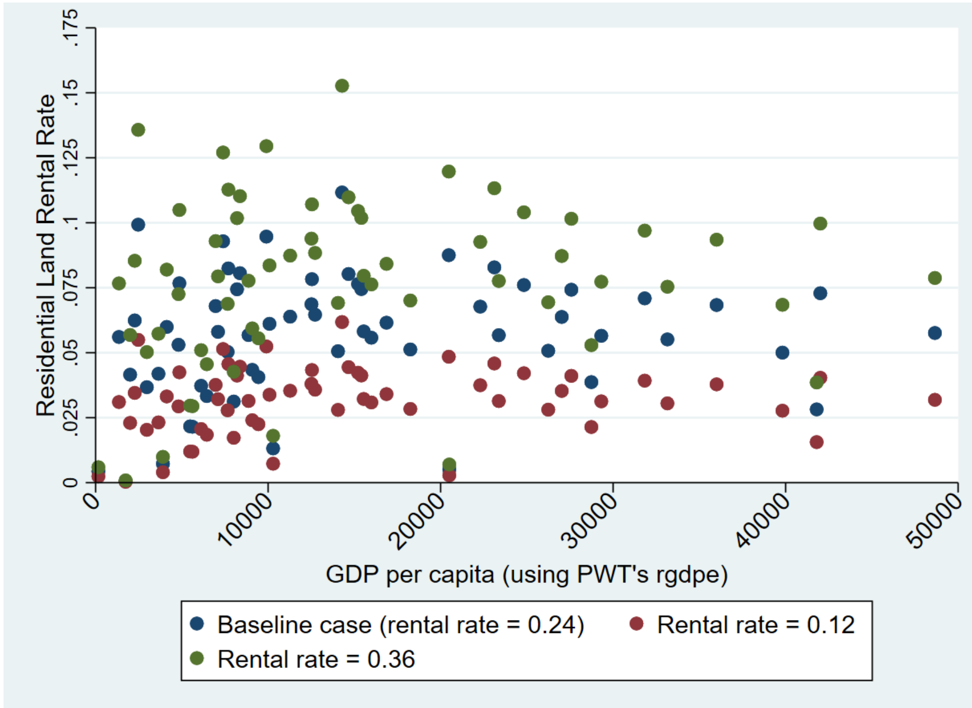
However, we found estimations of rental rates for some countries and years for some products. Below, we show the data available on rental rates for milk, which is one of the main components of pasture lands. There are similar numbers for cattle and other products of pasture land. If you and the Editor think it would be useful, we could apply the same method that the World Bank used for Oil to this case. However, the results in the graphs above suggest that the global gains of misallocation are very unlikely to change.

Pastoral Land Usage: Milk	
Continent	Rental Rate
Europe	20.2
Africa	41.8
Americas	46.1
Asia	30.2
Oceania	34.5

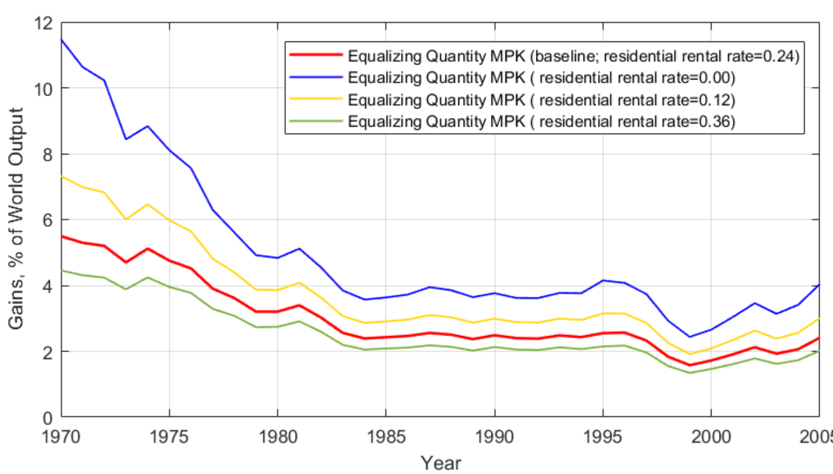
A.5 Urban Land

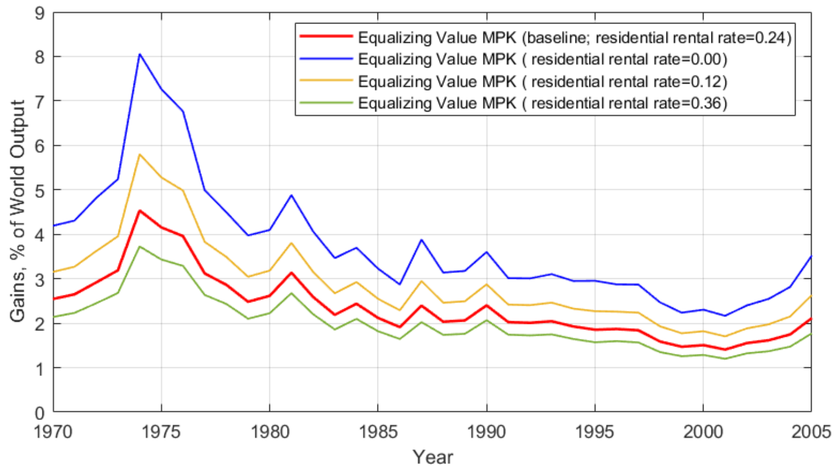
We adopt the assumption in CF of allowing 24% of the rents of physical capital as rents to urban land. We we did it to make our results as comparable as CF, making it clear that the differences in the two papers were not driven by urban land. Indeed, if we take them out, the results of our paper would be qualitatively the same but quantitatively much stronger. That is, we would find more global misallocation, a stronger trend towards efficiency in between 1970. The patterns in the reallocation of physical and human capital would be qualitatively the same but their magnitude would be larger.

Taking 24% of physical capital rents would imply variation across countries and years on the shares of outputs accrued as rents to urban land, because the physical capital output shares of countries vary. The blue dots in the next figure show, for the year 2000 and for our sample of countries, the implied urban land shares using the 24% in CF. The red and green dots show the implied urban land rates assuming instead 12% and 36%, respectively.



As shown by this figure, there is not a systematic variation across GDP levels. The range of the rates in the benchmark case is between 0 and 10%. This range moves proportionally with changes to the 24% rate. In the next figures, we show the global misallocation results when we assume that the urban land rents are 36, 24 (our benchmark in the paper), 12, and 0. In the left panel, we show the global misallocation results using the quantity MPK and in the right panel the results for the value MPK.





As indicated above, the qualitative patterns are the same. Quantitatively, reducing the amount of rents accrued to urban land would increase the implied degree of misallocation and would imply a steeper trend towards efficiency between 1970 and mid-1980s. We discuss this result in the main text.

Our assessment is that the rent of 24% is the most appropriate for our exercise for several reasons. First, it allows our results to be comparable with CF, and as such, allows us to make it clear that it is the difference in the measurement of the other natural resources that drives the differences in the results. Second, returns to urban land shouldnt be assumed to be part of physical capital and a rate of 24%, while coming from an isolated study for Canada, remains as the only measure available.

B List of Countries

Our methodology allows us to extend the data that we put together relative to the one used in CF because data on *rent flows* are available for more country and years than the *capital stocks* used in CF. We compute the share of natural resources of output for a benchmark set of 79 countries for which data are available for every year from 1970 to 2005. We organize these countries by regions: **Africa:** Burkina Faso, Côte d'Ivoire, Cameroon, Kenya, Morocco, Mozambique, Niger, Nigeria, Senegal, Tunisia, Tanzania, South Africa, and Zimbabwe. **Asia:** Bahrain, China, Hong Kong, Indonesia, India, Iran, Israel, Jordan, Republic of Korea, Kuwait, Sri Lanka, Malaysia, Oman, Philippines, Qatar, Saudi Arabia, Singapore, Thailand, Turkey, and Taiwan. **Europe:** Austria, Belgium, Bulgaria, Switzerland, Cyprus, Germany, Denmark, Spain, Finland, France, the United Kingdom, Greece, Hungary, Ireland, Iceland, Italy, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, and Sweden. **Latin America and the Caribbean:**

Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Ecuador, Costa Rica, Dominican Republic, Guatemala, Honduras, Jamaica, Mexico, Panama, Peru, Paraguay, Trinidad & Tobago, and Uruguay. **Oceania:** Australia and New Zealand. Japan and the United States, and Canada were left separated for their substantial role in the world economy.

We exclude Burkina Faso, Nigeria, and Oman from our reallocation exercises because these countries do not have data on human capital. This implies a total of 76 countries for our benchmark sample. 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.

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