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Natural Resources and Total Factor Productivity Growth in Developing Countries

Testing A New Methodology

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Abstract

Estimates of total factor productivity growth, a measure of increases in the efficiency of production, have traditionally been based on a two-factor model of labor and fixed capital. Because profits are measured residually in the System of National Accounts, they implicitly include rents on natural resource exploitation, with the result that the contribution of fixed capital to growth in the inputs to gross domestic product is misstated, particularly in resource dependent developing countries. This leads to incorrect measures of total factor productivity growth. Using data on natural resources from the World Bank's Wealth of Nations database and methods combining the Solow growth accounting model with recent work at the Organisation for Economic Co-operation and Development, this paper makes new estimates of total factor productivity growth for 74 developing countries over 1996–2014. In the aggregate, including natural resources as a factor of production increases estimated total factor productivity growth across all country income classes and regions of the world when compared with the traditional two-factor approach. In addition, the estimated total factor productivity growth including natural resources is less volatile over time in the great majority of countries compared with the traditional approach. The availability of World Bank data on natural resource quantities and rents for a wide range of countries suggests that natural resources should be included in total factor productivity growth estimation going forward. Further research could focus on the distinctive roles played by different natural resource endowments.

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"Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker."

Paul Krugman

1. Introduction

As the quote above suggests, in a world of decreasing marginal returns to factors of production, the only way to ensure increasing growth and prosperity is to increase the efficiency of factor use. Rather than focusing on a sole production factor such as labor, economists beginning with Solow (1957) have developed methods of growth accounting which derive an indirect measure of the rate of change in the efficiency of use of all factors of production, termed 'total factor productivity' (TFP) growth or 'multi-factor productivity' (MFP) growth. With the exception of recent work at the OECD (discussed below), estimates of TFP growth at the macroeconomic level have excluded natural resources as a factor of production – a serious omission when considering developing countries. Natural resources make up on average 47% of total wealth in low-income countries, 36% in Sub-Saharan Africa, 27% in lower-middle-income and 17% in upper-middle-income countries. A particular concern is that agricultural land makes up 62% of natural wealth in low-income countries. The omission of natural resources was largely owing to a lack of comparable cross-country data on natural resource stocks and flows, measured according to System of National Accounts (SNA) standards.

The publication by the World Bank of *The Changing Wealth of Nations 2018* (Lange, Wodon and Carey 2018) has filled this gap, with data on the value of natural resource stocks and flows across 141 countries and spanning the period from 1995 to 2014. The OECD pioneered methodology to include natural resources (minerals and energy) in TFP estimations for OECD-member countries and a few other countries (Brandt et al. 2017). This paper tests the OECD approach for a broader set of natural resources and with some modifications described in section 2, for 74 middle- and low-income countries, exploiting the World Bank wealth database.

This study generalizes the preliminary 'version 0' estimates of TFP growth with natural resources by Hamilton (2018) in *The Changing Wealth of Nations 2018*. It is important to emphasize at the outset that the results reported here represent 'version 1' estimates and future work will refine the estimates. The intent of this paper is to test the methodology for developing countries, demonstrating the extent to which including natural resources in TFP growth measures matters. We will not attempt, at this early stage, to provide in-depth analysis and policy conclusions, which will be addressed in future work.

The work presented here builds on a large literature on macro-level growth accounting and TFP measurement (Hulten 2010). However, it is important to note that there is also a rich literature on measuring economic efficiency at the sector or firm level, using methods and data that are much more fine-grained than what will be presented here. The focus on the macro scale has advantages, in particular the ability to pick up, however indirectly, the effects of policy and institutional reforms that can have macroeconomic consequences, in addition to technical progress. Using the World Bank *Wealth of Nations* data also means that we can do broad comparisons of country, regional and income-class performance on TFP growth over time.

The *Wealth of Nations* data include estimates of fixed capital stocks (based on the Penn World Table), human capital, and stocks and flows of natural resources in both quantity and value terms. To produce the estimates of TFP growth below, the World Bank data are augmented by UN national accounts data on the composition of value added, total remuneration of labor from the Penn World Table, as well as the number of persons employed aged 15 or more from the ILO. We also employ indices of real agricultural output from the FAO.

We begin section 2 by considering the general approach to productivity measurement and the specific issues associated with the incorporation of natural resources into growth accounting, followed by a detailed specification of the methods and data used to measure TFP growth. While it may seem at first glance that adding another factor to the calculation would reduce TFP growth estimates, we will demonstrate that is not always the case. Results of the TFP growth calculations and key findings are highlighted in section 3. The final section sums up the results, identifies how new measures of TFP could be used for policy work in the World Bank, and suggests areas for further work.

2. Methods and Data

TFP growth is not a particularly intuitive concept for many people, but a simple formalization may help. If we compare the growth rate of production in an economy, which is measured by GDP, with a weighted average of the growth rate of the factor inputs to production, we will typically find a gap between the two. This gap is defined to be the growth rate of some unmeasured input to production which we term Total Factor Productivity. Determinants of this gap could include technological change, changes in economic policies and institutions, or changes in the management practices of firms – to name just a few. This section derives the equations used to estimate TFP including natural resources, then discusses the data used and how certain data challenges were addressed.

To formalize the concepts, we denote total factor productivity as A, and its growth rate as g_A. Similarly, we denote GDP as Y and its growth rate as g_Y. We assume that the inputs to production can be categorized as fixed capital K, with growth rate g_K, labor L with growth rate g_L, and natural resources N, with growth rate g_N. If we assume that there are corresponding shares of these factors in value added, denoted s_K, s_L and s_N, then these shares will sum to one. Crucially, there is generally no direct measure of the returns to fixed capital in the SNA, so it is defined as a residual after measuring wages (the contribution of labor to value added) and resource rents (the contribution of natural resources to value added); formally we can say that

$s_K = 1 - s_L$ in the case with no explicit measure of natural resource rents, and $s_K = 1 - s_L - s_N$ when such a measure does exist. s_K is, in an important sense, too large when data on resource rents are lacking.

If we assume that we have no direct measure of natural resource rents then the traditional approach to TFP growth measurement has been to calculate,

$$g_A = g_Y - (s_K g_K + s_L g_L)$$

This formalizes the statement above – TFP growth is measured as the difference between the growth rate of GDP and a weighted average of the inputs to production. In this formula the weights are, quite naturally, the share of the factors in value added, s_K and s_L.

If we have measures of the natural resource rents and so can measure the share of rents in value added s_N and the growth rate of resource inputs g_N, then s_K is correspondingly lower and we can write the formula for TFP growth measurement including natural resource inputs as,

$$g_A = g_Y - (s_K g_K + s_L g_L + s_N g_N)$$

Now the weighted average of inputs to production includes the contribution to natural resources. These two formulae are the basis for measuring TFP growth with and without natural resource inputs in this study.

Recent work at the OECD has provided an approach to treating natural resources as production factors, which they have applied to selected countries, mainly OECD member countries, using World Bank data on minerals and energy (Brandt et al. 2017; See Annex I for the OECD approach to TFP). An important finding, derived below and by Brandt et al. (2017), is that there is a systematic relationship between TFP growth measured using only factor data on capital and labor, and TFP growth that also measures natural resources as a factor of production. If we denote TFP growth excluding natural resources as g_A^{XNR} and with natural resources as g_A^{WNR}, it will be shown below that

$$g_A^{WNR} = g_A^{XNR} + s_N(g_K - g_N) \,. \qquad (1)$$

Where s_N is the GDP share of natural resource rents, while g_K and g_N are the growth rates of fixed capital and natural resources measured in volume terms. Given the high resource dependence of developing countries, this formula suggests there are potentially significant biases when measuring TFP growth in developing countries while ignoring natural resources as production factors.

Analytical framework

The framework we use for estimating TFP growth with natural resources as a factor of production is inspired by the recent work of the OECD. In what follows we adapt the approach

of Solow (1957) to include natural resources.[1] The basic assumptions in Solow (1957) are that production factors are valued at their marginal product, that production exhibits constant returns to scale, and that technical progress is Hicks-neutral. Assuming that all variables are functions of time unless stated otherwise, the equation for GDP Y when capital and labor are the only production factors is,

$$Y = AF(K, L) \qquad (2)$$

Here A is the familiar index of efficiency. We introduce a natural resource input N to production which is costly to produce, with cost function $f(N)$. The economic value of a marginal unit of resource is therefore given by $(F_N - f')$, i.e. the marginal rental value. Aggregate production can be consumed, invested or spent on resource extraction. The resource extraction cost is an intermediate input to the economy.

As in Solow (1957), we assume that production $AF(K, L, N)$ exhibits constant returns to scale.[2] If we assume that the marginal cost of resource extraction is constant at $\bar{f}$, so that marginal cost equals average cost, then we can write GDP as,

$$Y = A((F(K, L, N) - \bar{f}N) \qquad (3)$$

In this formulation the efficiency factor A affects GDP as a whole and it is straightforward to show that GDP exhibits constant returns to scale in the production factors. GDP therefore equals the sum of resource rents, wages and the returns to fixed capital.

GDP growth is derived using expression (3),

$$\begin{aligned} \dot{Y} &= \dot{A}((F(K, L, N) - \bar{f}N) + AF_K\dot{K} + AF_L\dot{L} + A(F_N - \bar{f})\dot{N} \\ &= \tfrac{\dot{A}}{A}Y + AF_K\dot{K} + AF_L\dot{L} + A(F_N - \bar{f})\dot{N} \qquad (4) \end{aligned}$$

It follows that,

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{AF_K K}{Y} \cdot \frac{\dot{K}}{K} + \frac{AF_L L}{Y} \cdot \frac{\dot{L}}{L} + \frac{A(F_N - \bar{f})N}{Y} \cdot \frac{\dot{N}}{N} \qquad (5)$$

and the TFP growth rate is therefore,

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \frac{AF_K K}{Y} \cdot \frac{\dot{K}}{K} - \frac{AF_L L}{Y} \cdot \frac{\dot{L}}{L} - \frac{A(F_N - \bar{f})N}{Y} \cdot \frac{\dot{N}}{N} \qquad (6)$$

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[1] The OECD approach builds on Jorgensen (1963) to measure the annual user cost of fixed capital and derives TFP growth based on the decomposition of the costs of production. See Annex I.

[2] Note that constant returns to scale is used in this section to simplify the presentation. However, constant returns to scale are not strictly required to derive the empirical measures of TFP growth including natural resources presented in this report – it is sufficient to assume that the relevant weights in calculating the average growth rates of factor inputs are the corresponding shares of value added for each factor.

While expression (6) may appear to suggest that $\bar{f}N$ increases TFP growth, this interpretation is not entirely correct. Since $\bar{f}N$ is an intermediate cost of production, some incremental amount of capital and labor and natural resource must be used in its production. The term $\frac{\bar{f}N}{Y} \cdot \frac{\dot{N}}{N}$ simply offsets the weight of this incremental use of capital, labor and natural resource in measured TFP growth.

In expression (6), $\frac{AF_K K}{Y}$ is the factor share of fixed capital in GDP, which we denote s_K, while $\frac{\dot{A}}{A}$ is the growth rate of TFP, denoted g_A. Generalizing the notation, expression (6) can then be written as,

$$g_A = g_Y - s_K g_K - s_L g_L - s_N g_N \qquad (7)$$

As a result of the reapportioning of profits between fixed capital and natural resource rents described in the subsection below on data sources, the factor share of fixed capital can be measured residually as $s_K = 1 - s_L - s_N$ (this assumption is also used in Brandt et al. 2017 for countries where there are insufficient data to measure the annual user cost of fixed capital). For countries where natural resource rent data exist, the TFP growth rate with natural resources (WNR) is therefore calculated as,

$$g_A^{WNR} = g_Y - (1 - s_L - s_N) g_K - s_L g_L - s_N g_N \qquad (8)$$

For countries where no natural resource rent data exist, the traditional approach to calculating TFP growth has been to start with the simple Solow model of expression (2). The factor share of fixed capital in GDP and value added excluding natural resources (XNR) becomes $1 - s_L$ and the calculated TFP growth rate becomes,

$$g_A^{XNR} = g_Y - (1 - s_L) g_K - s_L g_L \qquad (9)$$

The difference in calculated TFP growth rates for the two approaches is therefore given by,

$$g_A^{WNR} - g_A^{XNR} = s_N (g_K - g_N) \qquad (10)$$

This is just expression (1), formally derived. The TFP growth rate estimated with natural resources will exceed the growth rate estimated excluding natural resources if the growth rate of fixed capital exceeds that of natural resources. The difference between the two TFP growth rates is proportional to the natural resource rent share of GDP.

This result extends easily to the case where there are two natural resources N_1 and N_2 with factor shares s_{N_1} and s_{N_2}, and growth rates g_{N_1} and g_{N_2}. The aggregate share of natural resources in GDP and the weighted average growth rate of these resources are given by,

$$s_N = s_{N_1} + s_{N_2} \text{ and } g_N = \left(\frac{s_{N_1}}{s_{N_1} + s_{N_2}} \cdot g_{N_1} + \frac{s_{N_2}}{s_{N_1} + s_{N_2}} \cdot g_{N_2}\right) \qquad (11)$$

With these definitions, the relationship between TFP growth with and excluding natural resources is again given by expression (10), and this result generalizes to more than two natural resources in the obvious way.

In terms of measurement, the growth rates of labor and natural resources are measured in volume terms (number of persons employed[3] and physical quantities of natural resources), while real values are used to measure the growth rate of fixed capital.

Brandt et al. (2017) derive the discrete time version of expressions (6) and (7), starting with the observation that $\frac{d}{dt}\ln(A) = \frac{\dot{A}}{A}$. They take logarithms of the ratios of factors at times t and $t-1$ based on a Taylor series approximation, but note that the discrete time expression corresponding to expression (6) can use factor shares for labor (for example) measured either as, $s_L(t) = \frac{F_L(t)L(t)}{Y(t)}$, which yields a Laspeyres index, or as $s_L(t-1) = \frac{F_L(t-1)L(t-1)}{Y(t-1)}$, which is a Paasche index. Since neither approach is obviously better than the other, they opt for a Törnqvist index which averages the factor shares. Denoting a simple average by a bar, we can therefore write the factor share of labor at time t as,

$$\bar{s}_L = 0.5 \cdot \left(\frac{F_L(t)L(t)}{Y(t)} + \frac{F_L(t-1)L(t-1)}{Y(t-1)}\right). \tag{12}$$

This obviously generalizes to the other factors of production and to shares of the overall factor returns to natural resources as shown in expression (11).

Following Brandt et al. (2017), we can therefore write the logarithmic form of the discrete time decomposition of TFP growth as,

$$\ln\left(\frac{A(t)}{A(t-1)}\right) = \ln\left(\frac{Y(t)}{Y(t-1)}\right) - \bar{s}_K \cdot ln\left(\frac{K(t)}{K(t-1)}\right) - \bar{s}_L \cdot ln\left(\frac{L(t)}{L(t-1)}\right) - \bar{s}_N \cdot ln(\frac{N(t)}{N(t-1)}) \tag{13}$$

Taking exponents, this becomes

$$\frac{A(t)}{A(t-1)} = \left(\frac{Y(t)}{Y(t-1)}\right) \cdot \left(\frac{K(t)}{K(t-1)}\right)^{-\bar{s}_K} \cdot \left(\frac{L(t)}{L(t-1)}\right)^{-\bar{s}_L} \cdot \left(\frac{N(t)}{N(t-1)}\right)^{-\bar{s}_N} \tag{14}$$

Noting that $\frac{A(t)}{A(t-1)} = \frac{A(t)-A(t-1)}{A(t-1)} + 1 = g_A + 1$, the *rate* of growth of TFP is therefore,

$$g_A = (g_Y + 1) \cdot (g_K + 1)^{-\bar{s}_K} \cdot (g_L + 1)^{-\bar{s}_L} \cdot (g_N + 1)^{-\bar{s}_N} - 1 \tag{15}$$

Applying the re-apportionment of profits into returns to fixed capital and resource rents, the factor share of fixed capital *with natural resources* is therefore given by $\bar{s}_K = 1 - \bar{s}_L - \bar{s}_N$. Paralleling the continuous time case, we calculate the factor share of fixed capital *excluding*

[3] Ideally the labor input would be measured in hours worked or full-time-equivalent employees, but these data are lacking for most developing countries. For OECD countries Brandt et al. (2017) use hours worked.

natural resources as $\bar{s}_K = 1 - \bar{s}_L$. Applying expression (15), the ratio of the growth rates of TFP with and excluding natural capital reduces to,

$$\frac{g_A^{WNR}+1}{g_A^{XNR}+1} = \left(\frac{g_K+1}{g_N+1}\right)^{\bar{s}_N} \tag{16}$$

In discrete time, the TFP growth rate with natural resources exceeds the growth rate calculated excluding natural resources if fixed capital is growing faster than natural resources. The difference in the growth rates increases with the share of natural resources in GDP. This result is qualitatively exactly the same as the continuous time case. The generalization of this equation for two or more natural resources is given in Annex II.

In presenting the empirical results of these calculations in the next section, it is important to note that the calculation of the average rate of TFP growth for a given country is calculated as the average annual rate of change (AARC) of TFP. To measure the AARC of TFP growth over n years we must calculate the geometric mean of $g_A(t) + 1$ over all years, then subtract 1. Here $g_A(t)$ is the growth rate of TFP in year t:

$$\text{AARC} = ((g_A(1) + 1) \cdot (g_A(2) + 1) \ldots \cdot (g_A(n) + 1))^{\frac{1}{n}} - 1 \tag{17}$$

Because this is not a simple average of growth rates, we calculate the measure of variation in the TFP growth rate as the root-mean-squared (RMS) of the differences between the annual measures of TFP growth and the AARC. This notation signals that what is presented is not a classic standard deviation.

For calculating aggregates of TFP growth, such as for low-income countries as a group, or developing countries in South Asia, we measure a simple weighted average of the country figures, with country GDP in constant US dollars providing the weights.

Data sources

Table 1 presents the data sources for the TFP growth calculations. For detailed information on the measurement of the natural resources appearing in the *Wealth of Nations* database, the reader is referred to Appendix A of *The Changing Wealth of Nations 2018,* or the detailed methodology documentation which can be found at https://datacatalog.worldbank.org/dataset/wealth-accounting.

Table 1. Data sources

Indicator	**Source**
Resource rents: oil, natural gas, coal, minerals, cropland, pastureland, timber	*The Changing Wealth of Nations 2018*
Production: oil, natural gas, coal, minerals, timber	*The Changing Wealth of Nations 2018*
Agriculture Gross Production Index	Food and Agriculture Organization of the United Nations
Employed labor compensation	Penn World Table 9.0 (Feenstra et al 2015)

Number of employed, 15+	International Labour Organization
Physical capital stock	Penn World Table 9.0 (Feenstra et al 2015)
GDP	World Bank

Resource rents

A major challenge to including natural resources in TFP has been the lack of information on natural resources rents, their share in GDP and growth over time. The introduction of data on rents derived from natural resource use and extraction, as appears in the *Wealth of Nations* database, makes it possible to partition value added into the sum of wages, resource rents and profits derived from fixed capital. Because unit resource rents are measured as price minus the economic cost of extraction, this measure excludes both wages and the opportunity cost of capital. It is therefore possible to neatly divide profits into a natural resource rent component and a profit on fixed capital component. Since the three components (including wages) sum to total value added, a defensible measure of TFP growth can be derived as the growth rate of GDP minus the weighted average growth rate of the three factors of production, where the weights are the shares of each factor in value added.

Considering the agriculture sector, the natural resource in question is the land used for crop and livestock production. As a practical matter, however, the quantity of agricultural land in any given country is more or less fixed – with the exception of countries where land is still being converted from forest or grassland or wetlands to agricultural uses. In what follows we therefore opt to treat agricultural produce, both food and non-food, as the natural resource in question, and the associated land rents on agricultural production as part of the natural resource share of value added. To measure the growth in agricultural output as a factor of production we use the FAO's index of agricultural production (both food and non-food) measured in real terms.

While this approach to agriculture may appear artificial, it exactly parallels how timber production is treated in TFP growth estimation. The wood itself is considered to be the natural resource, and the growth rate of the quantity of timber produced is calculated year on year based upon timber production measured in cubic meters. The share of timber production in value added is the associated resource rent on timber harvest – which, arguably, could also be viewed as a type of land rent.[4]

Labor and the self-employed

In developing countries, particularly low-income countries, self-employment is a large share of total labor inputs– in Sub-Saharan Africa, for example, the share of formal wages in value added can be as low as 10%. For the share of labor in the equations above, s_L as measured in the SNA is too low because it includes only formal employment. The Penn World Table data on total compensation of labor add other components of value added (part of mixed income in developed countries, agricultural value added in low-income countries) to the SNA figures for the compensation of employees. As a result, the sum of returns to capital, labor and natural resources

[4] Note that there is some risk of double-counting the contribution of forests to TFP growth because, according to SNA principles, *plantation* forest outputs are measured as part of production in the agriculture sector.

exceed value added as measured in the SNA. We therefore normalize the returns to factors to sum to 1 after the disentangling of resource rents and profits has been carried out.[5] Another wrinkle in the calculation is that, because data on the number of people self-employed are lacking in many countries, the growth rate of labor inputs used in our calculation of TFP growth is based on the number of people in formal employment, which may not be a good assumption in many developing countries.

Fixed capital

Turning to fixed capital, the *Wealth of Nations* database uses capital stock estimates from the Penn World Table, built on the Perpetual Inventory Model, converted to constant 2014 US dollars.[6] To reach the final value, however, the underlying stock of capital at constant local prices and currency units (a measure of volume) is first converted to current international dollars at purchasing power parities (PPPs), then to current US dollars at market prices, then finally to constant 2014 US dollars. The various conversions involving prices and exchange rates lead inevitably to volatility in the final estimates of fixed capital. To avoid this volatility, we use the PWT figures for the volume measure – stock of capital at constant local prices – in our TFP estimation.

One final issue arises, however. The PWT methodology measures the total capital stock, both public and private. As a result of SNA conventions, however, public sector fixed capital is assumed to have zero profits. As a consequence, when measuring the contribution of fixed capital to GDP growth, we weight the growth rate of total fixed capital (g_K in the second formula) by the returns to capital measured in the SNA (s_K in the second formula), which are returns on productive capital. This approach introduces a potential bias to the extent that public sector fixed capital may grow at a rate different from productive fixed capital (that is, g_K may have two components, one for productive fixed capital and another for public sector fixed capital). We currently have no independent measure of public sector fixed capital, but there is recent work on this at the IMF (IMF 2017).

Comparison with OECD estimates of TFP

We have compared the results of measuring TFP growth using the above methodology with the OECD results published in OECD (2016) for specific countries.[7] In some cases these estimates are similar, in most cases they are not. The reasons for the disparity are many: OECD weights fixed capital at the user cost of capital, rather than surplus less resource rents; OECD has a more precise measure of labor input, based on hours worked; and the OECD adjustment for natural capital is based on an earlier and more limited version of the Wealth of Nations database. As a result, we do not publish the comparisons in this paper, but it will be an active point of

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[5] This approach is a heuristic which has the virtue of ensuring that the labor share does not change when constructing the 'with natural resource' and 'excluding natural resource' measures of TFP growth. The approach implicitly treats land rents in agriculture as part of the compensation of employees in agriculture-dependent economies, however, and should be re-visited in the next version of the *Wealth of Nations* database.

[6] See the online supplementary material from Feenstra et al. (2015) for details.

[7] We eliminate the adjustment made by OECD for pollution abatement expenditures to increase comparability of the estimates.

discussion with OECD going forward. At any event, our focus in this paper is squarely on developing countries, not high-income members of the OECD.

3. Empirical results

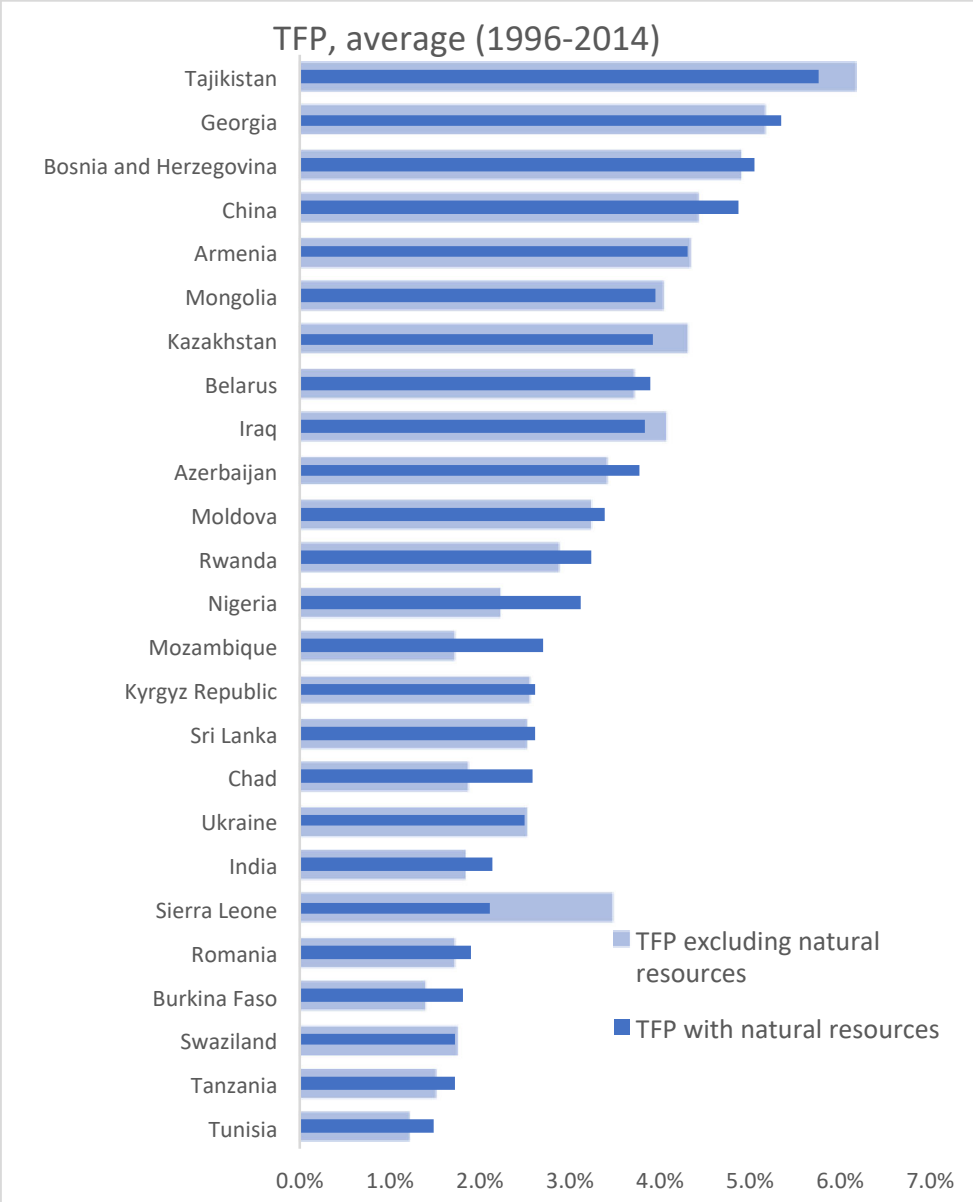
Based on the foregoing methodology, we derive a series of analytical results aimed at exploring TFP growth in developing countries, with and without natural resources incorporated. Our goal is to use the methodology to test whether it matters that natural resources are included in TFP estimates, specifically, i) does TFP growth differ and ii) does volatility of TFP growth differ when including natural resources, compared to traditional, 2-factor TFP that excludes natural resources? Results for selected countries and groups of countries are discussed in this section. The full set of results for all countries are given in Annex III.

TFP growth with and without natural resources: 25 top performers

Figure 1 ranks the 25 countries with the highest average annual growth of TFP including natural resources (hereafter, TFP with NR) over the period 1996-2014. The impact of including natural resources on TFP growth is mixed: in 16 of these 25 countries the estimated growth of TFP with NR exceeds growth of TFP excluding natural resources (hereafter, TFP without NR), while in 9 other countries including natural resources reduces TFP growth. In a few countries the two measures of TFP are very close. We remind the reader that adding natural resources to TFP calculations will not necessarily reduce TFP growth: the growth rate of TFP with NR exceeds the growth rate calculated excluding natural resources if fixed capital is growing faster than natural resources.

While much more analysis is needed to fully understand the reasons behind TFP growth, it is notable that many of the top performers are transition economies, 13 in all. African countries also feature prominently in this list, with 7 countries in the top 25. Since the transition countries of Eastern Europe and Central Asia suffered severe recessions immediately after the fall of the Berlin Wall, our analysis of 1996 to 2014 coincides with a period where the reforms of policies and institutions in these countries started to pay growth dividends. This is a possible explanation for the strong TFP growth (including natural resources). In Sub-Saharan Africa 1996 represented the start of debt relief under the Heavily-Indebted Poor Country initiative that led to substantial debt reductions in 30 African countries. This, combined with macroeconomic reforms, may be an explanation for the strong TFP growth performance (including natural resources) in many of these countries.

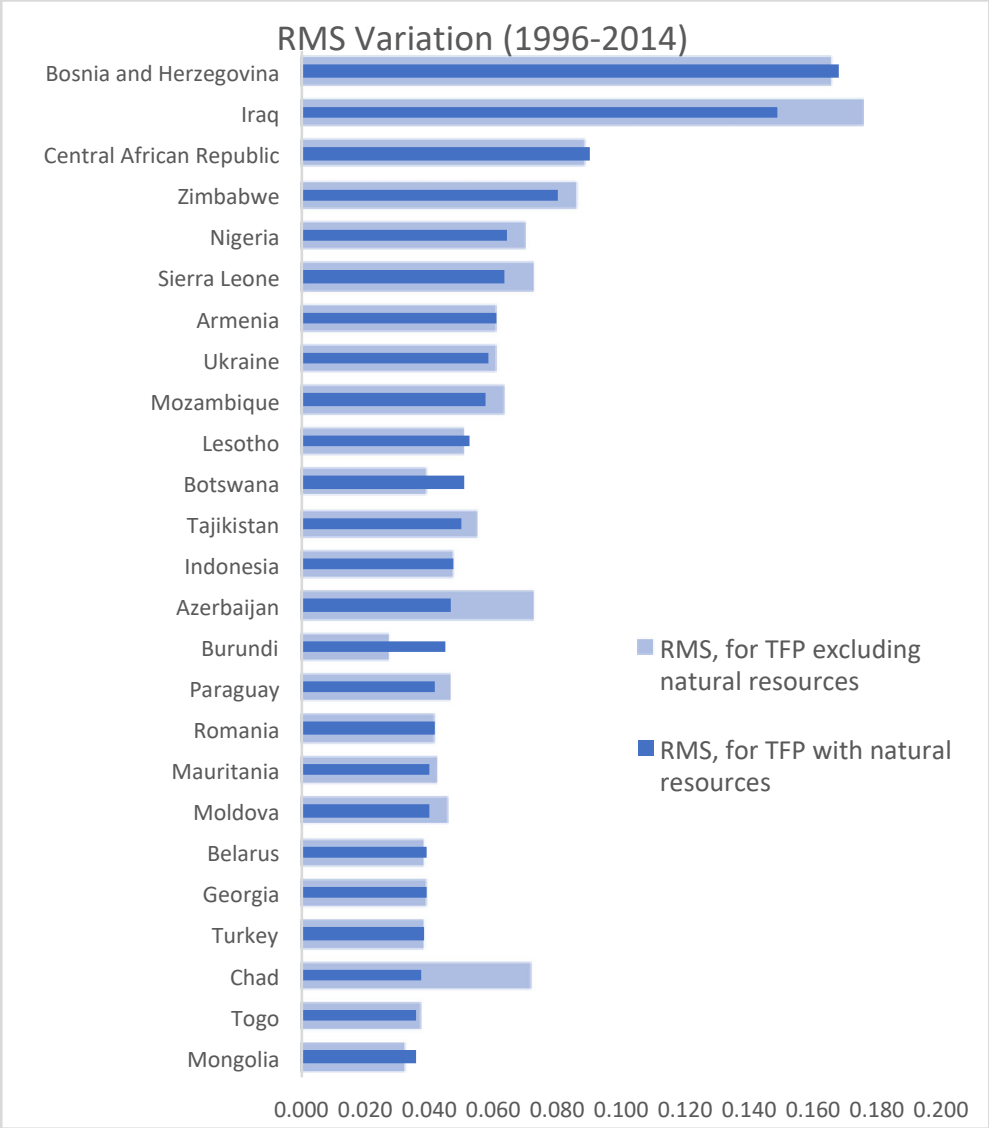
Figure 1. TFP growth over 1996-2014: top 25 countries by TFP growth with natural resources



Volatility of TFP measures

How does including natural resources affect the volatility of TFP growth year-to-year? Turning to a more technical measure, Figure 2 ranks countries by the RMS variation in growth of TFP with NR. In 13 of the 25 countries shown the variability of growth of TFP with NR is lower than the measure excluding natural resources. In five countries there is essentially no difference in variation.

Figure 2. Variation in TFP growth, with and excluding natural resources, top 25 countries ranked by RMS variation

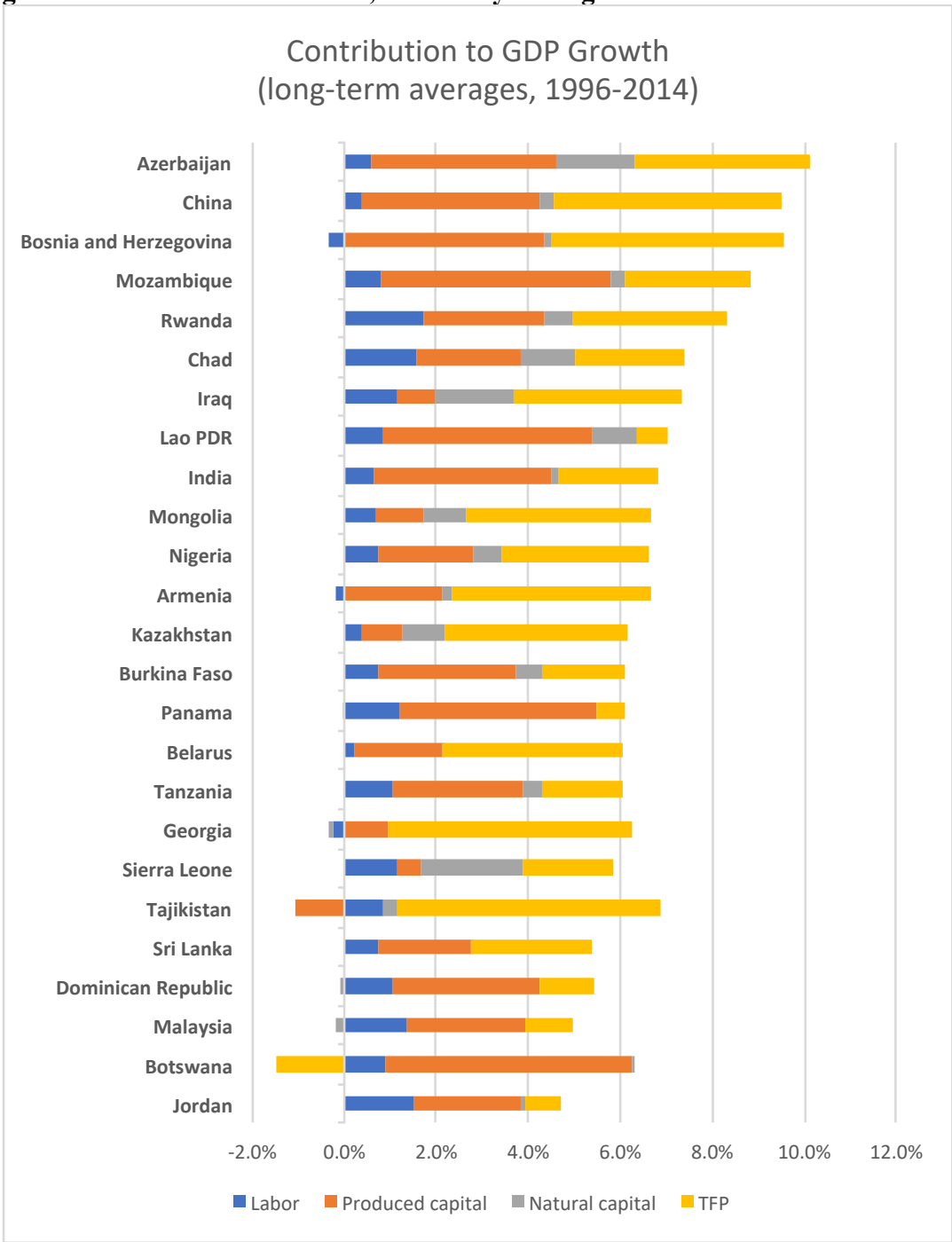


Note: These 25 countries have the highest variation in estimated TFP growth with natural resources.

Decomposition of GDP growth by factor input

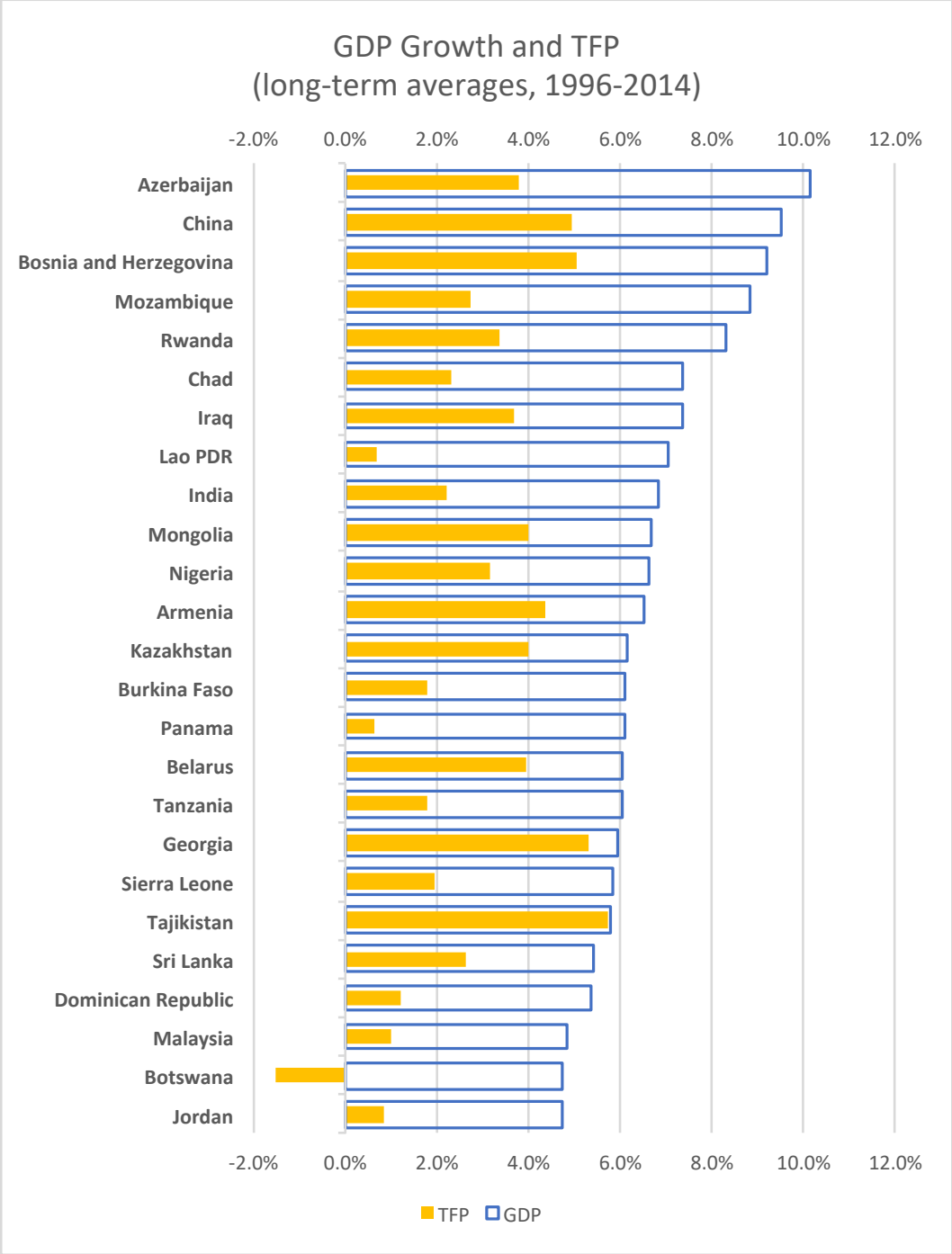
Figure 3 ranks countries by GDP growth over 1996-2014 and presents the decomposition of this growth into the contributions from fixed capital, labor, natural resources, and TFP growth (including natural resources). Figure 4 complements Figure 3 by showing only GDP growth and growth of TFP with NR. In eight of the 25 countries shown, growth of TFP with NR makes up more than one-half of GDP growth.

Figure 3. Decomposition of GDP growth for 25 countries with the highest share of TFP growth with natural resources, ranked by GDP growth



Note that data on diamonds are not available for Botswana, which biases the TFP estimates

Figure 4. TFP growth with natural resources and GDP growth, top 25 countries ranked by GDP growth



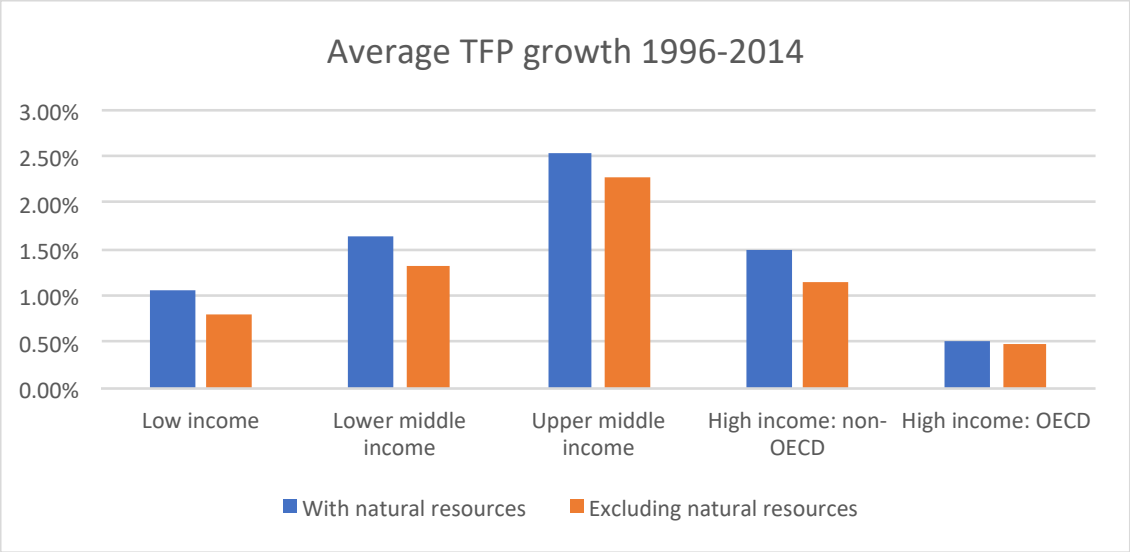
Note that data on diamonds are not available for Botswana, which biases the TFP estimates

Comparing TFP measures by region and income group

Figures 5 and 6 compare average TFP growth rates with and excluding natural resources for countries grouped by income class and region (where regions include developing countries only). In each income class we see that TFP growth with natural resources exceeds the measure

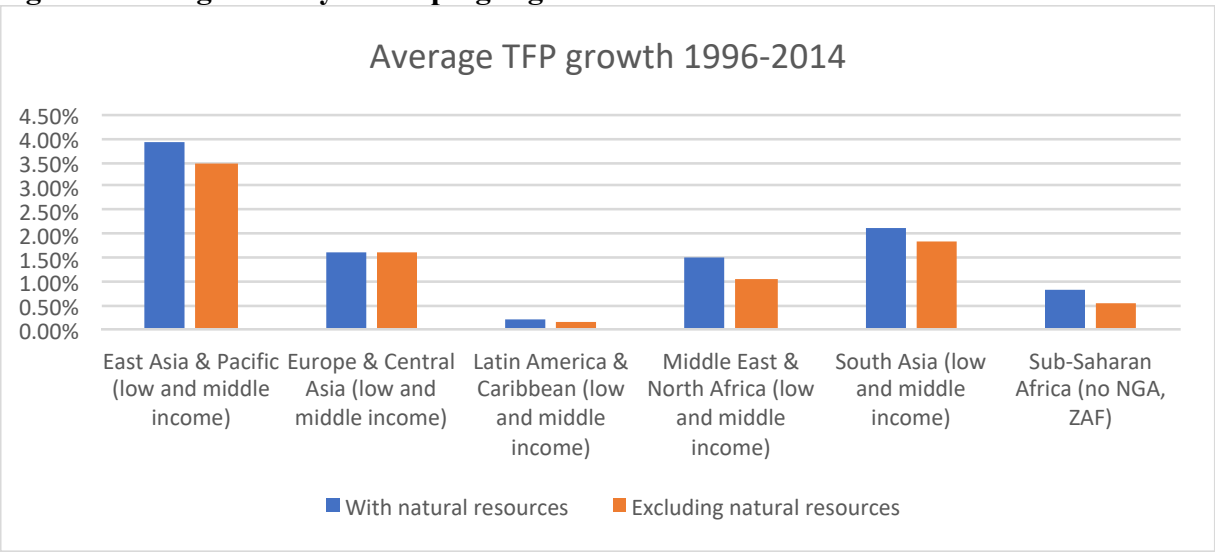
excluding natural resources. High-income OECD countries registered the lowest TFP growth by either measure over 1996-2014, but recall that these figures are not estimated based on the superior data available in these countries (see Annex I). Turning to developing regions, East Asia and the Pacific clearly dominates TFP growth (thanks to China), while Sub-Saharan Africa is the second lowest. The striking result is for Latin America and the Caribbean, where TFP growth was extremely low over this time period.

Figure 5. TFP growth by income class



Note that the averages reported for OECD countries may vary from OECD (2016) and Brandt et al. (2017). High income non-OECD countries are largely petroleum exporters. China dominates the figures for upper middle income countries, while India dominates lower middle income.

Figure 6. TFP growth by developing region

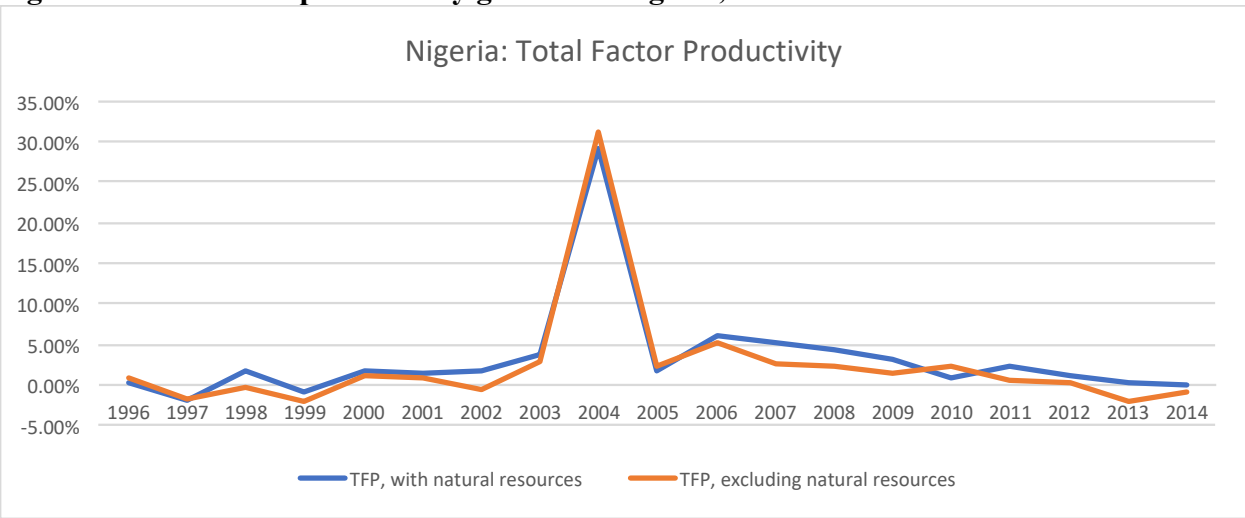


Note that the Sub-Saharan Africa figures exclude Nigeria and South Africa owing to their combined 70%

share of GDP in the region. Excluding these countries yields more representative estimates for the region. China dominates the East Asia and Pacific figures, while India dominates South Asia.

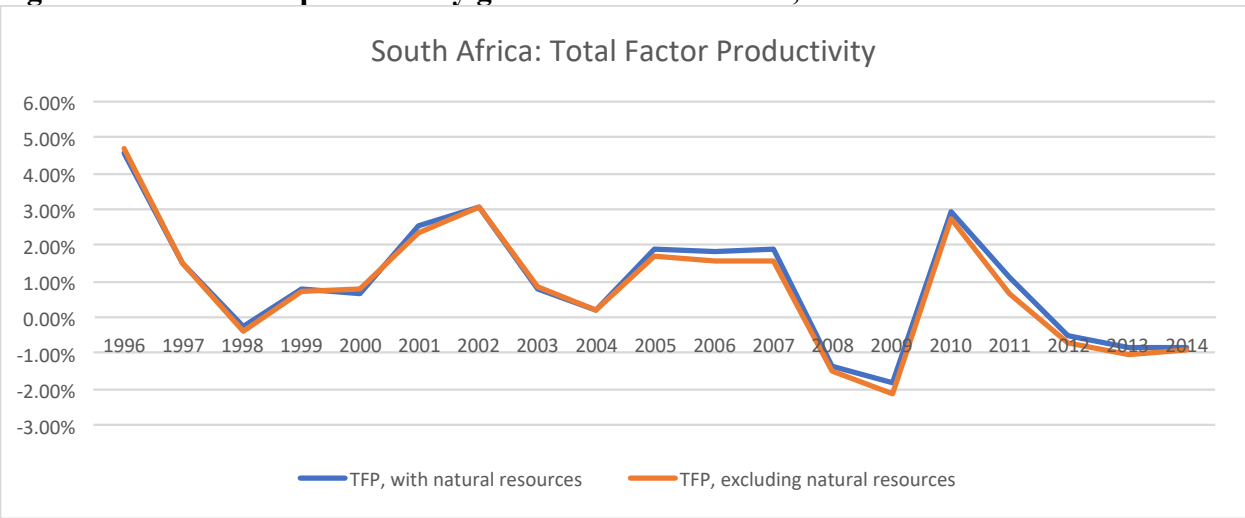
Because Nigeria and South Africa were excluded from the Sub-Saharan Africa estimates in Figure 6 (owing to their dominant GDP share), Figures 7 and 8 plot the two measures of TFP growth for these countries separately. In the case of Nigeria there is a clear anomaly in the GDP growth data in 2004, which boosts the TFP growth rate excluding natural resources in particular – further work on Nigerian data will clearly be required. South Africa exhibits high volatility in the TPF estimates, with modest average rates of TFP growth over the period.

Figure 7. Total factor productivity growth in Nigeria, 1996-2014



Note: Average TFP growth with natural resources was 3.11%, compared with 2.23% excluding natural resources

Figure 8. Total factor productivity growth in South Africa, 1996-2014



Note: Average TFP growth with natural resources was 0.94%, compared with 0.82% excluding natural resources.

Tables 2 and 3 present a result from the growth accounting that underlies TFP estimation – Figure 3 presents the full growth accounting for the fastest growing countries measured by GDP. These tables isolate the effects of natural resource growth – Table 2 presents countries where growth in natural resource extraction and harvest added more than 10% to GDP growth, while Table 3 presents countries where the decline of natural resource inputs decreased GDP growth by 1% or more. To be clear, Table 3 shows that (other things being equal) the GDP growth rate of Ukraine would have been 2.7% on average over 1996-2014 if natural resource inputs had been constant.

Table 2. Countries where growth in natural capital inputs added more than 10% to GDP growth over 1996-2014

	GDP growth rate	Natural capital contribution
Sierra Leone	5.8%	37.5%
Niger	4.5%	25.6%
Iraq	7.4%	22.7%
Togo	3.3%	17.0%
Azerbaijan	10.1%	16.9%
Chad	7.4%	16.6%
Kazakhstan	6.2%	15.0%
Suriname	3.7%	14.3%
Lao PDR	7.1%	14.0%
Mongolia	6.7%	13.9%
Bolivia	4.1%	12.1%
Burundi	2.3%	10.9%
Guinea	3.0%	10.5%

A note on interpretation: The 37.5% contribution that natural capital growth makes to the GDP growth rate of Sierra Leone (for example) amounts to 2.2% of the total 5.8% GDP growth rate.

Table 3. Countries where decline in natural capital inputs reduced GDP growth by more than 1% over 1996-2014

	GDP growth rate	Natural capital contribution
Ukraine	1.6%	-1.1%
Georgia	5.9%	-1.1%
Dominican Republic	5.4%	-1.4%
Romania	2.6%	-1.7%
Fiji	2.2%	-1.9%
Moldova	3.0%	-3.1%
Malaysia	4.8%	-3.4%
Iran, Islamic Rep.	3.6%	-5.3%
Gabon	2.0%	-34.0%

See the note on interpretation for Table 2.

Table 4 returns to TFP growth measures and highlights the top 20 countries with the largest boost to TFP estimates if natural resources are included. The list is, unsurprisingly, dominated by resource-dependent countries, but it also includes China and India. Not shown in the table are those countries where TFP growth with natural resources is less than growth estimated excluding natural resources. There are 16 such countries, of 74 total in our sample, with the difference in growth rates exceeding 1% only for Sierra Leone. In addition, there are 16 countries where including natural resources in TFP growth estimation reverses the sign of TFP growth from negative (excluding natural resources) to positive.

We would like to better understand how TFP growth varies systematically across groups of countries with characteristics that may be particularly important for including natural resources. It is not possible in this paper to fully analyze these variations, but we will take a closer look at several natural resource dependent economies to shed light on this. We consider in turn, the top three countries with i) the largest agricultural land share of total wealth, ii) the largest share of petroleum assets in total wealth, and finally iii) the overall largest share of natural resources in total wealth (excluding any overlap with the top agriculture and petroleum shares).

TFP growth in countries with high dependence on agriculture

Agriculture makes up a significant share of total wealth in many of the poorest countries in the world and in Figure 9 we present the year by year estimates of TFP growth with and without the inclusion of natural resources, as well as the average TFP growth over the 1996-2014 period. The countries chosen are the top three countries by share of agricultural land in total wealth. In the case of **Guinea**, TFP growth measured with or without natural resources shows a general downward trend, but the trend is notably more moderate when natural resources are included. Recalling expression (16), this tells us that fixed capital is growing more rapidly (or falling less steeply) than the natural resource input. In the years where TFP growth by either measure is negative, this indicates that the weighted average of factor inputs is growing faster (or falling less steeply) than GDP.

Table 4. Top 20 countries where including natural resources in TFP growth estimates from 1996 to 2014 leads to an increase in estimated TFP growth

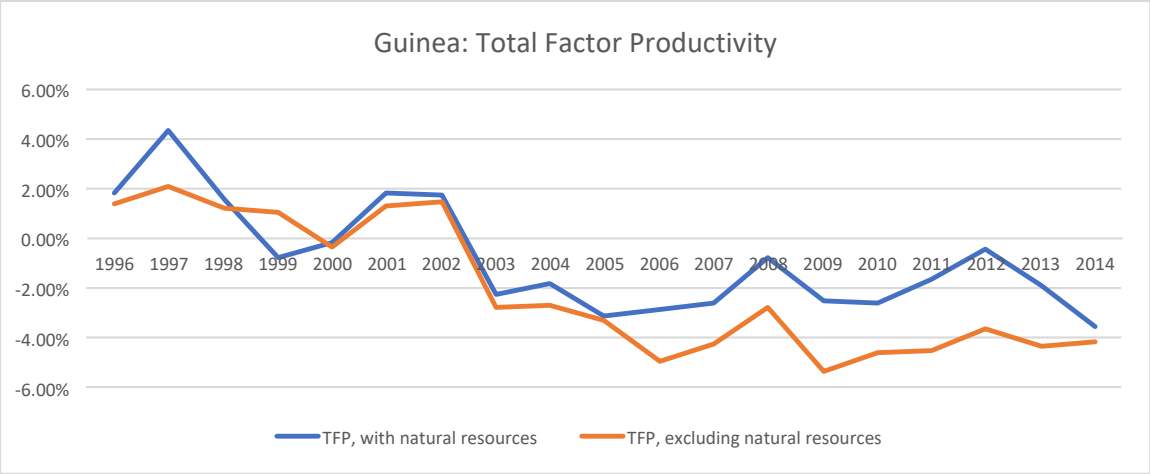
	TFP growth excluding natural resources	TFP growth Including natural resources	Difference
Mauritania	-1.2%	0.7%	1.87%
Gabon	-0.4%	0.9%	1.33%
Guinea	-2.1%	-0.8%	1.26%
Iran, Islamic Rep.	0.3%	1.3%	1.04%
Mozambique	1.7%	2.7%	0.98%
Burundi	-0.6%	0.3%	0.97%
Nigeria	2.2%	3.1%	0.88%
Chad	1.9%	2.6%	0.72%
Malaysia	0.4%	1.0%	0.67%
Egypt, Arab Rep.	-0.6%	0.0%	0.60%
China	4.4%	4.9%	0.44%
Burkina Faso	1.4%	1.8%	0.41%
Indonesia	0.1%	0.5%	0.39%
Rwanda	2.9%	3.2%	0.35%
Dominican Republic	1.0%	1.4%	0.35%
Azerbaijan	3.4%	3.8%	0.35%
Ecuador	0.1%	0.4%	0.31%
India	1.8%	2.1%	0.29%
Tunisia	1.2%	1.5%	0.26%
Lao PDR	0.5%	0.7%	0.24%

Note: Botswana is excluded owing to the lack of data on diamonds

In the **Central African Republic**, the two measures of TFP growth nearly coincide in each year. The trend in each case oscillates around 0, with the notable exception of 2013 where we see a steep drop. This presumably coincides with the episodes of civil disorder in the CAR that year. In the **Kyrgyz Republic** both measures show significantly positive growth over the chosen period, perhaps reflecting the beneficial impacts of policy reforms and an opening up of the economy after the fall of the Berlin Wall. The levels of the two measures of TFP growth largely track each other except for sharp divergences in 2012 and 2013, suggesting that the growth rates of factor inputs diverged strongly owing to local circumstances in the economy.

Figure 9. Agriculture-dependent countries, share of wealth 2014 and TFP growth 1996-2014

Guinea	Agriculture share of total wealth	55.2%	TFP growth with natural resource	-0.8%
			TFP growth excluding natural resource	-2.1%



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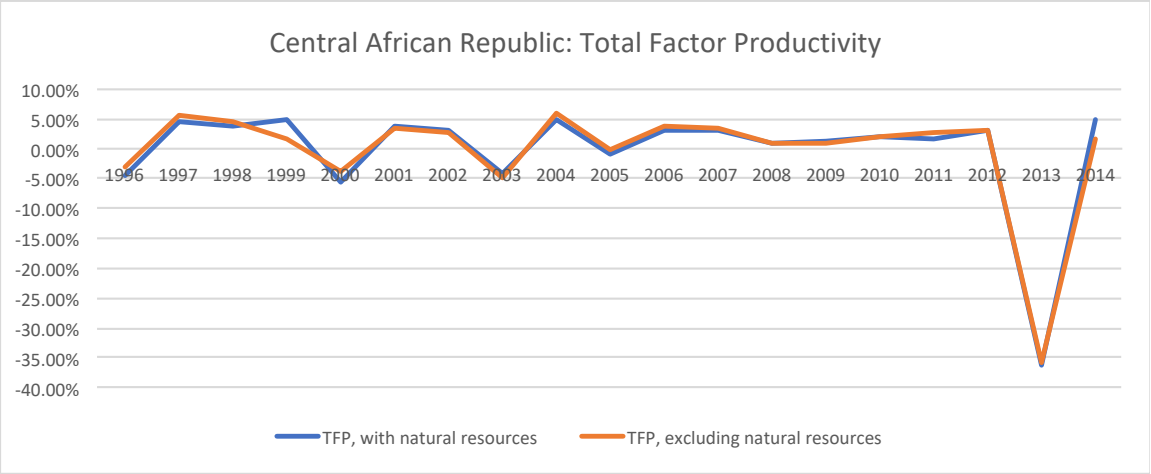
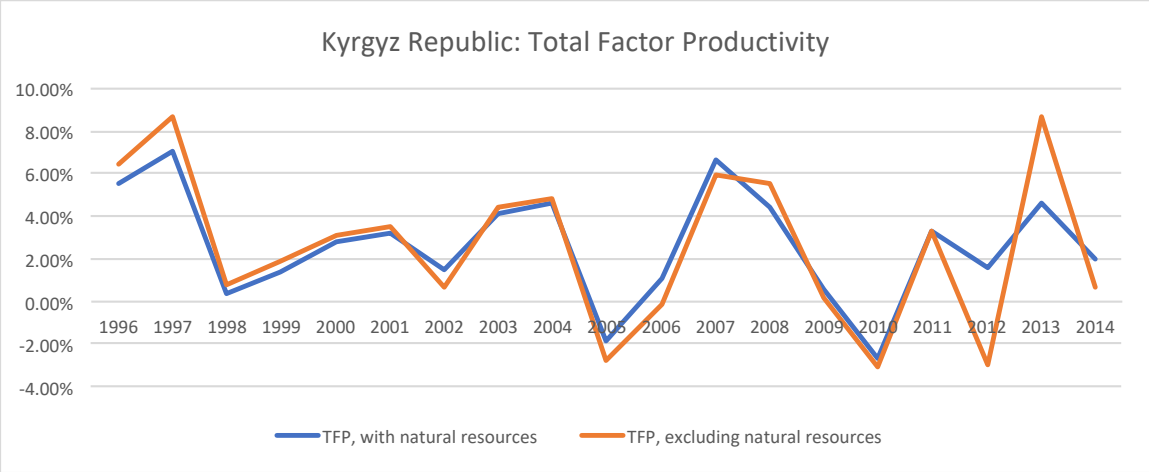
Centre-Afrique	Agriculture share of total wealth	44.0%	TFP growth with natural resource	-0.8%
			TFP growth excluding natural resource	-0.8%



Kyrgyz Rep	Agriculture share of total wealth	40.9%	TFP growth with natural resource	2.6%
			TFP growth excluding natural resource	2.6%

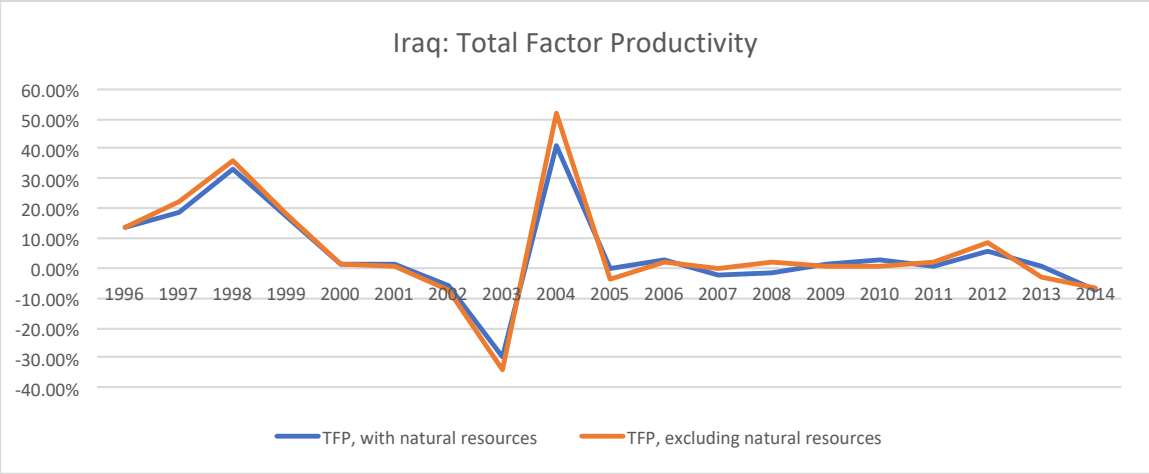


TFP growth in countries with high dependence on petroleum

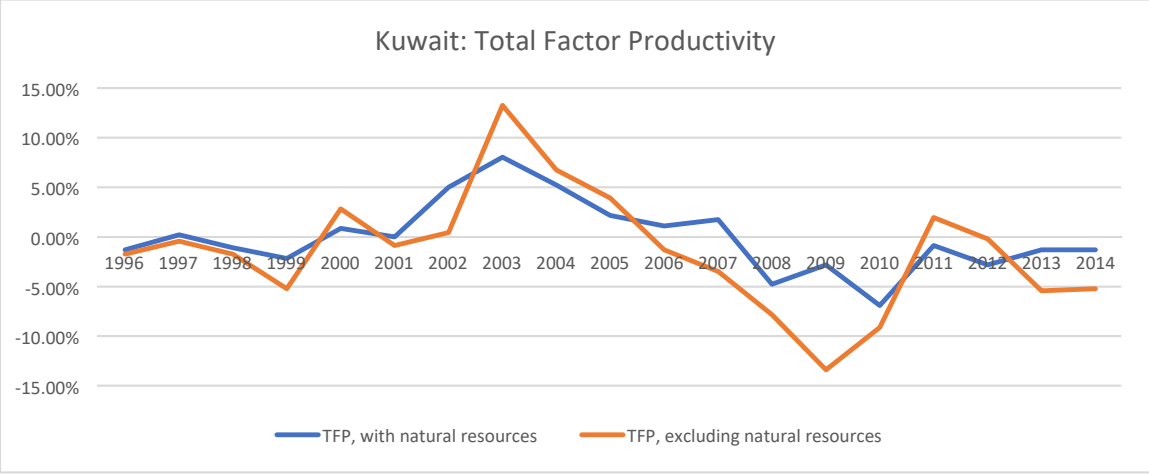
Turning to the petroleum producers, Figure 10, the general picture is of extreme volatility in TFP growth measures, which is unsurprising considering the boom and bust nature of the petroleum market. We present the top three most petroleum-dependent economies in our database. The case of **Iraq** is particularly extreme given the advent of the Iraq War in 2003, which led to a steep decline in economic activity followed by a sharp recovery. In **Kuwait** TFP growth is negative on average, but growth measured with natural resources is generally higher (or less negative), suggesting that growth in fixed capital is higher than growth in petroleum extraction. In **Saudi Arabia** TFP growth is highly volatile and almost trendless, as the low estimates of average TFP growth over 1996 to 2014 indicate.

Figure 10. Petroleum-dependent countries, share of wealth 2014 and TFP growth 1996-2014

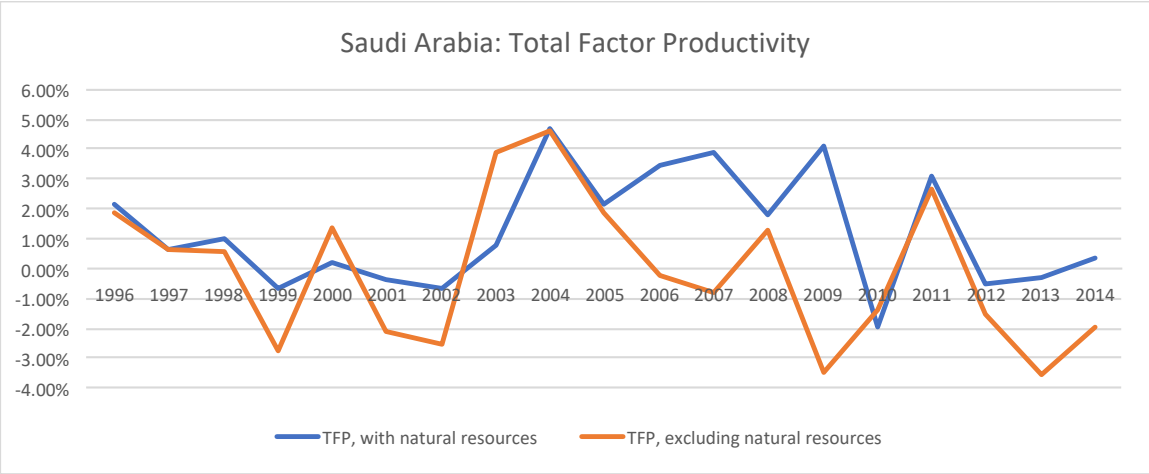
Iraq	Petroleum share of total wealth	67.3%	TFP growth with natural resource	3.8%
			TFP growth excluding natural resource	4.1%



Kuwait	Petroleum share of total wealth	52.4%	TFP growth with natural resource	-0.1%
			TFP growth excluding natural resource	-1.6%



Saudi Arabia	Petroleum share of total wealth	48.5%	TFP growth with natural resource	1.2%
			TFP growth excluding natural resource	-0.1%

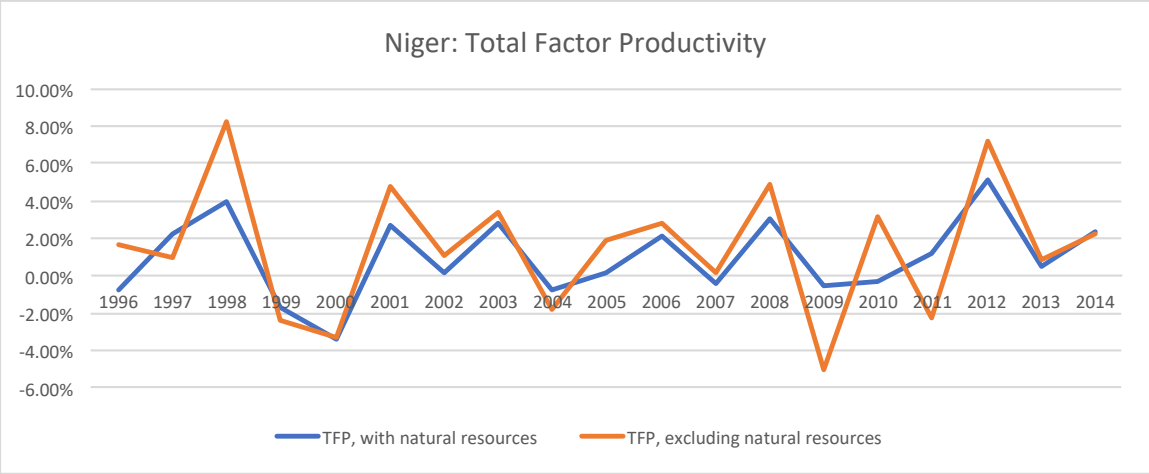


TFP growth in countries with high overall dependence on natural resources

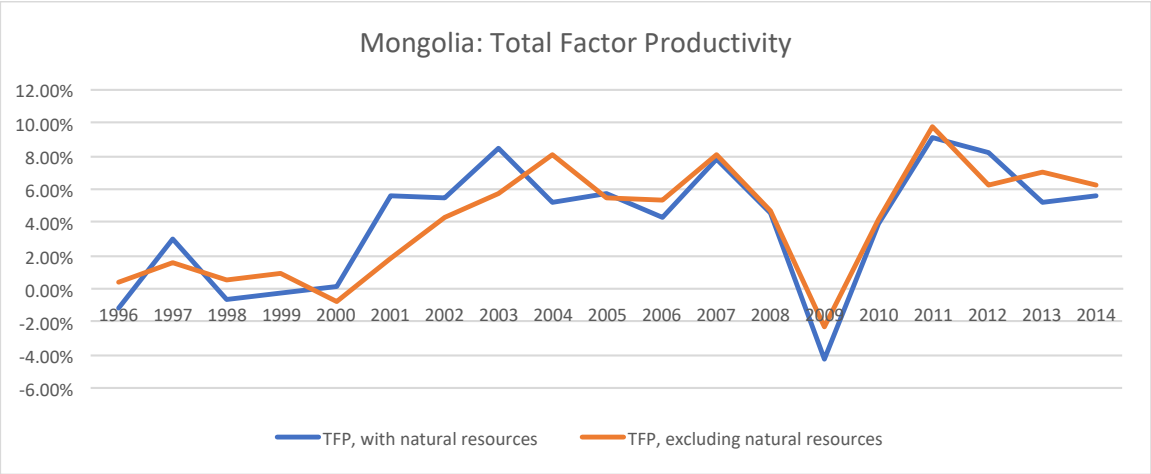
In Figure 11 we present the top three natural resource dependent countries, with the provision that we wanted to avoid overlaps with the top countries by share of agricultural land or petroleum assets. Implicitly, therefore, we have chosen mineral producers. In **Niger** the two measures of TFP growth oscillate, with a small upward trend. In contrast, **Mongolia** shows a strong upward trend in TFP growth (aside from a sharp fall and rise in 2009) with very little difference between the average TFP growth rates with and without natural resources. TFP growth in **Mauritania** is almost trendless, with a slight positive growth rate for the measure including natural resources and a small negative growth rate for the measure excluding natural resources.

Figure 11. Resource-dependent countries, share of wealth 2014 and TFP growth 1996-2014

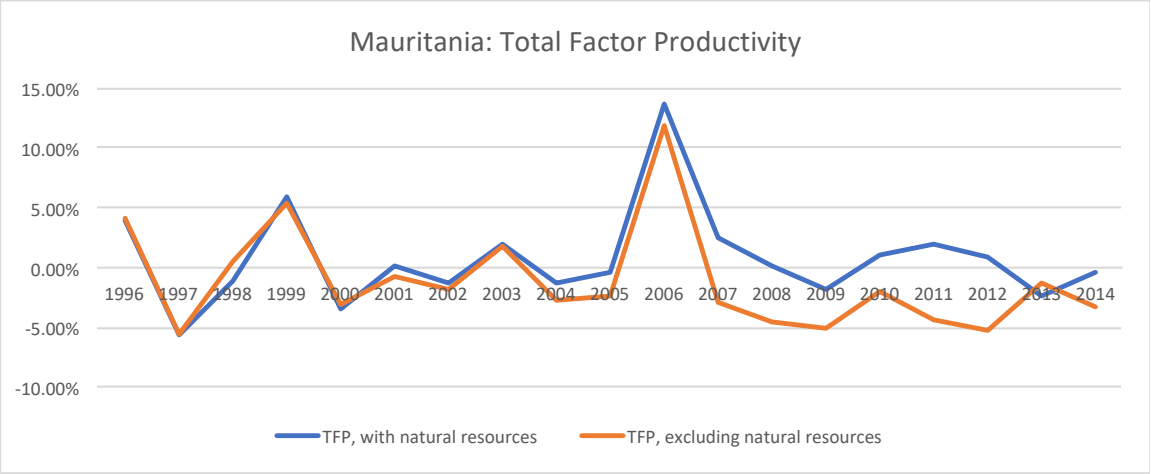
Niger	Total resources share of total wealth	73.0%	TFP growth with natural resource	1.0%
			TFP growth excluding natural resource	1.4%



Mongolia	Total resources share of total wealth	63.3%	TFP growth with natural resource	3.9%
			TFP growth excluding natural resource	4.0%



Mauritania	Total resources share of total wealth	59.8%	TFP growth with natural resource	0.7%
			TFP growth excluding natural resource	-1.2%



Finally, in Annex III Table A.1 we see the full listing by country of TFP growth over 1996-2006, 2007-2014, and 1996-2014. The sharp impact of the financial crisis is immediately obvious in small or negative TFP growth rates over 2007-2014. Table A.2 lists the contribution of natural resources to GDP growth for our sample of countries over the full period, highlighting the major positive contribution that natural resources make to GDP growth.

4. Conclusions and next steps

We began this study by emphasizing the large reliance of developing countries, and particularly low-income countries, on natural resources as a component of wealth. The traditional approach to TFP growth estimation has, to date, excluded natural resources, with the exception of recent

work of the OECD. As the methodology for measuring TFP growth indicates, excluding natural resources can result in misleading estimates of TFP growth. The methodology also shows that introducing natural resources as a factor of production will not always boost the measure of TFP growth compared to traditional measures.

Our results for 74 developing countries over 1996 to 2014 confirm that including natural resources in TFP growth estimation does have significant impacts on estimated TFP growth. In 59 of these countries, including the developing giants – China and India – including natural resources in estimates of TFP growth yields an increase in average TFP growth compared to traditional estimates. But including natural resources in TFP growth estimation reverses the sign of the average growth from negative using traditional methods to positive in 16 countries. When natural resources are included in TFP growth estimation, the results show TFP growth to be an important contributor to GDP growth in many countries – not only China and India, but the transition economies as well as selected African countries including Nigeria and Mozambique. A word of caution is in order for the overall picture of African TFP growth, however – some of the countries highlighted are subject to fragility, conflict and violence, and the data quality may therefore suffer.

Including natural resources in TFP growth estimation tends to reduce the variability of estimates from year to year, at least over the 1996-2014 period presented in this study. The full set of results for 74 developing countries in the Annex shows that in only 17 countries did the variability of TFP growth estimates with natural resources exceed the variability excluding natural resources. This could simply reflect the period chosen, but it may also be related to the introduction of another source of variation in the calculation of the weighted average growth rate of factor inputs.

Table 4 ranks the differences between TFP growth with and excluding natural resources, highlighting the top 20 countries where the former dominates. Not surprisingly, a long list of petroleum producers – Gabon, the Islamic Republic of Iran, Nigeria, Chad, Malaysia, the Arab Republic of Egypt, Azerbaijan, and Indonesia – appear in the top 20. But it is notable that China and India are also on this list.

Perhaps the most troubling result of our analysis is the very low TFP growth performance of developing countries in Latin America and the Caribbean. As seen in Figure 6, the average TFP growth of the region as whole over 1996-2014 amounted to 0.24% including natural resources and 0.15% excluding natural resources. This result is certainly consistent with recent analysis at the Inter-American Development Bank (2018).

In terms of how TFP including natural resources could inform policy work at the World Bank, one of the examples is analysis with the Long Term Growth Model (LTGM; website: www.worldbank.org/LTGM). TFP growth is used as an input into the LTGM which is used to analyze what growth targets are feasible for a country, what combination of growth fundamentals (TFP, human capital growth, investment, etc.) are required to reach the growth target, and what growth paths would prevail if current trends continue. The model also allows us to look at the implications of growth for poverty reduction. The calculation of trend TFP growth feeds into all these calculations. That is, it affects what growth or poverty targets are feasible, what would be

achieved if current trends continue, implied poverty rates and also the best way to reach those growth or poverty goals. For countries that are dependent on natural resources—all the low-income countries and many middle-income countries—providing a measure of TFP growth that includes natural resources could improve analysis with LTGM.

It is important to repeat the point we made in the beginning: these are early estimates of TFP growth including natural resources. We foresee a program of work aimed at sorting out remaining issues in the data as well as methodology. But this initial work provides a rich picture of the potential biases that excluding natural resources in TFP measurement may introduce in what is a profoundly important indicator of macroeconomic performance, especially in resource dependent economies. The evidence is that traditional methods, which exclude natural resources, may have under-estimated TFP growth in the majority of developing countries. That said, there are significant data issues to be addressed, and much more work needed to fully understand the reasons behind TFP growth estimates.

Priorities for further work include assessment of the robustness of the underlying data including possible correlation among variables, understanding the drivers behind the volatility of TFP trends over time, cross-sectional comparisons in order to aid benchmarking; and better understanding the role of the types of natural capital. Further work on agricultural land could draw on the extensive literature in that field, where sectoral TFP growth estimates have traditionally included land.

We expect that this analysis will motivate the uptake of this work at the World Bank. We encourage colleagues to further explore this topic by accessing the full data set and an Excel-based tool to help analysis that will be made available on the Environment and Natural Resources GP's intranet site by August 2018.

Annex I. The OECD approach to TFP measurement presented in Brandt et al. (2017)

Brandt et al. (2017) highlight two broad approaches to TFP measurement depending upon whether estimates exist of the user cost of capital u (also termed the rental value of capital). The OECD productivity manual (OECD 2001) employs the approach of Jorgensen (1963) to measure this user cost in discrete time,

$$u(t) = p(t)\big(r(t) + d(t)\big) - (p(t) - p(t-1))$$

Here p is the price of a capital asset, r is the return on capital and d is the rate of depreciation of the asset, and the final term measures capital gains.

While the OECD productivity database has detailed estimates of u for most OECD countries and selected non-members, the estimates do not exist for the vast majority of developing countries. In Brand et al. (2017) the authors fall back to an assumption of constant returns to scale in production in order to measure TFP growth for the Russian Federation, Mexico, Chile and South Africa – countries where estimates of the user cost of capital are not available.

In countries where user cost estimates exist for fixed capital, the OECD approach is to measure TFP growth by subtracting the weighted average of the growth rates of factors of production from the growth rate of GDP; in this instance the weights are the factor costs, including the user cost of capital, normalized to sum to 1. Where these estimates do not exist then the weights applied to the growth rates of factors of production are simply the factor shares in value added – wages and profits derived from fixed capital, with the latter measured as a residual. These sum to 1 by assumption.

Annex II. Generalization of TFP calculations for multiple natural resources

If there are two natural resources N_1 and N_2 with factor shares $\bar{S}_{N_1}$ and $\bar{S}_{N_2}$, then we can generalize expression (16). As in previous equations, the bar over the factor shares indicates that these are Tönqvist indices.

The factor share of fixed capital with natural resources is now $\bar{S}_K = 1 - \bar{S}_L - \bar{S}_{N_1} - \bar{S}_{N_2}$, while the factor share without natural resources is $\bar{S}_K = 1 - \bar{S}_L$. Applying expression (15) again, the ratio of the growth rates of TFP with and excluding natural capital reduces to,

$$\frac{g_A^{WNR}+1}{g_A^{XNR}+1} = \frac{(g_K+1)^{\bar{S}_{N_1}+\bar{S}_{N_2}}}{(g_{N_1}+1)^{(\bar{S}_{N_1})} \cdot (g_{N_2}+1)^{(\bar{S}_{N_2})}}$$

$$= \left(\frac{g_K+1}{(g_{N_1}+1)^{\left(\frac{\bar{S}_{N_1}}{\bar{S}_{N_1}+\bar{S}_{N_2}}\right)} \cdot (g_{N_2}+1)^{\left(\frac{\bar{S}_{N_2}}{\bar{S}_{N_1}+\bar{S}_{N_2}}\right)}} \right)^{\bar{S}_{N_1}+\bar{S}_{N_2}}$$

The denominator in expression (17) is the weighted geometric mean of the growth rate of the two natural resources, where the weights are 'within natural resource' factor shares. If the growth rate of fixed capital exceeds this weighted geometric mean then the growth rate of TFP with natural resources will exceed the growth rate without natural resources. This weighted geometric mean is in fact the aggregate growth rate of natural resources, $g_N + 1$. As in expression (16), the effect of this difference in growth rates is magnified by the overall factor share of natural resources, $\bar{S}_N = \bar{S}_{N_1} + \bar{S}_{N_2}$. This result generalizes to the case of more than two natural resources in the obvious way, and the weighted geometric mean growth rate can be derived for sub-categories of natural resources such as minerals and fossil fuels.

Annex III. TFP Growth Results by Country

Table A.1. TFP with and excluding natural resources, by time periods

	1996 – 2006		2007 – 2014		1996 – 2014	
Country	**TFP with natural resources**	**TFP excluding natural resources**	**TFP with natural resources**	**TFP excluding natural resources**	**TFP with natural resources**	**TFP excluding natural resources**
Armenia	7.5%	7.5%	0.1%	0.2%	4.3%	4.3%
Azerbaijan	5.6%	6.3%	1.2%	-0.5%	3.8%	3.4%
Belarus	6.1%	6.0%	0.9%	0.7%	3.9%	3.7%
Benin	1.7%	1.7%	0.9%	0.9%	1.4%	1.4%
Bolivia	0.2%	0.3%	0.7%	0.6%	0.4%	0.4%
Bosnia and Herzegovina	9.0%	8.9%	-0.2%	-0.3%	5.0%	4.9%
Botswana	-1.2%	-1.4%	-1.3%	-2.1%	-1.2%	-1.7%
Brazil	0.2%	0.3%	0.8%	0.8%	0.5%	0.5%
Bulgaria	-0.7%	-1.0%	-1.7%	-1.9%	-1.1%	-1.3%
Burkina Faso	3.1%	2.8%	0.1%	-0.5%	1.8%	1.4%
Burundi	-1.3%	-1.1%	2.5%	0.0%	0.3%	-0.6%
Cameroon	1.5%	1.3%	0.7%	0.4%	1.1%	0.9%
Central African Republic	1.2%	1.4%	-3.5%	-3.6%	-0.8%	-0.8%
Chad	3.0%	3.6%	2.0%	-0.5%	2.6%	1.9%
China	5.1%	4.7%	4.5%	4.0%	4.9%	4.4%
Colombia	-0.1%	-0.2%	0.2%	0.2%	0.1%	0.0%
Costa Rica	0.6%	0.5%	0.6%	0.4%	0.6%	0.4%
Côte d'Ivoire	0.5%	0.8%	2.6%	2.3%	1.4%	1.4%
Djibouti	-1.1%	-1.1%	1.2%	1.0%	-0.1%	-0.2%
Dominican Republic	1.0%	0.9%	1.9%	1.2%	1.4%	1.0%
Ecuador	-0.1%	-0.1%	1.0%	0.3%	0.4%	0.1%
Egypt, Arab Rep.	0.3%	-0.2%	-0.3%	-1.0%	0.0%	-0.6%
Fiji	0.7%	0.6%	0.4%	0.3%	0.6%	0.5%
Gabon	0.3%	-0.8%	1.8%	0.1%	0.9%	-0.4%
Georgia	6.6%	6.4%	3.6%	3.5%	5.3%	5.2%
Guatemala	-0.2%	-0.2%	1.1%	1.1%	0.4%	0.4%
Guinea	0.0%	-0.5%	-2.0%	-4.2%	-0.8%	-2.1%
Honduras	0.8%	0.7%	-0.2%	-0.4%	0.4%	0.3%
India	2.3%	2.1%	1.9%	1.5%	2.1%	1.8%
Indonesia	-0.7%	-1.0%	2.0%	1.6%	0.5%	0.1%
Iran, Islamic Rep.	1.3%	0.7%	1.4%	-0.4%	1.3%	0.3%

	1996 – 2006		2007 – 2014		1996 – 2014	
Country	**TFP with natural resources**	**TFP excluding natural resources**	**TFP with natural resources**	**TFP excluding natural resources**	**TFP with natural resources**	**TFP excluding natural resources**
Iraq	6.8%	6.9%	-0.1%	0.3%	3.8%	4.1%
Jamaica	-0.7%	-0.7%	-1.2%	-1.3%	-0.9%	-0.9%
Jordan	1.9%	1.8%	-0.7%	-0.8%	0.8%	0.7%
Kazakhstan	5.1%	6.0%	2.4%	2.0%	3.9%	4.3%
Kenya	0.3%	0.3%	0.7%	0.3%	0.5%	0.3%
Kyrgyz Republic	2.7%	2.8%	2.5%	2.2%	2.6%	2.6%
Lao PDR	0.9%	0.7%	0.4%	0.1%	0.7%	0.5%
Lebanon	-0.1%	-0.2%	0.5%	0.4%	0.1%	0.1%
Lesotho	0.5%	0.4%	1.5%	1.3%	1.0%	0.8%
Macedonia, FYR	0.5%	0.5%	-1.1%	-1.1%	-0.1%	-0.2%
Malaysia	1.3%	0.6%	0.7%	0.1%	1.0%	0.4%
Mauritania	1.0%	0.6%	0.2%	-3.6%	0.7%	-1.2%
Mauritius	1.5%	1.5%	0.6%	0.6%	1.1%	1.1%
Mexico	0.1%	0.0%	-0.7%	-1.1%	-0.3%	-0.4%
Moldova	3.1%	2.9%	3.8%	3.8%	3.4%	3.2%
Mongolia	3.2%	3.0%	4.9%	5.4%	3.9%	4.0%
Morocco	0.8%	0.9%	0.5%	0.4%	0.7%	0.7%
Mozambique	5.2%	4.6%	-0.7%	-2.1%	2.7%	1.7%
Namibia	1.1%	1.0%	-1.3%	-1.6%	0.1%	-0.1%
Nicaragua	0.8%	0.8%	0.7%	0.7%	0.7%	0.8%
Niger	0.7%	1.5%	1.4%	1.3%	1.0%	1.4%
Nigeria	3.8%	3.3%	2.2%	0.8%	3.1%	2.2%
Panama	0.9%	0.8%	0.2%	0.1%	0.6%	0.5%
Paraguay	-1.2%	-1.2%	2.1%	2.2%	0.2%	0.2%
Peru	-0.3%	-0.3%	0.7%	0.2%	0.1%	-0.1%
Philippines	1.1%	1.1%	1.7%	1.9%	1.4%	1.4%
Romania	3.2%	3.0%	0.2%	0.0%	1.9%	1.7%
Rwanda	4.5%	4.7%	1.6%	0.5%	3.2%	2.9%
São Tomé and Príncipe	1.1%	1.1%	1.7%	1.6%	1.3%	1.3%
Senegal	1.2%	1.0%	-1.0%	-1.2%	0.2%	0.1%
Sierra Leone	1.8%	2.9%	2.5%	4.3%	2.1%	3.5%
South Africa	1.6%	1.5%	0.1%	-0.2%	0.9%	0.8%
Sri Lanka	2.0%	1.9%	3.5%	3.4%	2.6%	2.5%
Suriname	0.4%	0.2%	0.2%	0.3%	0.3%	0.3%
Eswatini	1.5%	1.5%	2.1%	2.1%	1.7%	1.7%
Tajikistan	5.2%	5.5%	6.6%	7.2%	5.8%	6.2%

	1996 – 2006		2007 – 2014		1996 – 2014	
Country	**TFP with natural resources**	**TFP excluding natural resources**	**TFP with natural resources**	**TFP excluding natural resources**	**TFP with natural resources**	**TFP excluding natural resources**
Tanzania	2.8%	2.8%	0.2%	-0.3%	1.7%	1.5%
Thailand	0.7%	0.7%	0.9%	0.9%	0.8%	0.8%
Togo	0.5%	0.4%	0.4%	0.6%	0.5%	0.5%
Tunisia	1.8%	1.8%	1.0%	0.5%	1.5%	1.2%
Turkey	1.5%	1.4%	-0.9%	-0.9%	0.5%	0.4%
Ukraine	4.2%	4.2%	0.2%	0.2%	2.5%	2.5%
Zimbabwe	-4.5%	-4.5%	1.6%	1.6%	-2.0%	-2.0%
Income Group						
Low income	1.4%	1.4%	0.6%	-0.1%	1.1%	0.8%
Lower middle income	1.6%	1.4%	1.7%	1.2%	1.6%	1.3%
Upper middle income	2.6%	2.4%	2.5%	2.1%	2.5%	2.3%
High income: non-OECD	2.1%	2.1%	0.6%	-0.1%	1.5%	1.1%
High income: OECD	0.9%	0.8%	0.0%	0.0%	0.5%	0.5%
Developing Region (low and middle income)						
East Asia & Pacific	3.9%	3.5%	3.9%	3.5%	3.9%	3.5%
Europe & Central Asia	2.8%	2.8%	0.1%	-0.1%	1.6%	1.6%
Latin America & Caribbean	0.1%	0.1%	0.4%	0.2%	0.2%	0.2%
Middle East & North Africa	2.2%	2.0%	0.6%	-0.2%	1.5%	1.1%
South Asia	2.3%	2.1%	2.0%	1.6%	2.2%	1.9%
Sub-Saharan Africa (no NGA, ZAF)	1.0%	0.9%	0.7%	0.1%	0.9%	0.6%

Table A.2. Natural capital contribution to GDP growth (1996-2014)

Country	GDP (average growth rate, 1996 to 2014)	Natural capital contribution
Armenia	6.5%	2.8%
Azerbaijan	10.1%	16.9%
Belarus	6.1%	0.2%
Benin	4.5%	8.8%
Bolivia	4.1%	12.1%
Bosnia and Herzegovina	9.2%	1.7%
Botswana	4.8%	0.3%
Brazil	3.0%	6.0%
Bulgaria	2.7%	0.8%
Burkina Faso	6.1%	8.6%
Burundi	2.3%	10.9%
Cameroon	4.0%	3.8%
Central African Republic	-0.3%	-36.9%
Chad	7.4%	16.6%
China	9.5%	3.0%
Colombia	3.5%	4.7%
Costa Rica	4.1%	1.4%
Côte d'Ivoire	2.6%	4.7%
Djibouti	3.0%	3.7%
Dominican Republic	5.4%	-1.4%
Ecuador	3.6%	4.1%
Egypt, Arab Rep.	4.3%	0.4%
Fiji	2.2%	-1.9%
Gabon	2.0%	-34.0%
Georgia	5.9%	-1.1%
Guatemala	3.6%	3.2%
Guinea	3.0%	10.5%
Honduras	3.7%	2.7%
India	6.8%	2.1%
Indonesia	4.1%	1.2%
Iran, Islamic Rep.	3.6%	-5.3%
Iraq	7.4%	22.7%
Jamaica	0.4%	3.7%
Jordan	4.7%	1.8%
Kazakhstan	6.2%	15.0%
Kenya	4.0%	7.4%
Kyrgyz Republic	4.7%	7.5%
Lao PDR	7.1%	14.0%

Country	GDP (average growth rate, 1996 to 2014)	Natural capital contribution
Lebanon	3.7%	-0.4%
Lesotho	3.8%	2.5%
Macedonia, FYR	2.8%	5.0%
Malaysia	4.8%	-3.4%
Mauritania	4.2%	1.9%
Mauritius	4.5%	0.2%
Mexico	2.9%	-0.3%
Moldova	3.0%	-3.1%
Mongolia	6.7%	13.9%
Morocco	4.5%	3.6%
Mozambique	8.8%	3.4%
Namibia	4.6%	0.8%
Nicaragua	3.9%	5.2%
Niger	4.5%	25.6%
Nigeria	6.6%	9.3%
Panama	6.1%	-0.1%
Paraguay	3.0%	7.9%
Peru	4.7%	2.8%
Philippines	4.7%	3.8%
Romania	2.6%	-1.7%
Rwanda	8.3%	7.5%
São Tomé and Príncipe	4.2%	3.8%
Senegal	4.0%	2.8%
Sierra Leone	5.8%	37.5%
South Africa	3.1%	2.2%
Sri Lanka	5.4%	0.2%
Suriname	3.7%	14.3%
Eswatini	3.3%	2.3%
Tajikistan	5.8%	4.9%
Tanzania	6.1%	6.7%
Thailand	3.2%	3.0%
Togo	3.3%	17.0%
Tunisia	4.1%	-0.6%
Turkey	4.0%	1.1%
Ukraine	1.6%	-1.1%
Zimbabwe	-0.4%	-16.9%

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