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Is Egypt Really More Productive than the United States? The Data behind the Penn World Table

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Abstract

A new feature in recent versions of the Penn World Table (PWT) is data on comparative levels of total factor productivity (TFP) across countries. TFP is defined as the efficiency with which inputs are transformed into outputs, and differences across countries can be due to factors such as better technology or better resource allocation. Yet, surprisingly, in PWT version 10.0, several countries have a TFP level well above that of the United States. In this article we discuss use the case of Egypt in 2017. PWT then reports a productivity level that is 23 per cent higher than that of the US despite having an income level of only one fifth of the US. We trace this anomalous outcome to the underlying data on comparative inputs. A fully satisfactory answer to the question in the title is elusive at this point, but the analysis highlights the data challenges that affect TFP level estimates, alongside more familiar modeling and measurement challenges.

One of the benefits of the development of the System National Accounts, and subsequent global measurement effort, is comprehensive and consistent cross-country data on consumption, investment and production. These data, in turn, can be used to systematically account for the sources of economic growth (e.g., Solow, 1957). Growth accounting lead to estimates of total factor productivity (TFP) growth as the growth in output that cannot be accounted for by growth of factor inputs, capital and labour. Similarly, the development of measures of comparative levels of prices and output for a large set of countries (e.g. Kravis, Heston and Summers, 1978), opens the door for development accounting, which aims to assess how much of the

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differences in income levels across countries can be accounted for by differences in input levels. The residual variation is variation in TFP levels across countries.

A result from the development accounting literature is that approximately half of the variation in GDP per worker can be accounted for by variation in factor inputs and the other half due to variation in TFP levels.[2] An implication of this result is that TFP levels show less variation than GDP per worker levels. For example, if we look at data for 2017 from the Penn World Table (PWT) version 10.0.[3]. The GDP per worker level of a country in the 95th percentile of the country distribution is 25 times higher than that of a country in the 5th percentile. For TFP levels, the multiple is only 3.6.

This substantial cross-country variation makes understanding why TFP levels differ an important research question. Two broad (proximate) explanations can be relevant, namely that individual firms are less productive in one country than another, for example because of differences in technology adoption (e.g., Comin and Hobijn, 2010), or the allocation of resources between firms may be less efficient (e.g., Jones, 2011). Regardless of which of these explanations is most important, it implies that a high-productivity economy is more efficient in meaningful ways.

To the extent that high-productivity economies are also high-income economies, this implication seems to fit many people's priors. But in PWT, 10.0 some countries with income levels that are comparatively low, show TFP levels that exceed the TFP level of the United States. The most extreme example is Egypt, which in 2017 had a TFP level in PWT that was 23 percent higher than in the US, despite a GDP per capita level that is only one-fifth of the US level. Yet concluding that Egypt's firms are more technologically advanced or its economic system more successful in allocating resources to productive firms and industries than the United States may strike observers as implausible. Put simply, if Egypt's economy were truly so efficient, why are Egyptians not richer?[4]

Before drawing that conclusion, it is important to realize that measured TFP levels are the outcome of choices (and constraints) regarding the model, measurement and data. Modelling choices are about the underlying economic model and its assumptions, measurement choices are about how concepts of output and input are defined and measured, while data choices are about the approximations and assumptions that are necessary to operationalize the output and input concepts that the earlier choices prescribe. In this article, we emphasize choices and constraints regarding data; below we provide some discussion and examples of model and measurement choices.

In this article, we give an overview of the

2 See, for example, the surveys by Caselli (2005) and Hsieh and Klenow (2010).

3 See, Feenstra, Inklaar and Timmer (2015) introducing the more recent version of the Penn World Table and section two from a summary

4 Whenever we talk of an economy being more or less productive or efficient, this should be read as a statement about total factor productivity (TFP), unless otherwise noted.

model, measurement and data choices that underlie TFP level data in the Penn World Table, version 10.0 (Feenstra *et al.* 2015). We then zoom in on the case of Egypt as a marked outlier in terms of measured TFP level and we focus on data for 2017. We compare Egypt to a group of countries in the Middle East and North Africa region, because cultural, climatic or geographic factors may have a similar impact on outputs and inputs in these countries. We also compare Egypt to a group of countries at a similar income level, as income may affect outputs and inputs similarly. We find that, compared to these regional and developmental peer groups, Egypt has a low employment rate, low investment rate and a high price level of capital.

We compute counterfactual TFP levels, replacing observed Egyptian values by average values from the two peer groups and these counterfactual TFP levels are notably lower than observed ones. However, it is the combination of the three factors (employment, investment and capital prices) that leads to Egypt's status as a TFP outlier. This is clearly a conundrum for data users. Throwing out Egypt or any other country raises the question what the criterion should be and no simple criterion for the underlying data presents itself. Earlier versions of PWT have reported letter grades to provide a sense of data quality but following the same grading logic would give Egypt the second-highest data-quality grade. Likewise, the statistical capacity indicator for developing countries of the World Bank has Egypt in the 10 percent of highest-scoring countries. At the same time, accepting these numbers is hard as well, as discussed above. From the perspective of developers of the Penn World Table, there is no clear solution to this conundrum, other than to outline why it is such a conundrum.

The choice to focus on Egypt in 2017 should not be taken to imply that this is the only problematic case. For 59 of the 66 years for which PWT reports TFP level estimates for Egypt, the TFP level exceeds the US level. And beyond Egypt, there are 45 other countries for which PWT reports TFP levels that are higher than in the US for one or more years. Many of those countries, such as Belgium, the Netherlands and Taiwan, have high income and labour productivity levels, so high TFP levels are no surprise. But this list also includes countries, such as Gabon and Jordan with notably lower income and labour productivity levels. We could also use the relationship between income level and TFP level to identify outliers and, again, there is a broader range of countries and years that deviates substantially from the cross-county pattern and could be classified as outliers. Despite this longer set of problematic/remarkable cases, focusing on the case of Egypt can be useful to illustrate how researchers may use the PWT data to gauge the plausibility of figures they are interested in. Those with a specific interest in data for one country may especially benefit from such a diagnostic approach before deciding how to proceed.

As discussed earlier, our emphasis in this article is on data choices and constraints, leaving aside modelling and measurement choices. The typical model underlying TFP level estimates is the Solow model and its assumptions on constant returns to scale, perfect competition, Hicks neutral technical change and no complementarities between inputs. Many of these modeling choices have been criticized, primarily in the context of growth accounting (see, e.g. Hulten, 2010). A general assessment of how changing these assumptions would affect estimated TFP levels is hard to give, but the impact could be substantial. Alternatively, different modelling choices may primarily affect the interpretation. As shown in Basu *et al.* (2020), traditional 'Solow residual' measures of TFP may still be relevant for consumer welfare, even if Solow-model production-side assumptions are not satisfied. This is because the Solow residual still reflects the trade-off between the output available for consumption versus the effort, in terms of labour hours supplied and deferred consumption that is used for investment, that is needed to produce that output.

Measurement choices also have an important impact on estimated TFP levels. For example, Lagakos *et al.* (2018) show that workers in high-income countries accumulate more human capital on the job than those in lower-income countries, an effect that is not accounted for in traditional measures of human capital (as used in PWT). As a result, factor input variation in PWT would be understated while TFP variation is overstated. Similarly, the productive use of subsoil assets, such as oil or iron ore, is typically not included as part of factor inputs, even though rents from their extraction are an important contributor to GDP in resource-rich countries in (predominantly) the Middle East and Africa. As Freeman, Inklaar and Diewert (2021) show, this omission of subsoil assets as a factor input leads to an overstatement of TFP levels in those countries.

It is important to note that TFP is—by construction—a residual and any measurement or data problem in output or inputs will be reflected in that number. Given the conceptual and practical challenges in measuring input of human and produced capital, this could prompt users to rely on measures that are less sensitive to such problems, such as comparative labour productivity. Such a choice risks throwing away the baby with the bath water as the TFP estimates for Egypt in 2017 (and a set of other countries and years) are outliers to a broader pattern of factors input use and productivity that fits more closely with economic intuition and theories. But, again, caution may be in order when zooming in on specific countries.

The article contains six sections. We first give a brief introduction to the Penn World Table in its current form in Section 1. In Section 2, we introduce a general development accounting framework that we use to measure TFP levels and that can be used to identify outliers. Section 3 covers the measurement of output and inputs in PWT. Section 4 presents the results of a development accounting analysis for 2017, followed in Section 5 by an in-depth analysis of the case of Egypt. Section 6 provides some concluding remarks.

The Penn World Table

The Penn World Table has a long history, originating in the pioneering work by Irving Kravis, Robert Summers and Alan Heston at the University of Pennsylvania to develop measures of comparative price and income levels that started in the

1960s.[5] The core feature of PWT has always been to combine National Accounts data on GDP, divided into consumption, investment and net exports, with data on comparative price levels for those same expenditure categories from the International Comparison Program (ICP) produced by the World Bank (2020). The result is a measure of "real GDP" that allows for comparisons of comparative income levels across countries, rather than only over time as in country National Accounts. And while ICP comparisons have been done at substantial intervals (5–6 years or more apart) and for an initially small group of countries, PWT has always provided annual data for global comparisons.

The article that introduced PWT version 5, Summers and Heston (1991), remains one of the most highly cited research papers in economics, in part due to its ubiquitous use in the literature on cross-country growth regressions but also as a standard dataset for measures of comparative income levels for most countries in the world since 1950.

With the release of PWT version 8.0 in 2013, the development of the database moved to the University of Groningen and the University of California, Davis. Feenstra, Inklaar and Timmer (2015) launched the "Next Generation of the Penn World Table", which introduced a series of measurement innovations:

1. Rather than relying on a single benchmark/reference year for comparative price levels, use each price benchmark. For example, PWT 7.0 and 7.1 were based on relative price data from ICP 2005 for the year 2005. For other years, relative prices are estimated based on inflation of each country relative to the reference country, the United States. In comparison, since PWT 8.0, relative prices for 1970 are based directly on data from ICP 1970 (for participating countries). This approach means that new releases of ICP do not lead to potentially major shifts in comparative income rankings going back in time, an approach that has since been adopted for more recent years by the World Bank (2020).

2. In earlier versions of PWT (and currently still in ICP), no explicit information was available about the relative prices of exports and imports. But in a world with many differentiated products and incomplete passthrough of exchange rate movements into prices, this is a substantial omission. As demonstrated in Feenstra and Romalis (2014), relative prices of imports and exports do vary substantially. Feenstra, Inklaar and Timmer (2015) provide a conceptual framework demonstrating the importance of accounting for these prices differences to draw sensible conclusions about the productive capacity of different economies.

3. PWT has traditionally emphasized measures of GDP, with a split by major expenditure category. However, for many questions, it is important to not only account for relative output, but also for relative inputs and productivity. Measures of comparative inputs and productivity were

5 A comprehensive history of their work and the development of the International Comparison Program (ICP) can be found here: https://www.rug.nl/ggdc/productivity/pwt/related-research-papers/heston$_{i}cp_{m}emoir_{2}017.pdf$.

introduced in PWT 8.0 and refined subsequently; we discuss this in more detail below.[6]

In 2021, version 10.0 of PWT was released, covering data for 183 economies and the period 1950–2019. The main data table, as well as a range of supporting datasets and documentation is available via www.ggdc.net/pwt.

Development Accounting

The tool we rely on to identify outliers in TFP levels is development accounting, which is typically used to assess the degree to which variation in observed per-capita factor inputs — capital and labour — can account for variation in output per capita. As we show in this section, one other outcome of such an analysis is to highlight the average relationship between factor inputs or productivity and output, i.e. countries with higher levels of output per capita tend to have higher levels of inputs per capita and higher productivity. Using this result, we can identify countries that fall outside this average range for more detailed scrutiny. The remainder of this section introduces the development accounting conceptual framework, but can be skipped without loss of continuity.

As detailed in Caselli (2005), the typical starting point in development accounting is an aggregate production function for country *m:*

$$Y_m = A_m f(K_m, L_m) = A_m f(K_m^{\alpha} L_m^{1-\alpha}) \tag{1}$$

A country's GDP, Y, is produced using production function f with input of capital K with input of capital L and labour and productivity level A. In equation (1) we assume a constant-returns to scale Cobb-Douglas production function with a constant output elasticity of capital α for expositional simplicity; in the implementation we rely on a translog production function.

Let a lower-case variable denote a quantity divided by country population, P_m, and let us express per capita quantities relative to the United States, to be indicated by a $\sim$.

This means that relative GDP per capita can then be expressed as

$$\tilde{y_m} \equiv \frac{Y_m/P_m}{Y_{US}/P_{US}}$$

Based on equation (1) and this notational convention, we can decompose a country's GDP per capita level relative to the United States into the contribution from differences in factor inputs and differences in productivity levels:

As discussed in Hsieh and Klenow (2010), this accounting for differences in GDP per capita levels answers the hypothetical question: by how much would GDP per capita increase if one of the factor inputs or productivity were to increase, holding constant the other two elements. This can be a sensible hypothetical when comparing growth over a short period of time as it is plausible to assume that the economy has not yet moved from one steady state to another. Yet when comparing across countries, it seems more plausi-

6 Some earlier versions of PWT did include measures of comparative capital stocks. In much of the literature on development accounting, researchers estimate their own measures of capital and productivity (Caselli 2005).

ble that the comparison is between countries in a (Solow model) steady state, i.e., where the investment response to the level of technology has worked itself out. Hsieh and Klenow (2010) argue that a more sensible hypothetical in a cross-country context would be based on:

$$\tilde{y_m} = \tilde{A}_m^{\frac{1}{1-\alpha}} \left(\frac{\tilde{k_m}}{\tilde{y_m}}\right)^{\frac{\alpha}{1-\alpha}} \tilde{l_m} \quad (2)$$

$$log\tilde{y_m} = (\frac{1}{1-\alpha})log\tilde{A_m} + (\frac{\alpha}{1-\alpha})log\frac{\tilde{k_m}}{\tilde{y_m}} + log\tilde{l_m} \quad (3)$$

This equation rearranges the production function in intensive form, with the expression in logs in the second row. The benefit of this expression is that it accounts for the endogenous response of investment, and thus capital stocks, to differences in human capital and productivity. This follows the logic of the Solow growth model, in which the capital/output ratio of a country is constant in the steady state.[7] This is particularly relevant in a cross-country context, where differences in steady states are likely a larger factor in accounting for income differences than different positions relative to the steady state. Put differently, this decomposition does justice to the idea that an important reason for low capital levels in low-income countries is that productivity and human capital levels are lower.

Output and input levels in equation (3) are expressed in per-capita terms. As we also discuss in Section 4, labour input is an estimate of total hours worked, adjusted for the impact of schooling levels, $l = \frac{L}{P} = \frac{(N*H^a)*h}{P}$,where N is the number of workers. H^a is the average number of hours worked [8] and h is an index of the average years of schooling with an assumed rate or return to schooling. Capital input is based on capital stocks by asset, weighted using rental price weights.[9]

Equations (1)–(3) assume a fixed output elasticity of capital . In PWT we follow Jorgenson and Nishmizu (1978), Schreyer (2007), Feenstra *et al.* (2015) and Inklaar and Diewert (2016) and assume a translog production function. From PWT 9.1 on, we also rely on a multilateral index, meaning the factor output and inputs are compared relative to a hypothetical average country based on all countries in our sample $c = 1, ..., C$. Given the translog production function we assume, the multilateral Törnqvist input index can be expressed as:

$$LogQ_m = \alpha \left[logK_m - \overline{logK}\right] + (1-\alpha_m)\left[logL_m - \overline{LogL}\right] \quad (4)$$

with $\alpha_m \equiv \frac{1}{2}(\frac{r_m K_m}{R_m K_m + W_m L_m} + \frac{1}{c}\sum_{c=1}^{C}\frac{r_c K_c}{r_c K_c + W_c L_c})$ is the two-country average share of capital income in GDP, and $\overline{logK}$ the cross-country average of capital input levels, $\overline{logK} \equiv \frac{1}{c}\sum_c logK_c$. Equation

7 In the Solow model, the parameters define a steady-state level for the capital/worker level and that implies a corresponding steady-state GDP/worker level. If productivity increases, then the marginal product capital is higher at the initial capital/worker level, leading to new investment and a rise in the capital/worker and GDP/worker level. The capital/output ratio is the same in the initial and the new steady state.

8 Data on average hours worked are not available for all countries. When not available, we assume that average hours worked in the country equal those in the United States, so that relative TFP estimates (USA=1) are not affected. See Section 6 for some further discussion of this assumption.

9 See Inklaar *et al.*. (2019) and the discussion in Section 3.

(4) gives the input index relative to a hypothetical average country, but that index can be expressed relative to any reference country, such as the United States. This implementation of α implies assuming constant returns to scale, so that total income equals total cost, and perfect competition in factor markets so that inputs are used up to the point where marginal product equals marginal costs.

To identify extreme values of relative TFP and the factor output and inputs, we will assess the role of each term in equation (3) in accounting for income differences by estimating the following regressions:

$$\frac{1}{1-\alpha_m} log(\tilde{A_m}) = \beta^A log(\tilde{y_m}) + \varepsilon_m^K \quad (5)$$

$$\frac{\alpha_m}{1-\alpha_m} log(\frac{\tilde{k_m}}{\tilde{y_m}}) = \beta^A log(\tilde{y_m}) + \varepsilon_m^K \quad (6)$$

$$log(\tilde{l_m}) = \beta^A log(\tilde{y_m}) + \varepsilon_m^A \quad (7)$$

These equations use the expression in the second row of equation (3), so after taking logs. That expression states that the log of relative GDP per capita, $\tilde{y_m}$ is equal to the contribution from productivity differences, $\frac{1}{1-\alpha_m} log(\tilde{A_m})$ the contribution from differences in the capital/output ratio, $\frac{\alpha_m}{1-\alpha_m} log(\left(\frac{\tilde{k_m}}{\tilde{y_m}}\right)$ and the contribution from differences in labour input, $log(\tilde{l_m})$ To assess how much each of these three factors contributes to the overall variation in GDP per capita, we run regressions (5a)–(5c).

Since the sum of the dependent variables equals the independent variable, the coefficients β^A, β^K and β^L add up to one and can inform us of the relative importance of each term in accounting for cross-country income differences. This approach for assessing the contributions to income differences was first used in Inklaar *et al.* (2019). Compared to the variance decomposition of (Caselli, 2005), this approach has as a benefit that covariances between inputs need not be separately accounted for. We will use these equations here not to assess the β_s but to identify outliers, i.e. countries that are far outside the typical cross-country relationship between inputs, productivity and income levels. But, first, implementing equations 5a–5c requires data on relative output and input levels.

Measurement of Output and Inputs

Current price GDP

We estimate real GDP by dividing GDP at current prices, in national currency, by purchasing power parities (PPPs) to correct for differences in prices across countries. "Real" in this context should thus be read as "in units comparable across countries". Nominal GDP data is readily available from the National Accounts as published by the United Nations. The primary contribution of PWT is in the estimation of PPPs at the level of consumption, investment, the trade balance and GDP for a long period of time.

As discussed in the previous section, the more recent versions of PWT–including PWT 10.0, which we use in this article–use all available PPP benchmark data for estimating the PPP time series. So, if a country participated in, for example, the ICP comparison for 1980, then the PPPs for 1980 are based on data from that comparison. As the relative prices for final consumption and trade are now based on linked benchmark data, the annual changes in the price levels and real GDP are no longer (automatically) consistent with growth rates as reported in the national accounts, since (in general) consecutive PPP benchmarks are not consistent with national inflation.[10]

To facilitate research into economic growth of a single country over time, PWT also includes a GDP volume series with the growth rates over time identical to those in the National Accounts. In this current article, we use the data for 2017, the year in which the most recent ICP benchmark comparison was held and the reference year for PWT 10.0. Using data for a benchmark year helps focus on the role of input data for productivity, i.e., the methods for estimating output and capital prices for non-benchmark years do not play a role.

Human capital

In PWT version 8.0, a human capital index based on the average years of schooling from Barro and Lee (BL, 2013) was introduced. The years of schooling were weighted using assumed rates of return to education, based on Mincer equation estimates by Psacharapoulos (1994).[11] This followed the approach of Caselli (2005) and assumes an average return on the first four years of 13.4 per cent, a rate of 10.1 per cent on years 5 to 8 and 6.8 percent on every year of schooling beyond 8 years.

In PWT version 9.0 the source for the years of schooling was revised to address criticism by authors such as De La Fuente and Domenech (2006) and Cohen and Soto (2007), who argue that the Barro and Lee data used source data inconsistently. The Barro and Lee (BL) data was supplemented with years of schooling data compiled by Cohen and Leker (CL, 2014).

We opt for either BL or CL depending on whether data for a country are only available from one of these sources, or whichever is closer to the level or trend over time in De La Fuente and Doménech (2006) and years of schooling data from UNESCO.[12]

The assumption of fixed rates of return to education across both time and space may underestimate actual differences in educational attainment between countries.[13] The human capital index could instead be based on country-specific weighting factors using observed wage and employment data, as implemented in, for example, the Total Economy Database produced by the Conference Board (2021). Human capital could also vary between other dimensions, such as gender, work experience and occupation. Unfortunately, data on wages by employment category are not available for

10 This is partly due to index number reasons, as PPPs rely on expenditure shares for multiple countries while national inflation data uses only home-country expenditure shares. Yet most of the inconsistency cannot be readily traced to a clear source, see Inklaar, Marapin, Woltjer and Timmer (2021). As a result, though, these real GDP estimates are less suitable to measure changes over time in a single country.

11 In a Mincer equation, differences in wages are explained by differences in individual characteristics, such as education. The return to education is then given by the coefficient of education on wages.

12 The source of years of schooling data is listed for each country and year in the labour detail file available for download in the additional data and programs sections on http://www.ggdc.net/pwt.

13 We follow the standard implementation of Caselli (2005), though see Lagakos, Moll, Porzio, Qian and Schoellman (2018) for a broader view of human capital in a development accounting context.

many of the lower-income countries in the PWT dataset or these do not span the full time series of the dataset. There is also no consensus about how much the quality of education differs.[14] The current PWT approach ensures that the widest range of countries can be incorporated in our growth and development accounting exercises and improves transparency.

Capital stocks and services

In PWT 9.1 we addressed two important shortcomings in the measurement of capital input. First, we estimated initial capital stocks based on better data and an improved procedure that does more justice to country-specific experiences. Second, we implemented a capital services methodology in accordance with standard productivity measurement theory. By doing so, we account for more of the cross-country variation in income levels. Inklaar *et al.* (2019) provide a full description of the estimation procedure, below we provide a short summary and a discussion of the potential issues and extensions.

The quantity of capital input K_i for each of the nine assets i distinguished in PWT is typically not directly observable.[15] Instead, it is based on estimated net capital stocks N_i which are in turn based on the total accrued investment l_i depreciated over time using the Perpetual Inventory Method (PIM):

$$N_{i,t} = (1-\delta)N_{i,t}{-_1} + l_{i,t} \qquad (8)$$

We next estimate the rental prices for each asset and take account of the differences in investment patterns, particularly evident between poor and rich economies. Following the framework of Jorgenson and Nishimizu (1978) — and more recently discussed in the OECD (2009) capital manual—the asset rental price at time t can be approximated as:

$$r_{i,t} = P_{i,t}^{N}\, i_t + P_{i,t}^{N}\, \delta_i - P_{i,t}{-_1^N}\frac{1}{5}\Big(\sum_{T=t-4}^{t} \hat{P_{i,T}}\Big) \qquad (9)$$

where i_t is the required rate of return on capital, P_i^N is the purchase price of asset i, δ_i is the geometric depreciation rate and $\hat{p}$ is the percentage change in prices. To address volatile asset prices, we use a five-year moving average to estimate the change in asset prices. Assuming that the flow of capital inputs from a particular asset is proportional to the stock of that asset, N_iK_i, we can express the income flow from asset i (the capital compensation for asset i) as r_iN_i and estimate relative capital input for equation (4) as:

$$LogK_m = \sum_i \frac{1}{2}(v_{i,m} + v_{i;})(logN_{i,m} - \overline{logN_i}) \qquad (10)$$

where $V_{i,m} \equiv \frac{r_{i,m}N_{i,m}}{\sum_i r_{i,m}N_{i,m}}$ is the share of asset i in total capital compensation in country m, $v_{i;} = \frac{1}{c}\sum_c v_{i,c}$ is the cross-country average compensation share and $\overline{logN_i} = \frac{1}{c}\sum_c logN_{i,c}$ the cross-country av-

14 One line of evidence for this is based on comparing wages of immigrants to the United States depending on whether they were educated in a low-income or a high-income country (Schoellman, 2012). See Hsieh and Klenow (2010) on the difficulty of (fully) accounting for quality differences in education based on within-country estimates of the return to education.

15 The assets distinguished are residential structures, non-residential structures, transport equipment, information technology equipment, communication equipment, other machinery, software, cultivated assets and other intellectual property products.

erage capital stock. As in equation (4), equation (8) is a multilateral Törnqvist index. For each asset, the capital stock of a country is compared to a geometric average of all countries and the differences in each capital asset, $\overline{logN_{i,m}} - \overline{logN_i}$ are weighted using the share of that asset in capital compensation.

In the standard Jorgensonian approach to rental prices, the required rate of return on capital is chosen to exhaust the income left after subtracting labour income from GDP. This gives an internal rate of return on capital and an important advantage is that this return sets 'pure profits' to zero and is thus consistent with the maintained assumption of perfect competition. An important drawback, in a global context, is that in some countries the rents from extracting natural resources like oil and gas is a sizeable fraction of GDP (Lange, Wodon and Carey, 2018). For those countries, computing the internal rate of return based on the income that does not flow to labour would substantially overestimate the required rate of return on assets.[16] So instead, we determine the income flowing to capital as nominal GDP minus labour income minus natural resource rents.[17]

Outliers from development accounting

This concise overview of the main variables that are used for development accounting highlights that numerous assumptions and choices on measurement and are necessary to compile the output and inputs data to assess relative TFP across country. We now take a more in-depth look at data from PWT 10.0 for the year 2017. As discussed above, we choose to focus on data for the most recent PPP benchmark comparison.

Using the resulting data from PWT 10.0, we then estimate equations 5a–5c for the year 2017, including data for the 114 countries with the required information for all variables. Chart 1 shows three scatter plots, for productivity, produced capital and human capital, against GDP per capita. The regression line is also plotted. The outlying levels of relative TFP in Panel (A) could reflect either extremely high or low productivity but could also result from measurement errors in either the inputs or output. Countries whose price level of GDP is identified as an outlier, for instance due to hyperinflation, are already excluded from Chart 1, so potential measurement errors are limited to capital output, labour input, the share of labour in GDP and nominal GDP.

Panel (b) demonstrates that most of the outliers identified in panel (a) also show extraordinarily low or high relative levels of capital to output. For Cote d'Ivoire (CIV), Egypt (EGY) and Mauritius (MUS), the very low level of capital intensity could explain at least part of the high relative productivity since relative human capital does not appear to be excessively low for these

16 Ideally, natural resources should be recognized as production factors in their own right. That is beyond the scope of this article but see Freeman, Inklaar and Diewert (2018).

17 Natural resource rents are from the World Development Indicators.

countries; see panel (c). For the Central African Republic (CAF), the low share of labour in GDP may be responsible for both the low observed level of relative TFP and high levels of capital to output in panels (a) and (b) respectively.

The countries that are identified here as outliers, by deviating substantially from the main cross-country pattern, depend on the year of the analysis. The analysis could have been done for all benchmark years or all years in PWT. The qualitative results are very similar, in the sense that data for many countries fit the broader pattern of inputs, productivity and output. The list of countries that are outliers in one or more years would be longer. Likewise, as discussed in the introduction, Egypt, Mauritius and Trinidad and Tobago (TTO) are not the only countries with a lower income level, yet a TFP level that exceeds the US level. This is to say that we could have picked from a longer list of countries for the case study that is to follow. Yet, the approach for the case study would be very similar, so it is a diagnostic tool that can be applied more broadly. More generally, we would recommend that users who are interested in a particular country should follow similar steps to see to whether their country fits the broader cross-country patterns or, if not, whether there are specific variables for which country observations are remarkable.

Case Study: Egypt

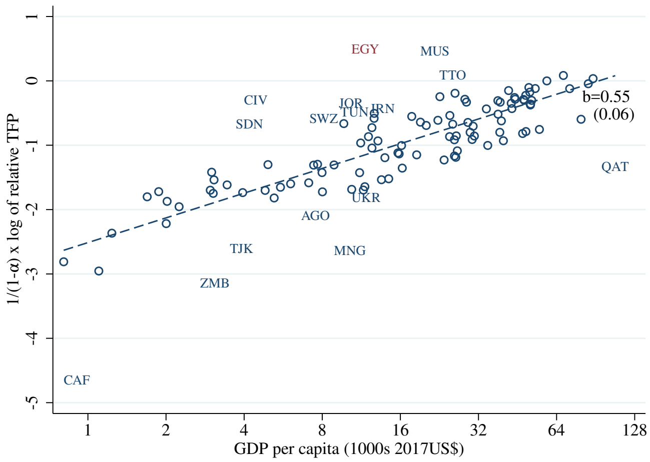
As a first step, Table 2 computes relative output, inputs and TFP compared to different groups of countries. This follows equation (4) and varies the set of countries C in the comparison. The first row shows the data directly from PWT with all 114 countries as reference group but, as in PWT, expressed with USA=1. The second row is based on a multilateral comparison with 12 countries in the Middle East and Africa (MENA) region and the third row uses a group of 19 countries that is within 20 percent of Egypt's level of GDP per capita. By expressing output, input and TFP relative to each reference country (group), we can highlight where data for Egypt are atypical.

The comparison versus the United States is like the standard presentation in PWT, though the numbers in Table 2 are a bilateral comparison, rather than a multilateral comparison with all countries. The MENA comparison group is chosen as regional factors, such as climate, geography and culture, are more similar within this group than with the overall world and it may be that these factors influence output and inputs in similar ways. The United Nations Arab Human Development Report project is one example of the usefulness of such a regional perspective. There is also important diversity in this region, for example, as some countries in the region rely heavily on oil and gas production while others do not. This is one reason why we also consider a second reference group, based on income level. The income reference group is chosen because, from Chart 1, we know that countries at similar income levels have more similar levels of inputs.

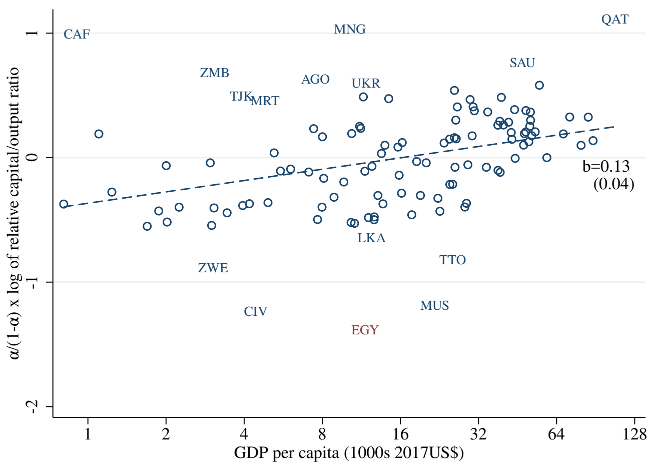
The first row expands on what we learned from Table 1. Egypt's GDP per capita level, y, is 20 per cent of the US and its TFP level A is 23 per cent higher. Egypt's employment-to-population ratio is considerably lower, at 55 per cent of the US

Chart 1: Development Accounting for 2017

Panel A: Total Factor Productivity



Panel B: Produced Capital



Human Capital

Source: Penn World Table, PWT version 10.0, Feenstra *et al.* (AER 2015).

Note: Shown are the 114 countries in PWT 10.0 for which TFP estimates can be made; omitted are countries that did not participate in ICP 2017 as well as those already designated as outliers in PWT. The line shows the OLS line of best fit. Also shown is the slope coefficient and associated robust standard error.

Table 1: Development Accounting for Egypt with Varying Reference Countries, 2017

Reference countries	y	l	Av. hours	HC	k	A
All, USA=1	0.2	0.55	1	0.7	0.07	1.23
MENA=1	0.5	0.7	0.99	1	0.18	1.68
Similar income=1	0.99	0.71	0.96	0.97	0.38	2.07

Source: Penn World Table, version 10.0, Feenstra et al. 2015)

Note: The table show levels for Egypt relative to reference countries. y: GDP per capita, l: employment/population ratio, Av. hours: average hours worked per worker, HC: human capital (years of schooling with assumed rates of return), k: capital/population ratio., A: total factor productivity. Total factor productivity is computed using equation (4) with varying set of countries. Row 1 uses all 114 countries in PWT, and expresses output, inputs and productivity relative to the United States. Row 2 uses Egypt plus 12 countries in the Middle East and North Africa (MENA) region with MENA=1 (BHR, IRN, IRQ, ISR, JOR, KWT. MAR, MLT, QAT, SAU, TUN). Row 3 uses Egypt plus 19 countries that are within 20 per cent of Egypt's GDP per capita level with group income=1 (ARM, BRA, BRB, CHN, COL, ECU, FJI, IDN, IRN, IRQ, JOR, LKA, MNG, NAM, PER, PER, TUN, UKR, ZAF

level; its human capital level stands at 70 per cent and its level of capital per head of the population is only 7 per cent of the US level.

Looking at rows 2 and 3 makes clear that the level of human capital in Egypt is comparable to that in the MENA region and the Similar income group, implying similar average years of schooling in the population. The most substantial differences appear for employment per capita l and capital per capita k Egypt's employment to population ratio is only 70 per cent of the average of the MENA and Similar income groups and its capital to population ratio is only 18 per cent for MENA and 38 per cent for the Income group. For these reasons, Egypt's TFP level relative to the MENA group is 68 per cent higher, despite an income level of only half of the MENA group. Egypt's average income level is, by construction of the group, very close to the Income group, but its TFP level is 107 per cent higher.

Of note is that PWT does not have information on average hours worked in Egypt, so for that reason this is not a contributing factor to TFP differences. As discussed above, PWT does account for differences in average hours worked where available, but data is typically more abundant for higher-income countries. If not available, TFP calculations are done assuming the same number of average hours worked. This assumption is also made for many countries in the MENA and Similar income group, leading to small differences across the rows. From the work of Bick, Fuchs-Schündeln and Lagakos (2018), we know that lower-income countries tend to work more hours per adult. They do have estimates for average hours worked in Egypt and those numbers imply that the average Egyptian workweek at 48 hours is much longer than the average US workweek of 39 hours. If we would use these numbers, Egypt's TFP level relative to the US would be 1.12 rather than 1.23, though the adjustment relative to the other groups would be smaller since the income differences are smaller.

Table 2 looks more closely at the low employment-to-population ratio $l = N/P$ by dividing this ratio into the employment-to-working-age-population ratio, N/P^A and the share of working-age population, P^A/P for a set of countries in the MENA region. The rate N/P^A is low at 40 per cent, though five other countries

Table 2: Employment, Working-age Population and Total Population in the MENA Region (in per cent).

Country	N/P	N/P^A	P^A/P
Egypt	27	40	66
Iran	30	39	76
Iraq	23	37	61
Israel	44	61	72
Jordan	22	33	65
Kuwait	57	72	79
Morocco	30	41	73
Qatar	76	87	86
Saudi Arabia	39	52	75
Tunisia	30	40	76

Source: : PWT for employment and population, WDI for working-age population.

Note: N is employment, P is population and P^A is the working-age population, i.e., the population aged 15–64.

in the table are close to or below this participation rate. Where Egypt stands out most is in its relatively low share of the working-age population, which is due to it having a large share of young people. Yet, Jordan and Iraq are similarly young and have similar employment-to-population ratio, which shows that Egypt's numbers are not beyond belief.

Table 3 examines capital input in more detail for the same group of countries. The aim is to understand the low level of capital input in Egypt. The final column corresponds to the capital input variable used for the 'produced capital' panel of Chart 1. Egypt clearly has the lowest level (0.34) of this group of countries, with Jordan (0.60) and Tunisia (0.58) closest. Starting from the first column, we can see that Egypt has a low investment rate, at 15 per cent of GDP. Only Iraq's investment rate, at 16 per cent, is close. This low investment rate is a longer-run feature of the Egyptian economy, as its nominal capital-output ratio is very low, at 1.74. Here again, Iraq's ratio is similar, at 1.72. Such a low investment rate could be a sign of under-recording of investment; also in a global comparison, there are few countries with investment that are so low. Such an investigation is beyond our scope, but in principle, cross-checks on data on imports or firm-level surveys could be useful.

How this nominal rate translate real differences in capital input depends on the relative prices for capital versus output. Comparing the GDP price and (capital) stock price columns shows that Egypt is almost the only country in the region for which the relative capital stock price is higher than the relative price of output; Tunisia is the only other country that break this pattern. When moving from capital stock prices to capital services prices, all countries show an increase in relative prices (USA=1). The main factor is that all countries have a higher internal rate of return on produced capital than the US (0.07), which means

18 See Inklaar *et al.* (2019) for an analysis showing that the internal rate of return tends to be higher in countries with lower income levels.

Table 3: Investment and Capital in the MENA Region in 2017

Country	Investment (% of GDP)	K/Y (nominal, stock)	GDP Price	Capital Stock Price	Capital Services Price	IRR	K/Y (real, services)
Egypt	15	1.74	0.17	0.20	0.78	0.28	0.34
Bahrain	28	3.29	0.48	0.30	0.74	0.17	1.14
Iran	20	3.77	0.41	0.26	0.86	0.09	0.75
Iraq	16	1.72	0.44	0.31	0.66	0.14	1.17
Israel	21	2.66	1.10	0.82	1.38	0.13	0.89
Jordan	20	2.47	0.40	0.31	0.85	0.17	0.60
Kuwait	27	2.20	0.53	0.30	0.69	0.09	1.42
Morocco	29	3.25	0.41	0.25	0.41	0.10	1.26
Qatar	45	2.63	0.56	0.32	0.64	0.16	1.77
Saudi Arabia	24	2.53	0.43	0.26	0.47	0.12	1.63
Tunisia	19	3.08	0.32	0.36	0.67	0.11	0.58

Source: Penn World Table 10.0 (Feenstra et al. 2015).

Note: Investment is gross fixed capital at current prices; K/Y (nominal, stock) is the current-cost net capital stock in local currency units over GDP; GDP Price is the purchasing power parity of GDP over the nominal exchange rate (XR) (USA=1), Stock Price is the PPP for investment goods, weighted using the share of each asset in the current-cost net capital stock, over XR; Services Price is relative rental price (equation (7)) for each asset, weighted by the share of each asset in capital costs, over XR; IRR is the internal rate of return, the return that equates capital cost to GDP minus labor costs minus natural resource rents; K/Y (real, services) is capital services input (PWT variable ck, USA=1) over real GDP (PWT variable CGDPo) relative to USA real GDP.

capital costs are higher.[18] The increase is largest in Egypt, the country with the highest internal rate of return of this group.[19] So, in summary, Egypt has a low level of capital input, in part because the country devotes a relatively small share of its resources to investment purposes and a result of the high capital prices is that those resources buy relatively few capital goods.

These figures suggest two possibilities. First, it could be that all these statistics are a true reflection of Egypt's economy. This seems hard to accept, since it implies improbably an improbably high TFP level for Egypt's economy. The second possibility is that Egyptian statistics are substantially mismeasured. This may be an attractive conclusion if the alternative is to accept that Egypt's economy is more productive than the US economy.

But an objective basis for such a conclusion is hard to find (other than that these data imply an improbable outcome). While Egypt has a low employment rate, a low investment rate and high capital prices compared to the two groups of comparison countries, they are not so far away from plausible measurements that they can be easily dismissed. For example, other countries with low investment rates are Brazil (15 per cent), Uruguay (16 per cent), Portugal (17 per cent) and Poland (18 per cent). It is also hard to find objective measures of the quality of the statistical sys-

19 This high internal rate of return is needed to reconcile the high observed share of capital income in GDP (64 per cent according to PWT) with the relative low level of capital. Note that the bank lending rate, as shown in the World Bank's @ World Development Indicators (WDI), also shows Egypt with the highest lending rate (18 per cent), with lower rates in United States (4 per cent) and other countries in the region (though data coverage is incomplete).

tem. The World Bank provides a 'statistical capacity' indicator, which is based on the frequency with which important data collection (e.g., an agricultural census) or revisions (to, e.g., consumption baskets for inflation) takes place. On this measure, Egypt in 2017 receives a score of 83 (out of 100), much higher than the average score of 53 for the MENA region and in the top 10 per cent of developing countries.

Several previous versions of PWT also included a letter grade (A–D) as an indicator of data quality.[20] This grade was based on three factors: 1) did the country participate in one or more official PPP benchmarks, 2) what was the inconsistency between consumer inflation and the change in consumption PPPs between benchmarks and 3) how high is the country's income level. Income level is included because resources available for the statistical system are assumed to increase with income level. Especially factors 1 and 2 are geared primarily at PPP measurement.[21] For this article, we replicated the letter grading using only factors 2 and 3, because all but three countries in PWT have participated in at least two official PPP benchmarks. The degree of inconsistency is measured between the two most recent PPP benchmarks, for 2011 and 2017, which is likely most relevant for the analysis of 2017 data. Following the earlier methodology, the inconsistency results are divided into five bins, with low inconsistency reflected in placement in a higher bin. Income levels are divided in six bins. The overall indicator is computed by giving the inconsistency bin score twice the weight of the income bin score as this final indicator is grouped into four bins. Following this procedure gives Egypt a grade of B, the second highest, while many MENA countries score much lower. For example, Iraq and Jordan have grade D and Tunisia grade C.

The correlation between these grades and the statistical capacity indicator is positive, but at a value of 0.36 not very high, which could mean that there are various dimensions to data quality or that these indicators do not capture data quality very well. But as Egypt scores high on both indicators, there is no (ex-ante) reason to doubt Egypt's statistics more than those of many other countries around the world.

Counterfactual TFP levels for Egypt

From Table 2–4 we have learned that the main reasons for the high Egyptian TFP levels is the low employment rate, the low investment rate and the high price of capital. To see the impact of these factors on TFP levels, we present in Table 4 three counterfactual Egyptian TFP levels for each country group. In each counterfactual, one factor is set equal to the unweighted geometric average of the country group. The first row of Table 4 shows that if Egypt would have had the same employment-to-population ratio as the average MENA country or the average country at similar income level, Egypt's TFP level would have been only 6 per

20 See, for example, the documentation to PWT 6.1 (https://www.rug.nl/ggdc/docs/appendix$_{p}wt_{6}1.pdf$).

21 See also Inklaar *et al.* (2021) on inconsistency between inflation and PPP changes.

Table 4: Counterfactual TFP levels for Egypt (USA=1)

	MEAN	Similar Income
Baseline	1.23	1.23
N/P	1.06	1.06
K/Y(nominal)	0.99	0.93
Stock PPP	0.91	0.94

Source: Penn World Table 10.0 (Feenstra et al. 2015).

Note: The baseline TFP level (USA=1) is the same as in Table 2. Subsequent rows recompute TFP, setting one of the three factors equal to the (unweighted geometric) average of the MENA or Income reference groups; see Table 2 for the country lists. Row N/P changes Egypt's employment-to-population ratio; K/Y (nominal) changes Egypt's ratio of the current-cost net capital stock in local currency units over GDP; Stock PPP changes the PPP for investment goods, weighted using the share of each asset in the current-cost net capital stock, over XR.

cent higher than that of the United States rather than 23 per cent higher. TFP would even be 1 to 7 per cent lower if Egypt had the same nominal capital-to-output ratio as the two country groups and 6 to 9 per cent lower if the capital stock price were the same.[22]

These are large adjustments and in most of these counterfactuals, Egypt no longer has a TFP level that is higher than that of the United States. In terms of ranking these factors, the most impactful seems to be the PPP for capital goods, followed by the nominal capital/output ratio and the employment/population ratio. But note that Egypt would still be an outlier if only one of these variables were changed. Recall from Chart 1 that countries with lower income levels tend to have lower TFP levels. From that relationship, the predicted TFP level for Egypt would be only 61 per cent of the US level.

Conclusions

As discussed in the introduction, understanding why some countries have higher TFP levels than others is an important goal of empirical development economics. From the literature we know that choices regarding the conceptual model for development accounting and regarding the measurement of outputs and inputs are important in telling us how large TFP differences across countries are. What we have illustrated in this article is how the data choices and constraints are likewise very important.

We have highlighted one country in one year, Egypt in 2017, with a very high TFP level compared to what we would expect given Egypt's income level and the average cross-country relationship between TFP and income level. That relationship predicts a relative TFP level of 61 per cent of the US level in 2017, while the model, measurement and data of PWT version 10.0 show a level of 123 per cent. We have used regional and income-level comparison groups of countries to illustrate that this exceptional TFP level is due to a low employment rate, a low investment rate and a high price of capital. Yet none of these variables is inherently implausible in these reference groups. Estimating counterfactual TFP levels for Egypt using values from ei-

22 The capital services price of Egypt differs by less from the other countries than the capital stock price, so this adjustment overstates the impact changing capital prices.

ther reference group for the employment-population ratio, the nominal capital stock or the price level of capital would lead to lower estimated TFP levels, but none of those individual counterfactual estimates gets close to the 61 per cent that would be the predicted value solely based on Egypt's income level and measured TFP levels for other countries.

One reading of these results follows the argument above: "See, we knew that Egypt could not be more productive and efficient than the United States and the country turns out to have these crazy output and input figures, so best to ignore this result or deem this measurement approach to be invalid." But with equal justification, this conclusion can be questioned: "So you are saying that Egypt must be employing more people than all sources say? And their investment levels are understated? And the price of capital is also mismeasured? Why would you distrust all these figures?" Egypt does not have a particularly weak statistical system, at least as judged by the World Bank's Statistical Capacity indicator or from replicating the data quality letter grades that was provided in some earlier versions of PWT. Neither of these data quality indicators speaks directly to the reliability of Egyptian National Accounts and price measurement — and we are not aware of any indicator that does. We do not see an interpretation that fits both the broader cross-country pattern (countries with lower income levels tend to be less productive) and the fact that none of these data points is inherently implausible in comparative perspective. That leaves us as PWT data developers with little choice but to present the numbers as they are and leave it to individual users to decide how to interpret the numbers in a way is suitable for their purpose.

While the title of this article suggested that we render a definite verdict on Egypt's TFP level, the broader goal of this article has been to show how a data user might proceed when faced with some figures in PWT (or other databases) that strike them as implausible. The development accounting framework is a useful guide to distinguishing outliers from regular patterns in the data. And especially if a user is interested in analyzing a particular country, we offered a diagnostic approach that may be useful for a more in-depth analysis. TFP, being a residual, will always be sensitive to measurement problems in output or inputs, so user beware.

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