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Is Zimbabwe More Productive Than the United States? Some Observations From PWT 8.1

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Abstract

In Penn World Table (PWT) 8.1, several developing countries stand out as outliers with high total factor productivity (TFP) levels relative to the United States (U.S.). For example, in 2011, Zimbabwe and Trinidad and Tobago are reported to have 3 and 1.6 times higher TFP levels than the U.S., respectively. In addition, for several other countries, such as Turkey and Gabon, the stated levels of TFP are very similar to that of the U.S. level (1.01 and 1.11 times the U.S. levels, respectively). Estimates for some of these countries seem rather unlikely when compared with other measures of productivity (such as output per worker). While in the construction of TFP levels PWT does use country-specific factor shares we show that their results are very similar to calculating TFP levels with a Cobb-Douglas production function where capital and labor shares are assumed to be the same across all countries, i.e., using a constant labor share of $2/3$ for all countries. A simple modification, using a constant labor share of $2/3$ for developed countries and $1/2$ for developing countries, generates more “plausible” estimates for TFP levels.

JEL classification: O11, O40, O47

Keywords: Total factor productivity; labor income shares; Penn Tables

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1 Introduction

One of the most important tasks in the study of economic growth and development is understanding the causes and consequences of productivity differences across countries.¹ The Penn World Table (PWT) has been one of the core sources for reliable data for such comparisons. It provides data on gross domestic product (GDP) at purchasing power parity (PPP), measures of relative levels of income, output, inputs, and productivity with country and period coverage depending on the release.² The first PWT, PWT 5.6, includes 152 countries and territories, for the period 1950-1992. The latest PWT is the PWT 8.1, which covers 167 countries between 1950 and 2011.³ PWT 8.0 and PWT 8.1 include a variable labeled ‘ctfp,’ which reports the measured total factor productivity (TFP) series for each country relative to the U.S. (TFP level at current PPPs, U.S.=1).

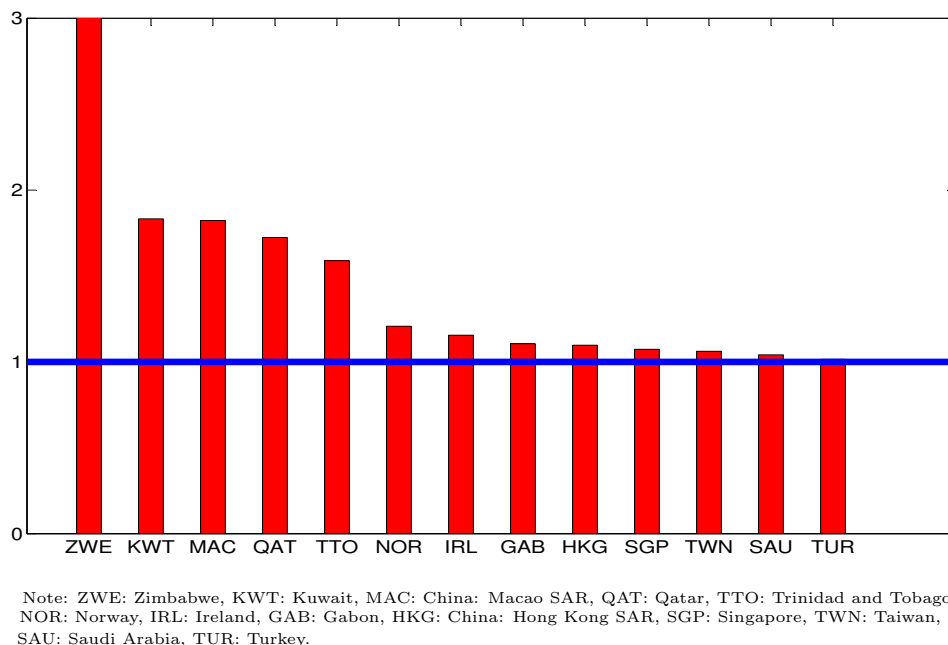


Figure 1: TFP levels in 2011 (relative to the U.S)

Figure 1 displays TFP levels relative to the U.S. TFP level for a number of countries using this measure, ‘ctfp’, from PWT 8.1 for 2011. Several countries stand out with TFP levels higher than the U.S. TFP level. For example, Zimbabwe and Trinidad and Tobago have 3 and 1.6 times higher TFP levels than that of the U.S., respectively. In addition, TFP levels of some other countries, such as Turkey and Gabon, are very similar to that of the

¹Many studies provide documentation of TFP levels across countries (see, for example, Islam, 1995, 2001; Hall and Jones, 1999; Helpman, 2004; Jones and Romer, 2010; Hsieh and Klenow, 2010; Jones, 2015).

²Although data from the PWT are widely used across the world, there is a literature questioning the reliability of data in different versions of the PWT from several angles. See, for example, Knowles, 2001; Dowrick, 2005; Ponomareva and Katayama, 2010; Breton, 2012, 2015; Johnson et al., 2013; Pinkovskiy and Sala-i-Martin, 2016.

³All versions of the PWT are available at: <http://www.rug.nl/research/ggdc/data/pwt/>

U.S. Are all the TFP levels reported in PWT 8.1 reasonable? Examining another measure of productivity, GDP per worker, raises some questions about the reliability of the TFP measure for some of these countries. For example, in 2011, GDP per worker in Zimbabwe was only 25.9% of the U.S. GDP per worker, even though Zimbabwe’s TFP level was 3 times that of the U.S.

In Figure 2, we plot measured TFP levels ($ctfp$) against output per worker in 2010 and in 2011 for 111 countries using PWT 8.1.⁴ The correlation between the two series is 0.81 in 2010 and 0.71 in 2011. If we exclude Zimbabwe, the correlation between two series increases to 0.89 in both 2010 and 2011. Zimbabwe is clearly an outlier in this sample.

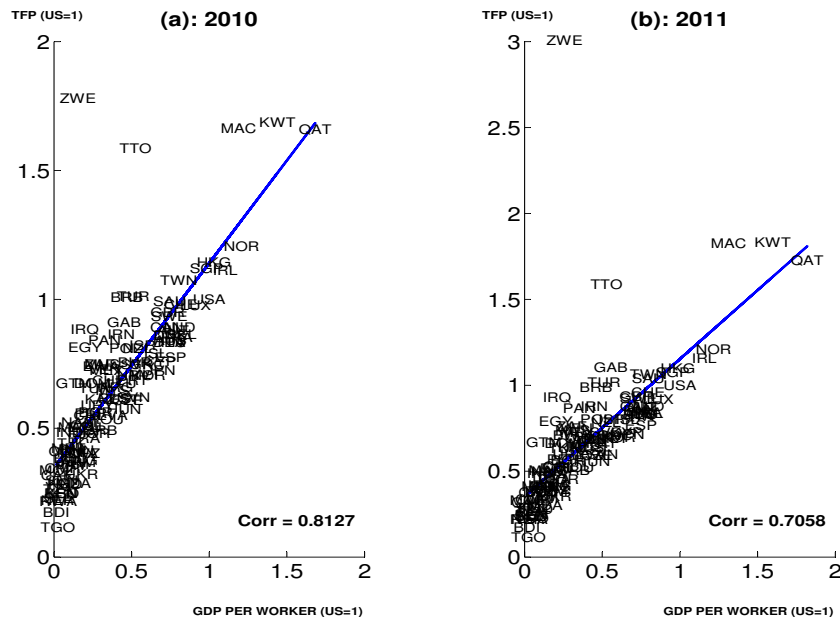


Figure 2: Reported TFP in PWT 8.1 in 2010 and 2011

It is of course possible for some countries to have higher TFP levels than the U.S. Indeed, several studies provide explanations for seemingly surprisingly high TFP levels in some countries. For example, resource-rich countries such as Gabon, Kuwait, Qatar, and Saudi Arabia are among the top countries in terms of TFP levels. The likely reason for this observation seems to be their high productivity in oil production. According to data from the World Bank, oil rent to GDP was 58.6% in Kuwait, 48.8% in Saudi Arabia, 45.3% in Gabon, and 29.9% in Qatar in 2011. Oil rent to GDP was also more than 10% in Norway and Trinidad and Tobago.⁵ Hall and Jones (1999) also report similar observations and subtract

⁴We use the variable $ctfp$ for TFP levels. This measure of TFP of the PWT is based on a Tornqvist index of inputs that incorporates variations in factor shares (see Feenstra et al., 2015). This point is also mentioned in Jones (2015). We use the variable $cgdpo$ (output-side real GDP at current PPPs (in mil. 2005US\$)) for GDP and the variable emp (number of persons engaged (in millions)) for employment. Using these two variables, we calculate GDP per worker (labor productivity). We use data for 111 countries, since data for the variable $ctfp$ are reported for these countries.

⁵Oil rents are the difference between the value of crude oil production at world prices and total costs of production. Data are from the World Bank’s World Development Indicators (World Bank, 2016).

the value added in the mining industry from GDP in computing their measure of output to deal with the issue.

It is also the case that several countries stand out as outliers or extreme cases in different studies that compare productivity levels across countries. For example, Puerto Rico stands out as the most productive country in 1998 in Hall and Jones (1999), in which Hall and Jones (1999) use the PWT 5.6. Hall and Jones (1999, footnote 8) note that an overstatement of real output in Puerto Rico might be responsible for such a finding.⁶

However, it is not clear why countries such as Turkey or Zimbabwe have higher TFP levels than the U.S. In this paper, we argue that the choice of the value for the shares of labor and capital for developing versus developed countries is likely to be the culprit behind some of the extreme TFP levels reported in PWT. While in the construction of TFP levels, PWT does use country specific factor shares, we show that their results are very similar to calculating TFP levels with a Cobb-Douglas production function where capital and labor shares are assumed to be the same across all countries, i.e., using a constant labor share of $2/3$ for all countries. While Gollin (2002) argues that factor shares adjusted for self-employed income and sectoral composition are remarkably constant across countries and Bernanke and Gürkaynak (2001) find no systematic tendency for country labor shares to vary with per capita income, other studies have argued that labor income shares in developing countries should be less than the corresponding shares in developed countries (Chen et al., 2010; Izyumov and Vahaly, 2015). There may be compelling reasons to investigate this issue further, as different factor shares generate very different conclusions about relative TFP levels for many countries. We show that a simple modification, using a constant labor share of $2/3$ for developed countries and $1/2$ for developing countries, generates more plausible estimates for differences in TFP levels between the U.S and several developing countries, including Zimbabwe and Turkey. Overall, we show that the level of factor shares used in these calculations makes a big impact on the comparison of TFP levels across countries and conclude that the relative TFP measure reported in PWT should be used with caution.

We note that our paper is silent on the trend changes in labor share. There is recent evidence pointing to declines in the labor share of production in most OECD countries in the last three to four decades. There has been a new emerging literature documenting and investigating different explanations for this phenomenon (see, for example, Elsby et al., 2013; Karabarbounis and Neiman, 2014). Some argue that these negative trends in labor share call into question the appropriateness of a Cobb-Douglas aggregate production function, with constant factor shares under competitive factor markets (Jayadev, 2007; Rodriguez and Jayadev, 2010). We abstract from this issue in this paper.

The paper is organized as follows. Section 2 presents a common framework to measure TFP levels and provides an alternative method where we treat labor income share to be

⁶In addition, differences in methodology matter; according to the results of several approaches, differences in TFP levels across countries are substantial. This case is well noted in Helpman (2004). Helpman (2004, p. 29) compares the findings of Islam (1995) and Hall and Jones (1999) and states the following observation: “Yet the estimated relative productivity levels differ substantially for some countries. An extreme example is Jordan, for which Islam’s estimate is 25 percent of U.S. productivity while Hall and Jones’s estimate is about 120 percent of U.S. productivity. These differences notwithstanding, both series of estimates show large cross-country variations in TFP.” Islam (1995) uses an econometric approach and panel data estimation while Hall and Jones (1999) use neoclassical assumptions about production to get the parameters.

different between developed and developing countries. Section 3 presents the results of alternative methods and compares the results. Section 4 concludes.

2 A Framework for Measured TFP

2.1 A Common Method

A well-known approach to calculate TFP levels in the development literature can be summarized, á la Caselli (2005), as follows. Labor productivity is apportioned, y_t^i , between endowments and TFP using the following constant returns to scale Cobb-Douglas technology:

$$Y_t^i = A_t^i \left(K_t^i \right)^{\alpha_i} \left((hE)_t^i \right)^{1-\alpha_i}, \quad (1)$$

where A , K , h , and α are, respectively, TFP, the stock of capital, human capital per worker, and capital factor income share. This form is re-written in an intensive form to arrive at the following decomposition of labor productivity:

$$y_t^i = A_t^i \left(k_t^i \right)^{\alpha_i} \left(h_t^i \right)^{1-\alpha_i}, \quad (2)$$

where k ($\equiv K/E$) represents capital deepening. Expressing the country i performance relative to that of the U.S. leads to the following ratio of TFP levels:

$$\frac{A_t^i}{A_t^{US}} = \frac{\frac{y_t^i}{\left(k_t^i \right)^{\alpha_i} \times \left(h_t^i \right)^{1-\alpha_i}}}{\frac{y_t^{US}}{\left(k_t^{US} \right)^{\alpha_{US}} \times \left(h_t^{US} \right)^{1-\alpha_{US}}}}. \quad (3)$$

Given times series for y_t^i , k_t^i , h_t^i , there is a tendency of using a common value of $\alpha = 1/3$ for each country in the related literature.⁷ This way of calculating TFP is widely used in many studies, such as Jones and Romer (2010), Hsieh and Klenow (2010), and Jones (2015). We call this approach *Method 1*.

$$\text{Method 1:} \quad \alpha_i = \alpha_{US} = 1/3. \quad (4)$$

There has been a tradition arguing that the factor shares in national income are roughly constant over time. The reference for this argument is based on Kaldor's stylized facts for the United States (see Kaldor, 1961). Gollin (2002) argues that factor shares adjusted for self-employed income and sectoral composition are remarkably constant across both time and countries, and that the capital shares cluster around one-third. In line with Gollin (2002), Bernanke and Gürkaynak (2001) find no systematic tendency for country labor shares to

⁷PWT 8.0 and PWT 8.1 provide data on y_t^i , k_t^i , h_t^i as well as α_t^i . In previous versions, there were no data for human capital. Data for human capital reported in PWT 8.0 and PWT 8.1 are consistent with the previous studies, i.e., data for average years of schooling are from Barro and Lee (2013) and data for returns to education are from Psacharopoulos (1994). Mincerian approach allows for conversion into years of schooling. See Caselli (2005) on how to construct human capital data using information from Psacharopoulos (1994) and Barro and Lee (2013).

vary with per capita income. Setting a common value of $\alpha = 1/3$ for each country has been a widely used practice in cross-country studies since then.

2.2 A Simple Modification

Method 1 rests on unification of factor shares across countries. A comparative perspective of countries at different levels of income (developing versus developed countries) may reveal some features of the relationship between the magnitude of the capital/labor income share and TFP differences that cannot be observed from *Method 1*.

Recent cross-country studies point to the observation that factor income shares might differ between developed and developing countries. For example, Izyumov and Vahaly (2015) contradict the factor income share conversion hypothesis for the 1990-2008 period (using a group of 55 developed and developing countries) and argue that a country in the middle of development distribution will have labor share that is 10-15 percentage points below that of a typical OECD country. Similarly, Chen et al. (2010) use 0.5 as the labor share for developing economies, because labor is cheap compared with advanced countries, leading to a lower labor share. Trapp (2015) discusses the challenges of measuring the labor income share of developing countries studying developing countries from 1990 to 2011 and argues that the average level of labor share is around 0.47. In addition to cross-country studies, there are some country-specific studies that argue that the value of labor share parameter in developing countries such as China and Turkey is around 0.5.⁸ The idea of using different labor shares for developing countries is also supported by Young and Lawson (2014) who study the relationship between the institutions of economic freedom and labor shares in a panel of up to 93 countries covering 1970 through 2009. They find that countries with higher economic freedom scores tend to have higher labor shares.⁹

In accordance with these discussions, we modify *Method 1* as follows:

$$\text{Method 2:} \quad \begin{cases} \alpha_i = 1/2 & \text{if country } i \text{ is a developing country} \\ \alpha_i = 1/3 & \text{if country } i \text{ is a developed country} \\ \alpha_{US} = 1/3. \end{cases} \quad (5)$$

To implement this method, we group countries according to different levels of economic development. First, the data of all economies are grouped into four categories of status of economic development according to the World Bank. In the World Bank's classification system, economies are ranked by their levels of gross national income (GNI) per capita. These economies are then classified as low-income countries (L), lower-middle-income countries (LM), upper-middle-income countries (UM), and high-income countries (H). The income group thresholds are updated annually at the beginning of the World Bank's fiscal year with an adjustment for inflation. This annual adjustment reflects the economies' development experiences. For example, China is classified as a low-income economy in 1990, a lower-middle-income country in 2000, and an upper-middle-income country in 2010. The World

⁸See Bai et al., 2006; Brandt et al., 2008; Brandt and Zhu, 2010; Zhu, 2012; Dollar and Jones, 2013 for China; Altuğ et al., 2008; Ismihan and Metin-Özcan, 2009; and Tiryaki, 2011 for Turkey.

⁹Young and Lawson (2014) report that the average labor share between 1970 and 2009 is 0.599 in Switzerland and 0.163 in Niger.

Bank reports the following thresholds in 2010:¹⁰ Low-income countries are defined as having a per capita GNI in 2010 of \$1,005 or less; lower-middle-income countries have incomes between \$1,006 and \$3,975; upper-middle-income economies have incomes between \$3,976 and \$12,275; and high-income economies have incomes \$12,276 or more. Second, equipped with the World Bank classification at hand, we group the countries under the categories of (i) low-income economies, (ii) lower-middle-income economies, and (iii) upper-middle-income economies as developing countries. Therefore, we set $\alpha = 1/2$ for these countries. We treat high-income economies as developed countries and set $\alpha = 1/3$ for these countries.¹¹

PWT 8.1 provides data on y_t^i , k_t^i , and h_t^i . We use the variable *cgdp* (output-side real GDP at current PPPs (in mil. 2005US\$)) for GDP and the variable *emp* (number of persons engaged (in millions)) for employment. Using these two variables, we calculate GDP per worker (labor productivity) for each country. We use the variable *ck* (capital stock at current PPPs (in mil. 2005US\$)) for k_t^i ; and we use the variable *hc* (index of human capital per person, based on years of schooling and returns to education) for h_t^i . To provide the results for *Method 1*, we set $\alpha = 1/3$ for all the countries in the sample while for *Method 2* we set $\alpha = 1/3$ for each developed country and $\alpha = 1/2$ for each developing country in the sample.

3 Results and Comparison of Methods

It is difficult to assess whether or not a particular measure results in a “reasonable” comparison of TFP levels across countries. Here, we provide some suggestive evidence. In Figure 3, we display TFP levels obtained from the two different methods we employ as well as the PWT measure, *ctfp*, for a select number of countries. First, we compare the relative TFP levels obtained using *Method 1* with the data provided in PWT. As mentioned before, PWT uses country-and time-specific factor shares to generate the country-specific TFP levels. Their measure, however, is very similar to the TFP measures we obtain by using the same factor shares for both developed and developing countries (where $\alpha = 1/3$). For Zimbabwe, for example, PWT reports a TFP level that is 3 times that of the U.S. Using *Method 1*, we obtain Zimbabwe’s TFP level to be twice as high as that of the U.S. On the other hand, *Method 2* generates fairly different TFP levels. For example, using *Method 2*, we obtain a TFP level for Zimbabwe that is 60% of the U.S. level.¹² Similar observations can be made for Turkey, Trinidad and Tobago, and Gabon. In all these cases, *Method 1* delivers results very similar to what is reported in PWT. *Method 2*, on the other hand, yields significantly

¹⁰Historical classifications by income are available at: siteresources.worldbank.org/DATASTATISTICS/Resources/OGHIST.xls

¹¹According to our classification, there are 43 developed countries and 68 developing countries in our 111-country sample.

¹²It is also possible that due to some of the macroeconomic changes in Zimbabwe in recent years, reporting of economic data may not have been reliable. This might have been especially the case after inflation peaked at an astounding monthly rate of 79.6 billion percent in mid-November 2008 (Hanke and Kwok, 2009; Hanke and Krus, 2012). In 2009, Zimbabwe started to adopt the U.S. dollar and became fully dollarized by law. Between 2009 and 2011, Zimbabwe’s GDP growth averaged close to 10%, making it one of the world’s fastest-growing countries, after recording a growth rate that was around minus 18% in 2008 (World Bank, 2016).

lower TFP levels relative to the U.S.

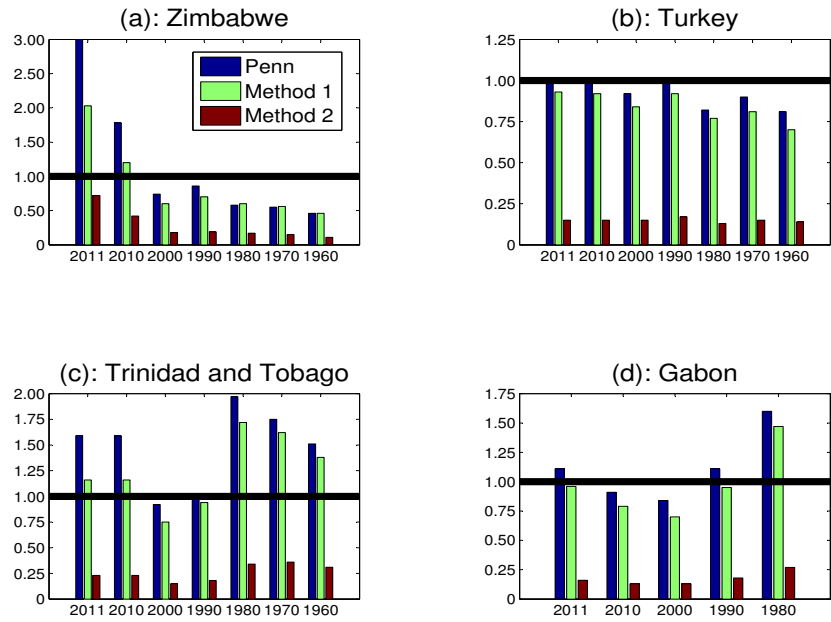


Figure 3: TFP levels in selected countries (relative to the U.S)

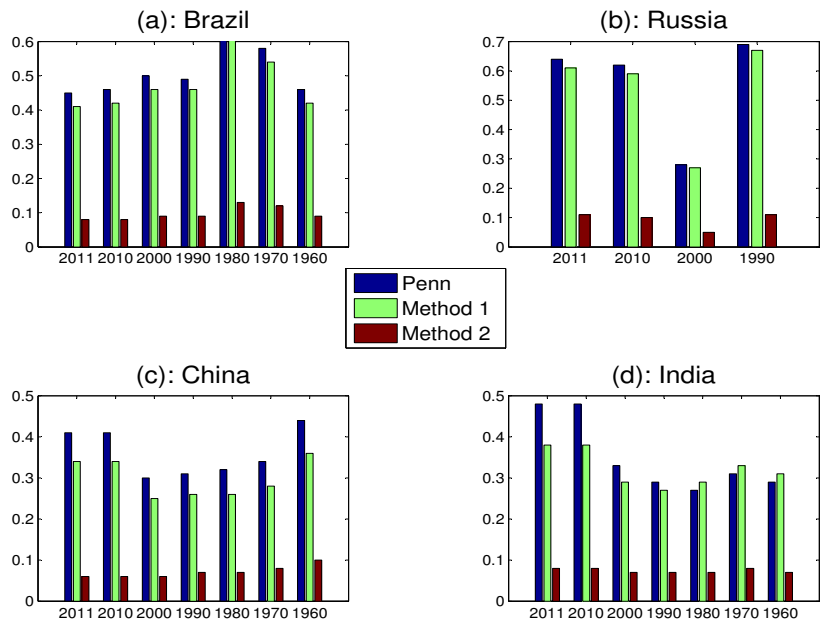


Figure 4: TFP levels in BRIC countries (relative to the U.S)

We have similar observations for the BRIC countries (Brazil, Russia, India, and China), the group of emerging markets that encompass significant shares of the world’s land coverage, population, and GDP (see Figure 4). For China, for 2011, PWT reports a TFP level that is 41% of the U.S. Using *Method 1*, we obtain China’s TFP level that is 34% of the U.S. On the other hand, using *Method 2*, we obtain a TFP level for China that is 6% of the U.S. level only. It is worth noting that a careful examination of the data leads Bai et al., (2006) to estimate the labor share of income to be $\alpha = 1/2$ for China. That is the value of the labor share used in *Method 2*. Similar observations are made for Brazil, Russia, and India. In all these cases, *Method 1* delivers results very similar to what is reported in PWT, whereas *Method 2* generates significantly lower TFP levels relative to the U.S.

Next, we examine the time series for the TFP levels for these countries for the different measures. Figure 5 shows the three different TFP levels as well as the GDP per worker for these countries. All the series reported are relative to the U.S. All three TFP series are highly correlated with each other. For example, the correlation between *ctfp* and TFP (*Method 1*) is 0.96 for Turkey. The corresponding correlation between *ctfp* and TFP (*Method 2*) is 0.94. However, differences in TFP levels are striking. Reported TFP series in PWT 8.1 are higher than those of our calculations for each method. For Turkey, in 2011, the value of *ctfp* is 1.01; the value of TFP (*Method 1*) is 0.93; and the value of TFP (*Method 2*) is 0.15. Turkey’s GDP per worker is 51% of the U.S. in 2011. Depending on the measure used, Turkey is either more productive than the U.S. or significantly less productive than the U.S.

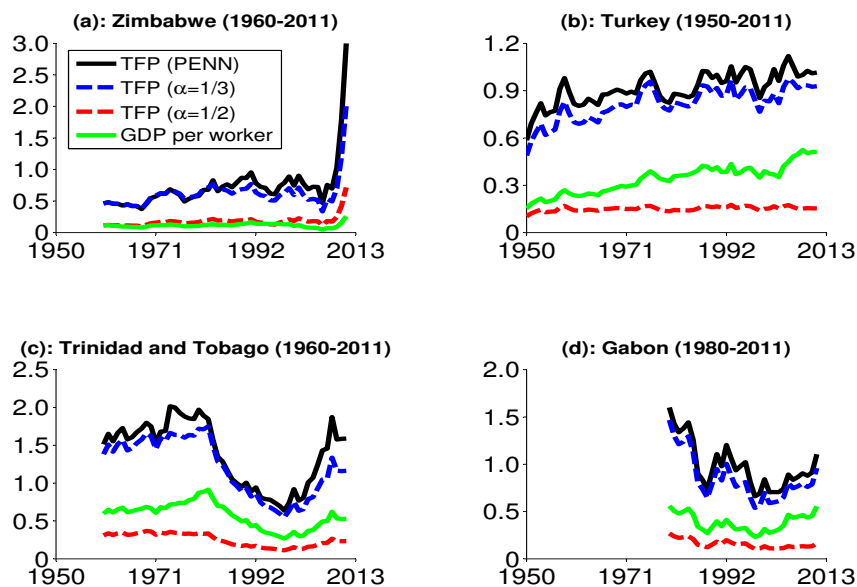


Figure 5: Productivity levels in selected countries

In Figure 6, we repeat the same exercise for the BRIC countries. Similar to the findings before, TFP levels obtained with *Method 1* yield results very similar to the data provided by PWTs. *Method 2*, on the other hand, generates substantially lower levels of TFP and is much closer to the GDP per worker measure provided for these countries.

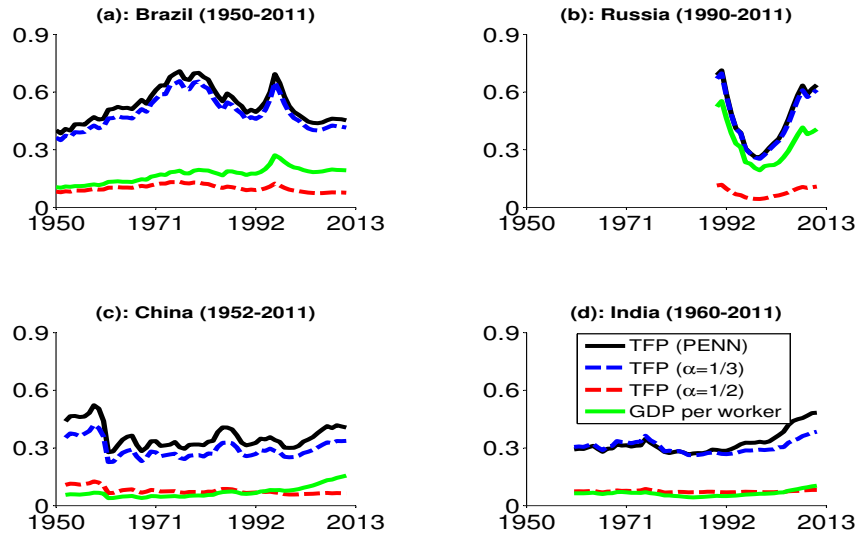


Figure 6: Productivity levels in BRIC countries

It may also be informative to look at the correlations between different TFP measures and output per worker for all the countries in PWT. In Figure 7, we provide three scatter plots of GDP per capita versus a particular TFP measure for the year 2010. Panels (a), (b) and (c) use the TFP measures obtained from PWT, *Method 1*, and *Method 2* respectively. The observations we have summarized using a select number of countries, remains to be valid when we examine the entire set of countries. The scatter plots using PWT data and *Method 1* yield similar results. Correlation between TFP and output per capita is higher under *Method 2*. This method also generates a larger number of low TFP observations.¹³

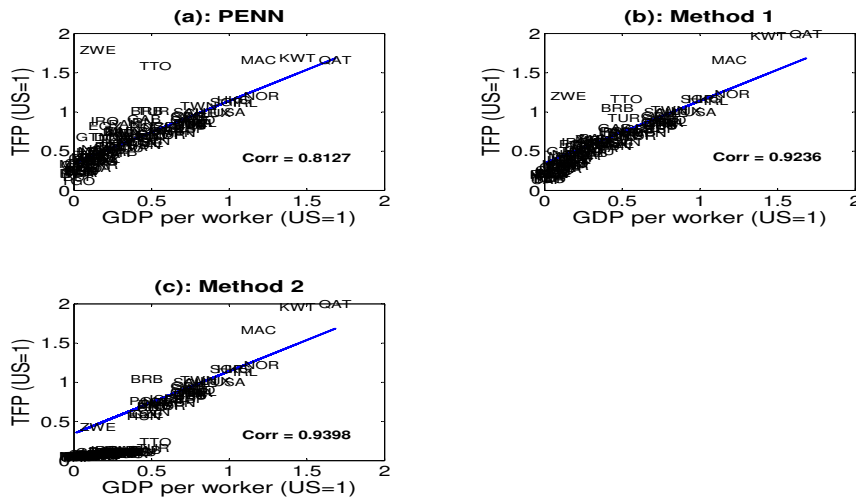


Figure 7: TFP and GDP per worker levels in 2010

¹³See Appendix A for a summary of this data for all decades since 1960.

We summarize the frequency distribution of productivity levels (relative to the U.S.) of 111 countries in 2011 in Figure 8. Panel (a) in Figure 8 displays that there are 17 countries that have output per worker levels less than or equal to 10% of the U.S. output per worker level in 2011. There are no countries in this region based on PWT data or *Method 1* as summarized in panels (b) and (c). However, with *Method 2* (panel (d)), there are 48 countries that have TFP levels less than or equal to 10% of the U.S. TFP level in 2011. In panel (d), with *Method 2*, there are 66 countries that have TFP levels less than (or equal to) 20% of the U.S. TFP level in 2011. On the other hand, according to the reported series in PWT, there are only two countries (Burundi and Togo) with TFP levels less than 20% of the U.S. TFP level in 2011. The corresponding number of countries is 8 if *Method 1* is used (Central Africa, Burundi, Togo, Tazmania, Niger, Mozambique, Senegal, and Lesotho).

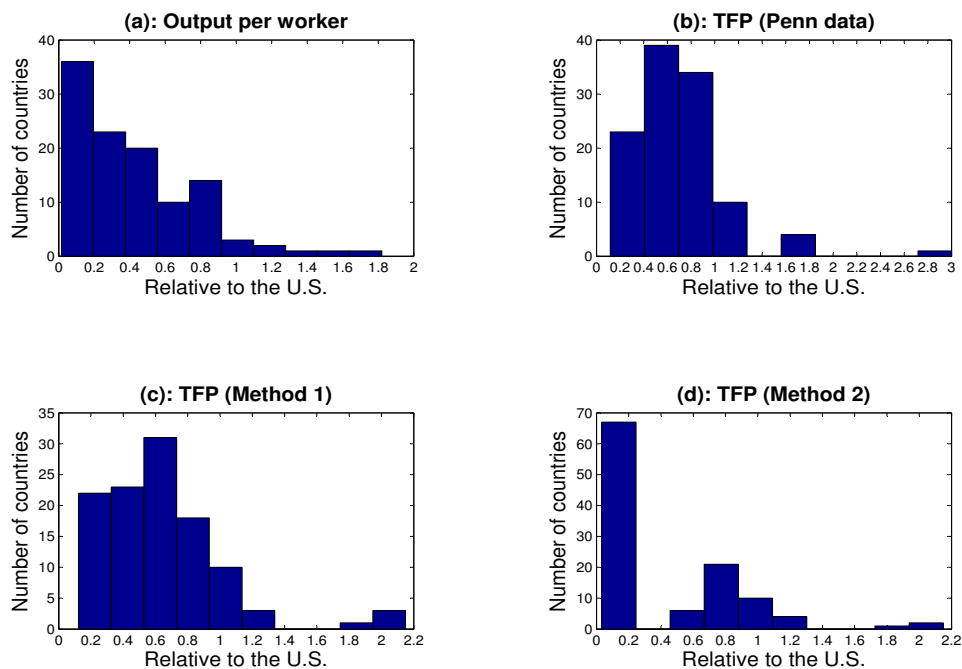


Figure 8: Frequency distribution of productivity levels in 2011

Method 2, in most of the cases, results in lower estimates of TFP levels. It is, however, difficult to know what kind of a frequency distribution is “reasonable”. Perhaps *Method 2* results in too many countries with very low TFP levels compared to the U.S. What we present simply provides evidence that TFP level comparisons are highly influenced by the factor shares used. Among the countries examined in this paper, we argue that the detailed studies conducted for Turkey and China do provide a more accurate calculation for their factor shares. The resulting TFP levels for these countries are significantly different from the ones in PWT and more similar to the ones obtained with *Method 2*.

Lastly, the simple average of TFP levels for 111 countries in 2011 is 0.41 if *Method 2* is employed. The corresponding average is 0.69 in PWT data and 0.64 if *Method 1* is employed. Figure 9 shows the unweighted averages for 68 developing countries in 2011. For example,

unweighted average of TFP levels for 68 developing countries in 2011 is 0.09 if *Method 2* is employed. The corresponding average is 0.55 in PWT data and 0.46 if *Method 1* is employed.

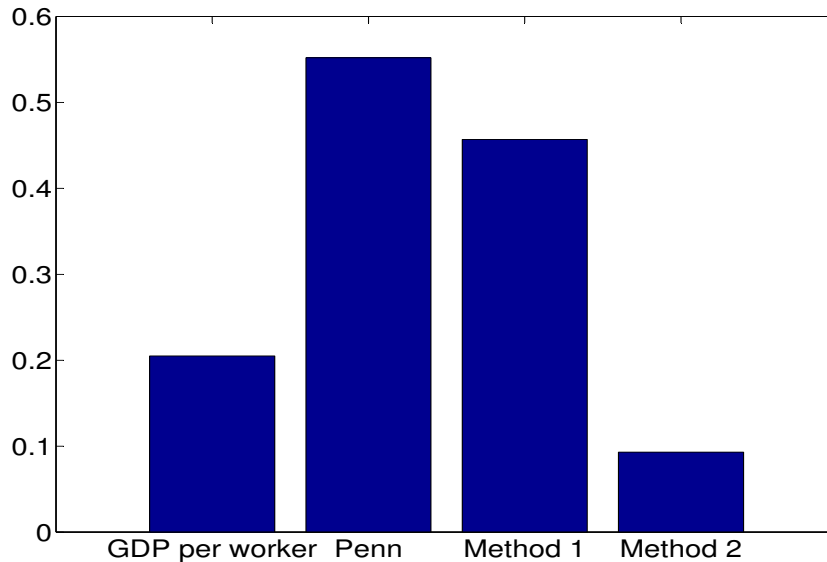


Figure 9: Unweighted averages for 68 developing countries in 2011

Overall, we conclude that the relative TFP measure reported in PWT should be used with caution. Differences in TFP measures obtained in the methods we report highlight the importance of the factor shares used in these calculations. For country-specific studies, we recommend a detailed analysis of the factor shares.

4 Concluding Remarks

One of the most important findings of the development accounting literature is that differences in measured TFP explain more than half of the cross-country differences in output per worker (Jones and Romer, 2010). The Penn World Table is the most widely used source for cross-country comparisons for these development and growth accounting procedures. Therefore, studying the data reported in the PWT is important. In PWT 8.1, which is the latest version of the Penn World Table, several developing countries stand out as outliers, with high TFP levels, relative to the U.S. Estimates for some of these countries seem rather unlikely when compared with other measures of productivity (such as output per worker). In this paper, we argue that the measure used for the share of labor and capital for developing versus developed countries is likely to be the culprit behind some of unexpected TFP calculations in PWT. While in the construction of TFP levels, PWT does use country specific factor shares, we show that their results are very similar to calculating TFP levels with a Cobb-Douglas production function where capital and labor shares are assumed to be the same across all countries.

A simple modification, using constant labor share of $2/3$ for developed countries and $1/2$ for developing countries, generates more plausible estimates for differences in TFP levels between the U.S and several developing countries. Measurement of factor income shares at the country-specific level is a demanding task considering the data problems that are well-cited, especially in developing countries. For example, as discussed widely in Gollin (2002), additional imputations of the labor income of self-employed and family workers should be made to adjust for the underestimation of the labor income share in the National Accounts Statistics. However, the number of careful studies at the country level has been increasing (see, for example, Bai et al., 2006; Bai and Qian, 2010 for China) that will make it possible to generate more accurate TFP comparisons across countries.

We argue that reported TFP levels in Penn World Tables should be used with caution, considering the possible measurement issues. We have dealt with a particular aspect of measurement problem here in a very stylized manner. We are aware of the fact there are more significant and bigger measurement problems for TFP levels, since cross-country differences in GDP per worker, physical capital, and human capital contribute to cross-sectional gaps in TFP levels. First, overstating of output in national income accounts is a source of measurement issues (see the discussion on Puerto Rico in Baumol and Wolff, 1996; Hall and Jones, 1999).^{14,15} Second, it is well known in the literature that some countries, because of government inefficiency and corruption, might be systematically overestimating the increase in physical capital taking place each period (see, for example, Prichett, 2000; Hsieh, 2002). Third, recent literature has incorporated the quality-adjusted measures of human capital into the growth accounting analyses, i.e., the knowledge and skills of the population as proxied by the consistent international test scores such as the Programme for International Student Assessment (PISA) (see Caselli, 2015 and Cubas et al., 2016 for a recent cross-country quantitative analysis concerning such issues).¹⁶ Cubas et al. (2016) argue that the quality of labor in rich countries is about twice as large as the quality in poor countries, and this results smaller disparities in TFP levels compared to those obtained from growth models using a Mincerian measure of labor quality. These are some of the possible avenues for future empirical work on productivity measurement to understand TFP differences across countries.

¹⁴Another important measurement issue is the relationship between intangible investment/capital and measured productivity since the inclusion/exclusion of intangibles (such as research and development, software, brands, etc.) changes the total output and the related calculations (see Corrado et al., 2009; McGrattan and Prescott, 2010).

¹⁵GDP revisions, especially in poor countries, have been a constant topic of discussion in recent years. It is reported in *The Economist* (2016) that “Nigeria’s GDP was revised up by 89% in 2014. Later that year, Kenya’s GDP was revised up by 25%. Ghana’s GDP had been upgraded by 60% in 2010.”

¹⁶Providing a coherent criticism of measuring a nation’s human capital by school attainment, Hanushek and Woessmann (2015) argue that internationally comparable measures of cognitive skills correlate highly with economic growth, and cognitive skills can explain away large differences in growth rates between world regions. Jones (2014) argues that ignoring complementarities and scarcity among human capital types would understate human variation; and implementing an accounting with generalized human capital (i.e., allowing workers to provide differentiated services) may account for the large income variations between rich and poor countries.

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Appendix A

Countries (and the three-letter country codes) for 1990, 2000, 2010, and 2011 are: (1) Argentina (ARG), (2) Armenia (ARM), (3) Australia (AUS), (4) Austria (AUT), (5) Burundi (BDI), (6) Belgium (BEL), (7) Benin (BEN), (8) Bulgaria (BGR), (9) Bahrain (BHR), (10) Bolivia (BOL), (11) Brazil (BRA), (12) Barbados (BRB), (13) Botswana (BWA), (14) Central African Republic (CAF), (15) Canada (CAN), (16) Switzerland (CHE), (17) Chile (CHL), (18) China, People's Republic of (CHN), (19) Côte d'Ivoire (CIV), (20) Cameroon (CMR), (21) Colombia (COL), (22) Costa Rica (CRI), (23) Cyprus (CYP), (24) Czech Republic (CZE), (25) Germany (DEU), (26) Denmark (DNK), (27) Dominican Republic (DOM), (28) Ecuador (ECU), (29) Egypt (EGY), (30) Spain (ESP), (31) Estonia (EST), (32) Finland (FIN), (33) Fiji (FJI), (34) France (FRA), (35) Gabon (GAB), (36) United Kingdom (GBR), (37) Greece (GRC), (38) Guatemala (GTM), (39) China: Hong Kong SAR (HKG), (40) Honduras (HND), (41) Croatia (HRV), (42) Hungary (HUN), (43) Indonesia (IDN), (44) India (IND), (45) Ireland (IRL), (46) Iran (Islamic Republic of) (IRN), (47) Iraq (IRQ), (48) Iceland (ISL), (49) Israel (ISR), (50) Italy (ITA), (51) Jamaica (JAM), (52) Jordan (JOR), (53) Japan (JPN), (54) Kazakhstan (KAZ), (55) Kenya (KEN), (56) Kyrgyzstan, (57) Republic of Korea (KOR), (58) Kuwait (KWT), (59) Sri Lanka (LKA), (60) Lesotho (LSO), (61) Lithuania (LTU), (62) Luxembourg (LUX), (63) Latvia (LVA), (64) China: Macao SAR (MAC), (65) Morocco (MAR), (66) Republic of Moldova (MDA), (67) Mexico (MEX), (68) Malta (MLT), (69) Mongolia (MNG), (70) Mozambique (MOZ), (71) Mauritania (MRT), (72) Mauritius (MUS), (73) Malaysia (MYS), (74) Namibia (NAM), (75) Niger (NER), (76) Netherlands (NLD), (77) Norway (NOR), (78) New Zealand (NZL), (79) Panama (PAN), (80) Peru (PER), (81) Philippines (PHL), (82) Poland (POL), (83) Portugal (PRT), (84) Paraguay (PRY), (85) Qatar (QAT), (86) Romania (ROM), (87) Russian Federation (RUS), (88) Rwanda (RWA), (89) Saudi Arabia (SAU), (90) Senegal (SEN), (91) Singapore (SGP), (92) Sierra Leone (SLE), (93) Serbia (SRB), (94) Slovakia (SVK), (95) Slovenia (SVN), (96) Sweden (SWE), (97) Swaziland (SWZ), (98) Togo (TGO), (99) Thailand (THA), (100)

Tajikistan (TJK), (101) Trinidad and Tobago (TTO), (102) Tunisia (TUN), (103) Turkey (TUR), (104) Taiwan (TWN), (105) United Republic of Tanzania: Mainland (TZA), (106) Ukraine (UKR), (107) Uruguay (URY), (108) United States (USA), (109) Venezuela (VEN), (110) South Africa (ZAF), (111) Zimbabwe (ZWE).

Countries (and the three-letter country codes) for 1980 are: (1) Argentina (ARG), (2) Australia (AUS), (3) Austria (AUT), (4) Burundi (BDI), (5) Belgium (BEL), (6) Benin (BEN), (7) Bulgaria (BGR), (8) Bahrain (BHR), (9) Bolivia (BOL), (10) Brazil (BRA), (11) Barbados (BRB), (12) Botswana (BWA), (13) Central African Republic (CAF), (14) Canada (CAN), (15) Switzerland (CHE), (16) Chile (CHL), (17) China (CHN), (18) Côte d'Ivoire (CIV), (19) Cameroon (CMR), (20) Colombia (COL), (21) Costa Rica (CRI), (22) Cyprus (CYP), (23) Germany (DEU), (24) Denmark (DNK), (25) Dominican Republic (DOM), (26) Ecuador (ECU), (27) Egypt (EGY), (28) Spain (ESP), (29) Finland (FIN), (30) Fiji (FJI), (31) France (FRA), (32) Gabon (GAB), (33) United Kingdom (GBR), (34) Greece (GRC), (35) Guatemala (GTM), (36) China: Hong Kong SAR (HKG), (37) Honduras (HND), (38) Hungary (HUN), (39) Indonesia (IDN), (40) India (IND), (41) Ireland (IRL), (42) Iran (Islamic Republic of), (43) Iraq (IRQ), (44) Iceland (ISL), (45) Israel (ISR), (46) Italy (ITA), (47) Jamaica (JAM), (48) Jordan (JOR), (49) Japan (JPN), (50) Kenya (KEN), (51) Republic of Korea (KOR), (52) Kuwait (KWT), (53) Sri Lanka (LKA), (54) Lesotho (LSO), (55) Luxembourg (LUX), (56) China: Macao SAR (MAC), (57) Morocco (MAR), (58) Mexico (MEX), (59) Malta (MLT), (60) Mongolia (MNG), (61) Mozambique (MOZ), (62) Mauritania (MRT), (63) Mauritius (MUS), (64) Malaysia (MYS), (65) Namibia (NAM), (66) Niger (NER), (67) Netherlands (NLD), (68) Norway (NOR), (69) New Zealand (NZL), (70) Panama (PAN), (71) Peru (PER), (72) Philippines (PHL), (73) Poland (POL), (74) Portugal (PRT), (75) Paraguay (PRY), (76) Qatar (QAT), (77) Romania (ROM), (78) Rwanda (RWA), (79) Saudi Arabia (SAU), (80) Senegal (SEN), (81) Singapore (SGP), (82) Sierra Leone (SLE), (83) Sweden (SWE), (84) Swaziland (SWZ), (85) Togo (TGO), (86) Thailand (THA), (87) Trinidad and Tobago (TTO), (88) Tunisia (TUN), (89) Turkey (TUR), (90) Taiwan (TWN), (91) United Republic of Tanzania: Mainland (TZA), (92) Uruguay (URY), (93) United States (USA), (94) Venezuela (VEN), (95) South Africa (ZAF), (96) Zimbabwe (ZWE).

Countries (and the three-letter country codes) for 1970 are: (1) Argentina (ARG), (2) Australia (AUS), (3) Austria (AUT), (4) Belgium (BEL), (5) Bulgaria (BGR), (6) Bahrain (BHR), (7) Bolivia (BOL), (8) Brazil (BRA), (9) Barbados (BRB), (10) Canada (CAN), (11) Switzerland (CHE), (12) Chile (CHL), (13) China (CHN), (14) Côte d'Ivoire (CIV), (15) Cameroon (CMR), (16) Colombia (COL), (17) Costa Rica (CRI), (18) Cyprus (CYP), (19) Germany (DEU), (20) Denmark (DNK), (21) Dominican Republic (DOM), (22) Ecuador (ECU), (23) Egypt (EGY), (24) Spain (ESP), (25) Finland (FIN), (26) France (FRA), (27) United Kingdom (GBR), (28) Greece (GRC), (29) Guatemala (GTM), (30) China: Hong Kong SAR (HKG), (31) Honduras (HND), (32) Hungary (HUN), (33) Indonesia (IDN), (34) India (IND), (35) Ireland (IRL), (36) Iran (Islamic Republic of) (IRN), (37) Iraq (IRQ), (38) Iceland (ISL), (39) Israel (ISR), (40) Italy (ITA), (41) Jamaica (JAM), (42) Jordan (JOR), (43) Japan (JPN), (44) Kenya (KEN), (45) Republic of Korea (KOR), (46) Kuwait (KWT), (47) Sri Lanka (LKA), (48) Luxembourg (LUX), (49) Morocco (MAR), (50) Mexico (MEX), (51) Malta (MLT), (52) Mozambique (MOZ), (53) Malaysia (MYS), (54) Niger (NER), (55) Netherlands (NLD), (56) Norway (NOR), (57) New Zealand (NZL), (58) Panama (PAN),

(59) Peru (PER), (60) Philippines (PHL), (61) Poland (POL), (62) Portugal (PRT), (63) Paraguay (PRY), (64) Qatar (QAT), (65) Romania (ROM), (66) Saudi Arabia (SAU), (67) Senegal (SEN), (68) Singapore (SGP), (69) Sweden (SWE), (70) Thailand (THA), (71) Trinidad and Tobago (TTO), (72) Tunisia (TUN), (73) Turkey (TUR), (74) Taiwan (TWN), (75) United Republic of Tanzania: Mainland (TZA), (76) Uruguay (URY), (77) United States (USA), (78) Venezuela (VEN), (79) South Africa (ZAF), (80) Zimbabwe (ZWE).

Countries (and the three-letter country codes) for 1960 are as follows: (1) Argentina (ARG), (2) Australia (AUS), (3) Austria (AUT), (4) Belgium (BEL), (5) Bolivia (BOL), (6) Brazil (BRA), (7) Barbados (BRB), (8) Canada (CAN), (9) Switzerland (CHE), (10) Chile (CHL), (11) China (CHN), (12) Côte d'Ivoire (CIV), (13) Cameroon (CMR), (14) Colombia (COL), (15) Costa Rica (CRI), (16) Cyprus (CYP), (17) Germany (DEU), (18) Denmark (DNK), (19) Dominican Republic (DOM), (20) Ecuador (ECU), (21) Egypt (EGY), (22) Spain (ESP), (23) Finland (FIN), (24) France (FRA), (25) United Kingdom (GBR), (26) Greece (GRC), (27) Guatemala (GTM), (28) China: Hong Kong SAR (HKG), (29) Indonesia (IDN), (30) India (IND), (31) Ireland (IRL), (32) Iran (Islamic Republic of) (IRN), (33) Iceland (ISL), (34) Israel (ISR), (35) Italy (ITA), (36) Jamaica (JAM), (37) Jordan (JOR), (38) Japan (JPN), (39) Kenya (KEN), (40) Republic of Korea (KOR), (41) Sri Lanka (LKA), (42) Luxembourg (LUX), (43) Morocco (MAR), (44) Mexico (MEX), (45) Malta (MLT), (46) Mozambique (MOZ), (47) Malaysia (MYS), (48) Niger (NER), (49) Netherlands (NLD), (50) Norway (NOR), (51) New Zealand (NZL), (52) Peru (PER), (53) Philippines (PHL), (54) Portugal (PRT), (55) Romania (ROM), (56) Senegal (SEN), (57) Singapore (SGP), (58) Sweden (SWE), (59) Thailand (THA), (60) Trinidad and Tobago (TTO), (61) Tunisia (TUN), (62) Turkey (TUR), (63) Taiwan (TWN), (64) United Republic of Tanzania: Mainland (TZA), (65) Uruguay (URY), (66) United States (USA), (67) Venezuela (VEN), (68) South Africa (ZAF), (69) Zimbabwe (ZWE).

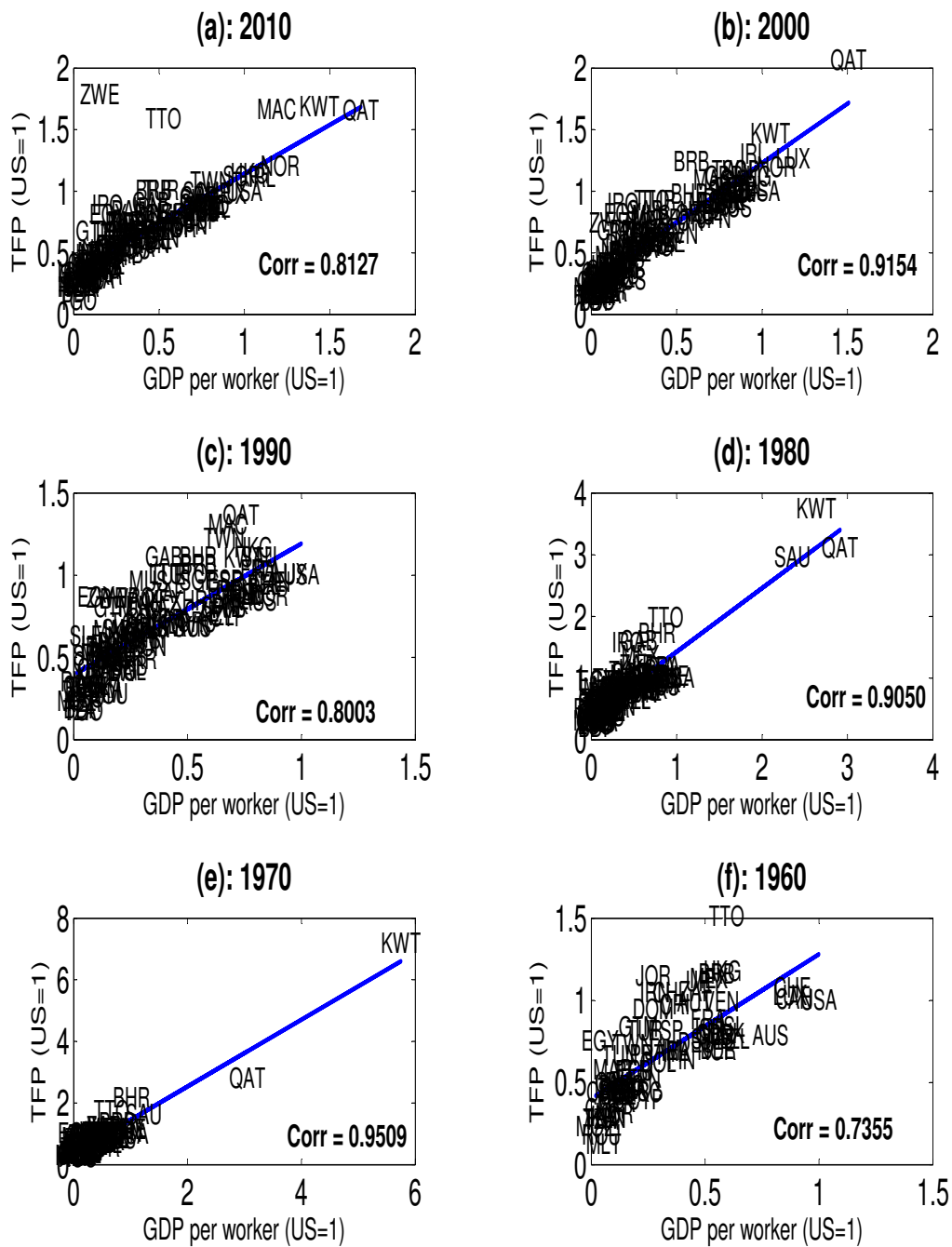


Figure A.1: TFP and GDP per worker: Data Reported in PWT 8.1

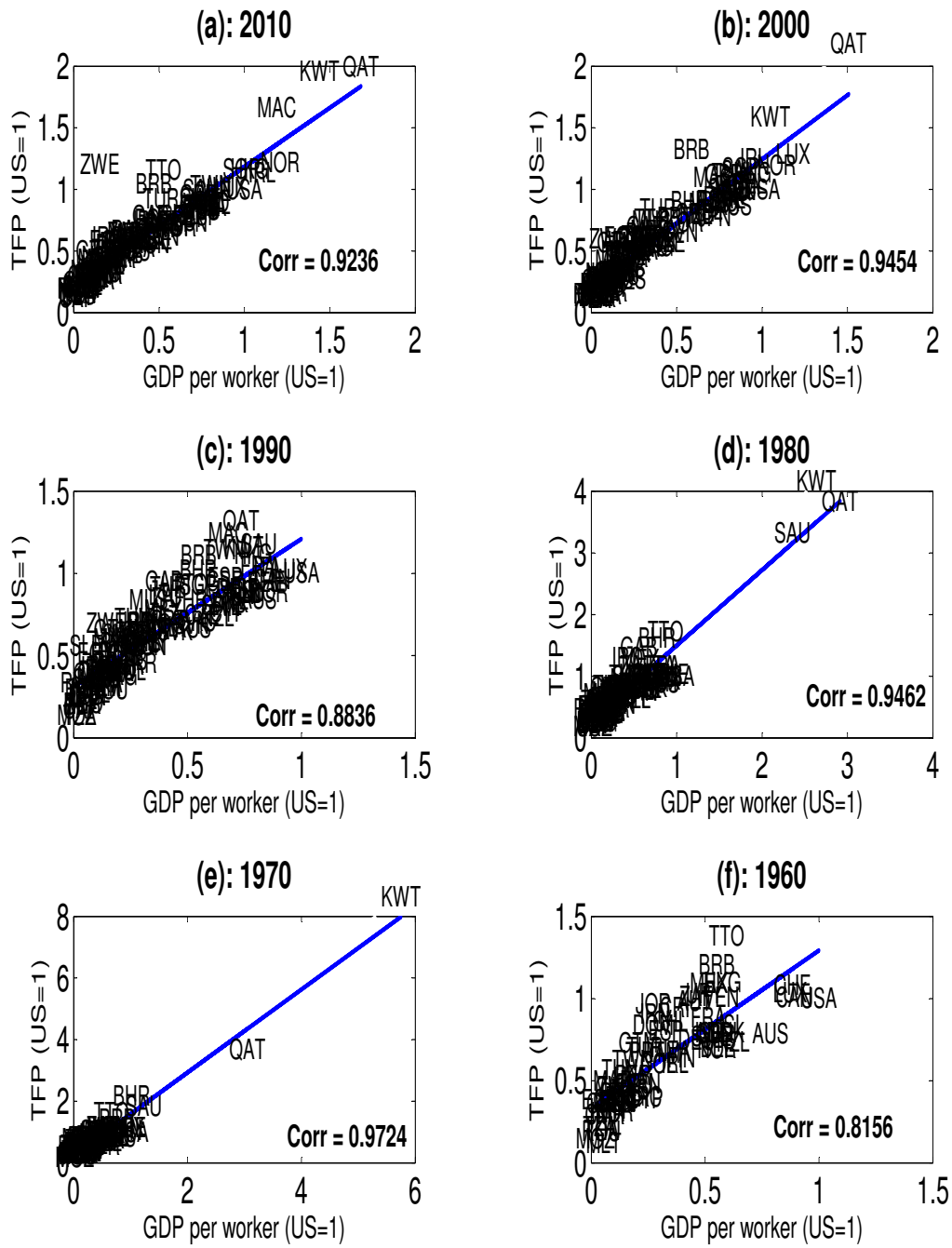


Figure A.2: TFP and GDP per worker: Method 1

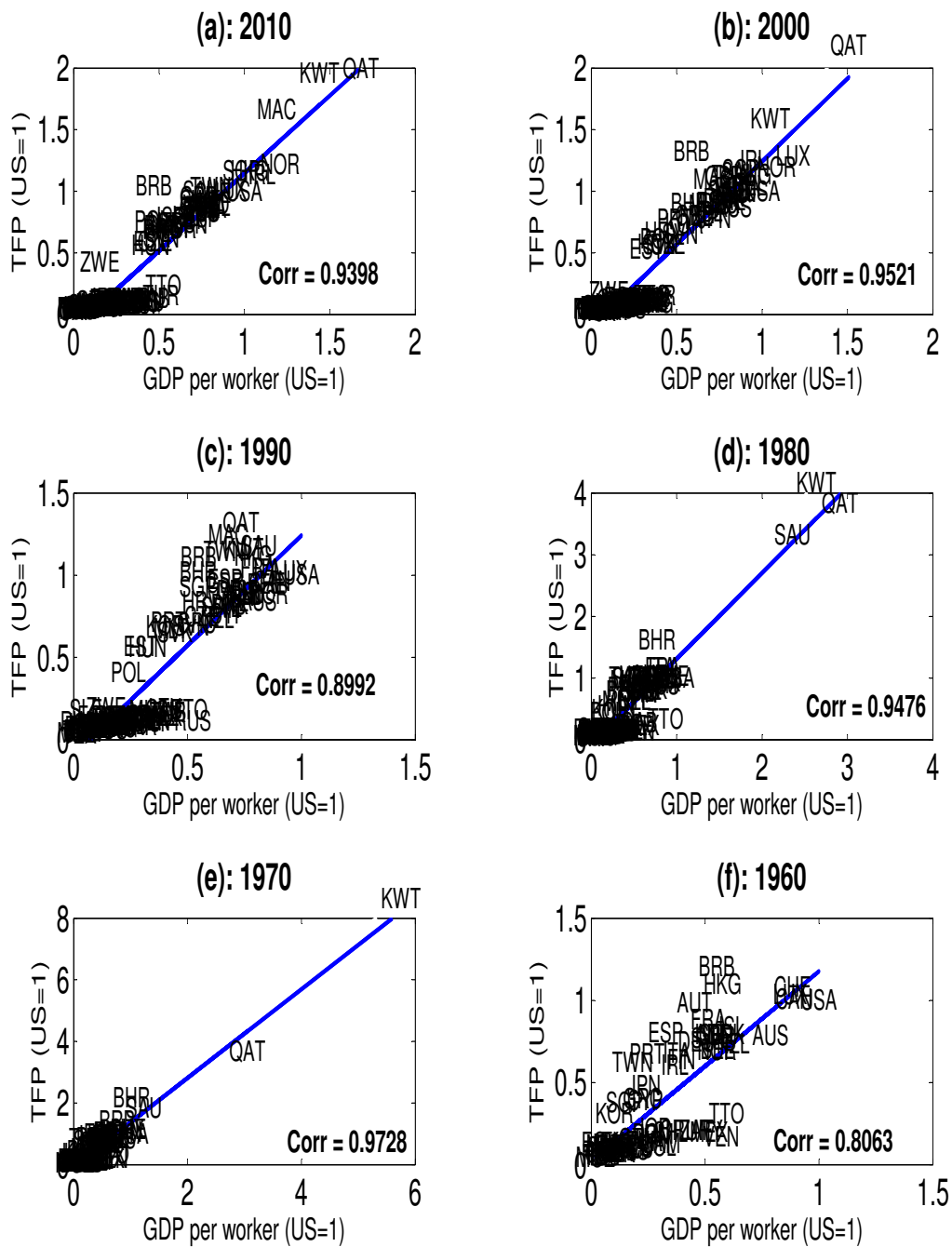


Figure A.3: TFP and GDP per worker: Method 2