What is new in PWT 9.1?

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April 2019

The release of the Penn World Table version 9.1 is the fourth release since the switch to the 'Next Generation of the Penn World Table', see Feenstra, Inklaar and Timmer (2015). If you are a first-time user of PWT, Section I of Feenstra et al. (2015) is still the recommended starting point, as the main structure of the database and definition of its variables are unchanged in PWT 9.1. PWT 9.1 does contain important new and revised data. This document provides an overview of the changes, with a more detailed discussion of particular topics in specific documents.

The changes fall in three broad categories, namely, I) the incorporation of new purchasing power parities (PPPs) data for a range of countries; II) the incorporation of revised and extended National Accounts data, covering the period up to 2017; and, most notably, III) a change in the methodology of capital measurement, with a move to the concept of capital services for estimating growth and comparative levels of productivity.

I. New PPP data

The previous release of PWT already included the latest round of ICP benchmarks for 2011. With PWT 9.1, we add new PPPs for the year 2014 for 7 former Soviet Union countries and 10 OECD countries, and for the period 2015-2017 we add an additional 37 European countries.[1] For years prior to 2015, a number of PPP benchmarks were revised by Eurostat, resulting in minor changes to the relative price levels of some European countries.

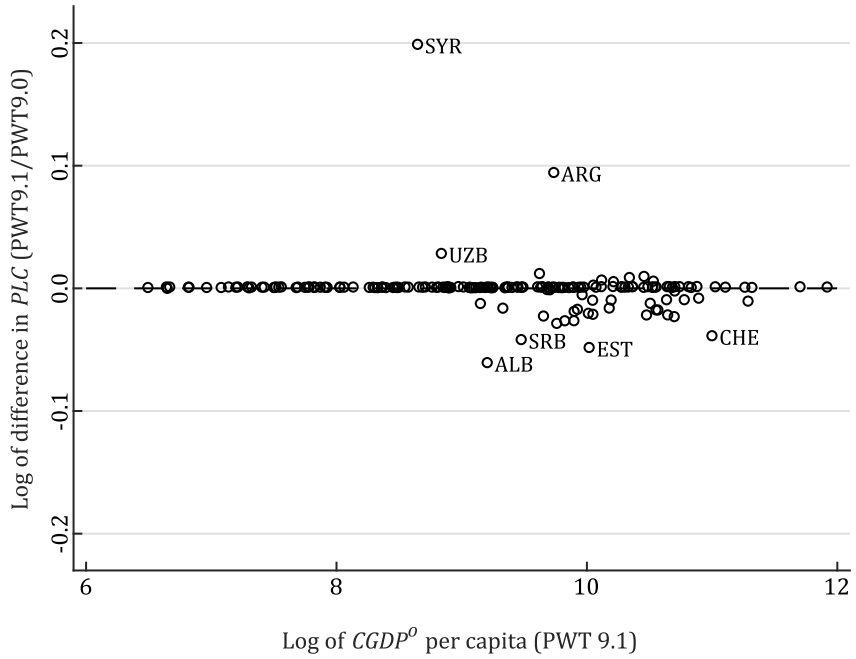
Compared to the previous release, the price levels for the basic expenditure categories listed in PWT 9.1 thus remain mostly unchanged. Figure 1 plots the ratio of the household consumption price level (*PLC*) in PWT 9.1 relative to the price level in PWT 9.0. The most notable outliers (Syrian Arab Republic, SYR, Argentina, ARG and Uzbekistan, UZB) were not included in the 2011 ICP. For these countries, the price level was extrapolated from an earlier ICP benchmark (mostly 2005); revisions to the household consumption price deflator from the national accounts explain

[1] The list of countries included in the 2015-2017 Eurostat benchmarks is: ALB, AUT, BEL, BGR, BIH, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ISL, ITA, LTU, LUX, LVA, MKD, MLT, MNE, NLD, NOR, POL, PRT, ROU, SRB, SVK, SVN, SWE, TUR; the former Soviet Union countries include: ARM, AZE, BLR, KAZ, KGZ, MDA, TJK; the OECD countries include: AUS, CAN, CHL, ISR, JPN, KOR, MEX, NZL, RUS, USA. In addition, PWT 9.1 reintroduces benchmarks for these OECD countries (except for CHL) for 2008 and 9 countries included in the 1996 ICP benchmark (ALB, BGR, EST, HRV, KOR, LTU, LVA, MKD, ROU), previously omitted from PWT 9.0.

the deviation from the price level originally listed in PWT 9.0. The other shifts in price levels shown in Figure 1 represent revisions to the Eurostat PPPs for European countries.

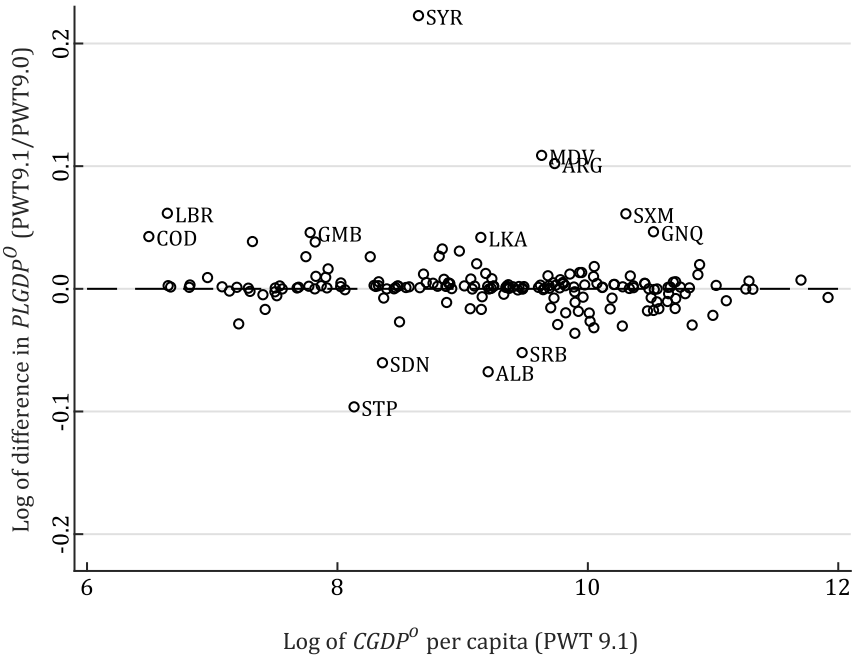
Figure 2 compares the GDP^0 price level for 2011 between PWT 9.1 and 9.0. Apart from the differences discussed above, revisions to the GDP expenditure composition result in some sizable adjustments (e.g. the Maldives, MDV, and Sao Tome and Principe, STP). Still, with the notable exception of the Syrian Arab Republic, price levels for GDP^0 mostly stay within a margin of 10 percent of the previous estimates for 2011.

Figure 1, Revisions to the household consumption price level for the year 2011, PWT 9.1 vs. 9.0



Note: $CGDP^0$ per capita is in 2011 USA dollars.

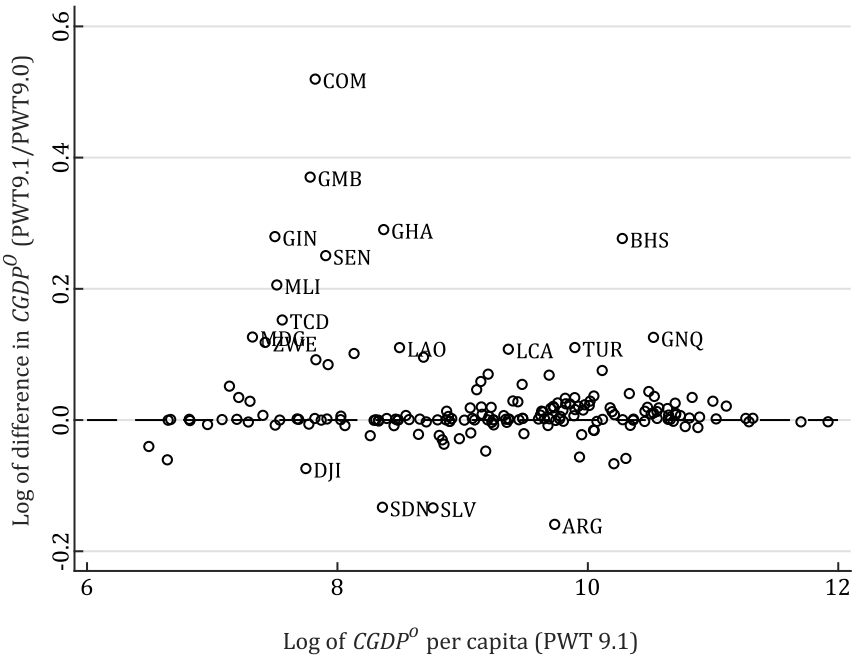
Figure 2, Revisions to the GDP^0 price level for the year 2011, PWT 9.1 vs. 9.0



II. GDP data from the National Accounts

Revisions in PWT are due to the incorporation of new PPP data, which mainly affects price levels, as well as new National Accounts (NA) data of countries which mainly affects nominal GDP levels and real growth rates. As the revisions to the PPPs in PWT 9.1 are relatively small, a substantial portion of the change in the levels of GDP originates from comprehensive revisions in the NA data. As was the case for the previous PWT, the largest revisions were observed for African countries. For the period 1960-2017, nominal GDP was adjusted upwards by 32 percent for Ghana (GHA), 43 percent for Guinea (GIN), and 51 percent for Gambia (GMB) on average. As discussed in the note accompanying PWT 9.0, these comprehensive revisions are both welcome and alarming, since they reflect the great effort made by national bureaus of statistics in Africa but also underscore the uncertainty regarding the true size of these African economies.

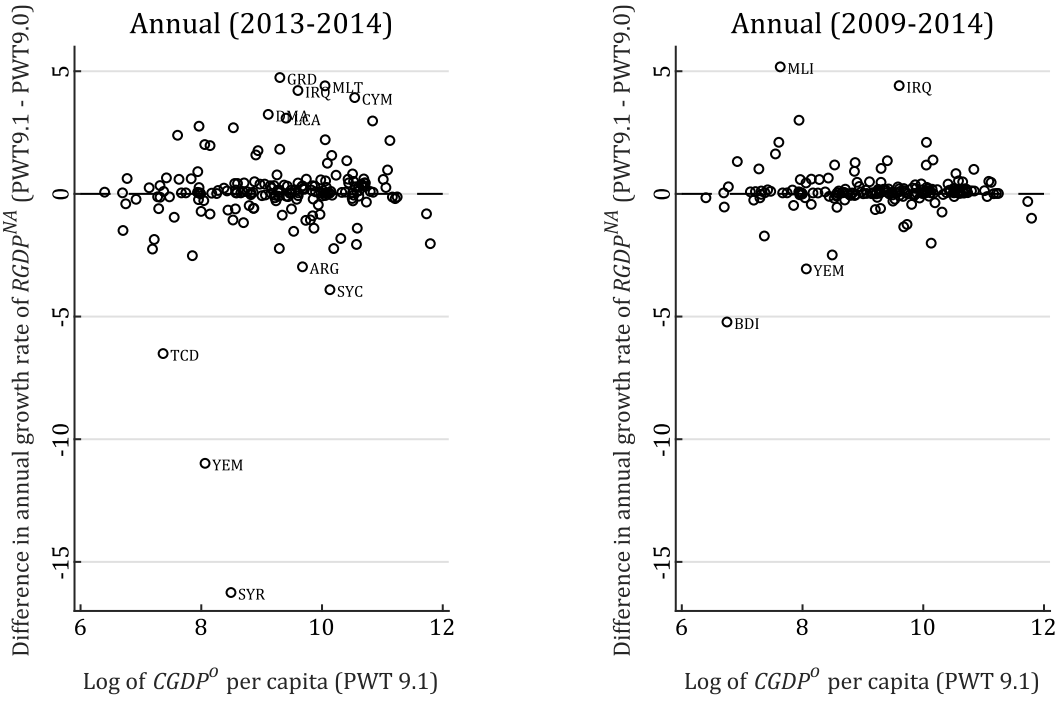
Figure 3, Revisions to the level of GDP at current PPPs for the year 2011, PWT 9.1 vs. 9.0



To illustrate recent revisions to PWT source data, Figure 3 shows the change in the level of GDP at current PPPs for the year 2011 between PWT 9.1 and 9.0. Apart from the fore mentioned African countries, the Bahamas (BHS), Turkey (TUR) and the Lao People's Democratic Republic (LAO) also saw some marked upward revisions to GDP. The real output-side GDP for Argentina was adjusted downward, not just by the revision to its relative price level discussed above, but also due to a revision of nominal GDP of minus 6 percent compared to the data used for PWT 9.0. Sudan (SDN) now excludes South Sudan, explaining most of the downward revision to its GDP estimates.

Data on economic growth is also subject to changing methods and revisions. Figure 4 illustrates the revision to the annual growth of the volume of GDP between 2013 and 2014 and the changes to the average annual growth rate between 2009 and 2014. As was evident for PWT 9.0, the average growth over the five-year period shows notably smaller revisions than the growth rate for 2013-2014.

Figure 4, Revisions to growth of GDP, annual and five-year, PWT 9.1 vs. 9.0



Note: difference in the average annual rate of growth of $RGDP^{NA}$, PWT 9.1 minus PWT 9.0, in percentage points.

III. Capital

In PWT 9.1 we modify our measure of capital substantially. The most important change is that we introduce new 'productive capital input' measures that are more appropriate for comparing productivity across countries and over time than the capital stock measures we had relied on previously. This new methodology, that relies on estimating user costs of capital and capital services is discussed in more detail in a paper by Inklaar, Woltjer and Gallardo Albarrán (2019). Below, we provide a brief summary and a discussion of the changes compared to PWT 9.0 that aims to provide a better understanding of why and by how much particular measures change.

Methodology

In PWT 9.1 we improve the measure of capital input in four areas. Specifically, we:

1. Implement a new method for estimating the initial capital stocks.
2. Revise the deflators for the investment series.
3. Introduce a new variable, the real internal rate of return on capital (IRR), which provides a measure of the required rate of return on capital.
4. Use the new IRR measure, together with asset-specific depreciation rates and investment deflators, to estimate the user cost of capital for each of the 9 assets distinguished in PWT.

This method allows us to weight the flow of services derived from the capital inputs based on an imputed rental rate, giving greater weight to short-lived, quickly depreciating assets like computers and software.

1. **Initial stocks.** In PWT 9.1, we estimate the capital stock for each asset based on the perpetual inventory method, similar to the procedure applied in previous releases. The capital stock at time *t* is thus based on all previous investments leading up to that year. Given that we only observe investment data for a limited period of time, an important challenge is to estimate the capital stock in the first year of the data. PWT 9.0 assumes that when a country's data is first observed, its nominal capital-output ratio is 2.6, based on contemporaneous evidence (Feenstra et al. 2015). New historical series for 38 countries show that across the development spectrum, nominal capital-output ratios have been increasing over time. In PWT 9.1 we implement a new method for estimating initial capital stocks using this country-specific information, in combination with the observed global trend to allow for more reliable estimation of capital input when a country's data is first observed. For recent years, the impact of this change in estimation method is limited, but especially for the early decades of PWT data, the estimated capital stock tend to be lower than in PWT 9.0.
2. **Investment deflators.** For some countries in PWT 9.0 we observed large discrepancies between the deflator for Gross Fixed Capital Formation (GFCF) as listed in the National Accounts and the investment deflator aggregated over all 9 assets from national. This is primarily driven by our use of multiple historical time series of investment data and the revisions to National Accounts that have since taken place. For PWT 9.1 we normalize the asset-specific investment deflators ensuring its aggregate always corresponds to the GFCF deflator. On average this results in a slight upward revision of the growth in the investment deflators, but the adjustment varies between countries and over time. For three assets, Information Equipment (IT) Communication Equipment (CT) and Software, investment deflators for all countries are based on the hedonic price series for the USA, published by the Bureau of Economic Analysis (BEA), as was the case for PWT 9.0.
3. **Internal rate of return.** The return on capital plays an important role in the economics literature, in particular the Lucas (1990) paradox of why capital is not flowing towards low-income countries. In PWT 9.1 we introduce a new variable, the real internal rate of return on capital (IRR), which allows us to track the development of the return on capital over time and compare levels across countries. We apply the method by Jorgenson and Nishimizu (1978), which is a more accurate measure of the return to capital than the often-used Marginal Product of Capital (MPK) because it accounts for differences in the

composition of the capital stock. The required rate of return on capital is chosen to exhaust the income left after subtracting labor income from GDP. This gives an IRR on capital which 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 IRR based on the income that does not flow to labor would substantially overestimate the required rate of return on assets. So instead, we determine the income flowing to capital as nominal GDP, minus labor income, and minus natural resource rents.

4. **Capital services.** In the capital accounts for PWT we observe systematic difference in investment patterns between countries: high-income countries tend to invest more in short-lived assets, such as computers and software, and less in long-lived assets like office buildings or roads. These differences are due to the higher relative cost of short-lived assets in low-income countries (Hsieh and Klenow, 2007) and lack of complementary assets such as human capital (Caselli and Wilson, 2004). Given these differences, the capital stock-based methodology used in PWT 9.0 and earlier releases, underestimates the role of physical capital in development accounting, as the weight given to short-lived assets is too low compared to the conceptually appropriate capital services methodology. In PWT 9.1, we improve the measure of physical capital by estimating the user cost of capital and comparing the implicit rental price of capital and the level of capital services rather than capital stock. The user cost of capital is based on the previously discussed IRR, the asset-specific rate of depreciation, and the change in the asset price, following the framework of Jorgenson and Nishimizu (1978).[2] As a result, the current (*CK*) and constant (*RKNA*) measures of capital input, as well as the price level of capital (*PL_K)* in PWT 9.1, now reflect capital services. All Total Factor Productivity (*TFP*) variables in PWT 9.1 are also based on capital services. We still include the updated capital stock measures and price levels of capital, as these can be useful for purposes other than productivity measurement. We have renamed these variables to *CN*, *RNNA* and *PL_N*. The 'capital detail' file, available on the PWT website, contains price levels and current values for investment, capital stock, capital consumption and capital services by assets. For capital services we also include the asset share, *Ksh*.

[2] This framework was more recently discussed in the OECD (2009) capital manual. See e.g. Jorgenson, Nomura and Samuels (2016), Inklaar and Timmer (2009) and Schreyer (2007) for more recent implementations of this methodology.

Results

The changes in methodology we introduce in PWT 9.1 represent a substantive change compared to the earlier versions and both the capital concepts and the results are notably different. To provide some intuition for these changes and how the new capital measures compare to the earlier concepts, we show in Table 1 how the different variables relate for the case of Indonesia in 2011, compared to the United States. Since Indonesia has a much lower income level than the United States, it serves as a helpful illustration for the more general patterns we discuss below. Readers who want to more thoroughly understand how exactly these variables relate, in terms of the equations and methods for aggregation across assets, should refer to Inklaar et al. (2019).

Table 1, example calculation of price levels and current capital stock/services for the year 2011

Variable description	Variable	Indonesia (IDN)	United States (USA)
Price level of capital formation	*PL_I*	0.42	1.00
Price level of capital stock	*PL_N*	0.27	1.00
Price level of capital services	*PL_K*	0.47	1.00
Average depreciation of capital	*delta*	3.6%	4.6%
Real internal rate of return	*IRR*	10.5%	7.5%
Share of capital compensation	$1 - LABSH$	54%	41%
Current capital stock per person employed	CN/EMP	0.28	1.00
Current capital services per person employed	CK/EMP	0.21	1.00

The first two rows show the price level of investment, *PL_I* and the price level of the capital stock *PL_N* (previously *PL_K*). The price level of the capital stock is considerably lower than the investment price level because (long-lived, non-traded) structures are given greater weight in the capital stock price index than in the investment price index. The price level of capital services (*PL_K*) gives greater weight to short-lived, tradable assets, which is one important reason why *PL_K* is higher. The other reason is that the relative price of capital services reflects the relative user cost of capital, which is determined by the required real rate of return on capital, the *IRR* and the depreciation rates, *delta*. The United States has a relatively larger share of short-lived assets, so a higher depreciation rate as a result. Indonesia has a substantially higher real rate of return, so the net result is that *PL_K* substantially exceeds *PL_N*.

The final two rows show the level of capital stock per worker and capital services per worker, in Indonesia relative to the United States. Since the price level of capital services is higher than the price level of the capital stock, it is to be expected that the level of capital services is lower than

the level of the capital stock. However, the difference between 28 percent and 21 percent is substantial less than implied by the change in the price level of capital services. That is because nominal capital input (nominal capital compensation) is larger relative to GDP in Indonesia than in the US, 54 percent versus 41 percent.

We now turn to illustrating some of the broader cross-country patterns and how these have changed due to the methodological changes introduced in PWT 9.1. Figure 5 provides a cross-country view for 2011 of the (real) IRR, showing a fair degree of variability in the return on capital. For most countries, the IRR lies between 5 and 25 percent, with a mean just above 10 percent for 2011. For this benchmark year there does not appear to be a significant relation between income and the return on capital. As shown by Inklaar et al. (2019), real IRR in PWT 9.1 declines over time, with a notable drop during the 1970s. Inklaar et al. also find that low-income countries have higher real IRRs over the long run, in accordance with the findings by David, Henriksen and Simonovska (2016). This underscores that a single-year comparison of returns, like the one shown in Figure 5, can be misleading for the long-run patterns.

Figure 5, Real internal rate of return for the year 2011, PWT 9.1

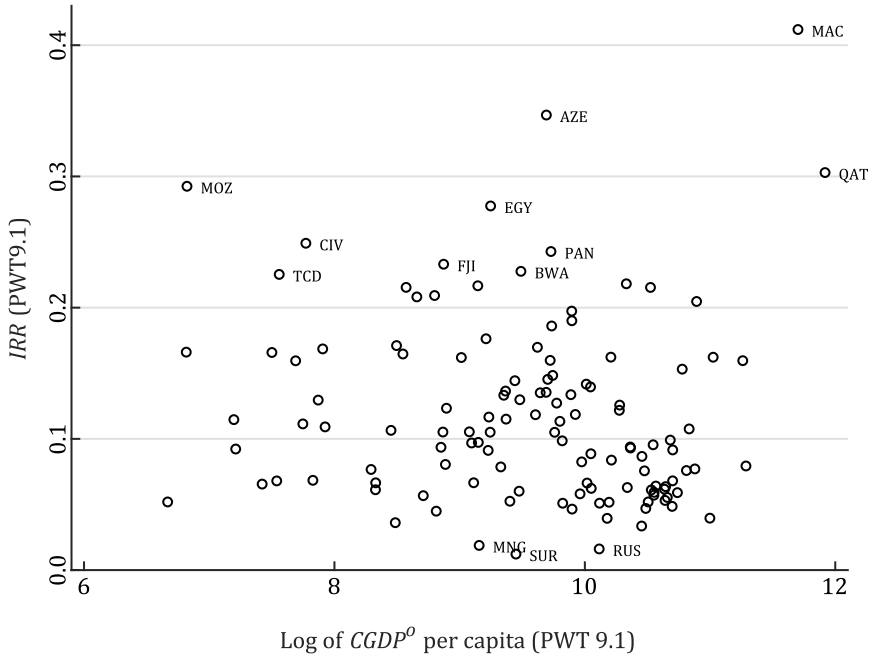
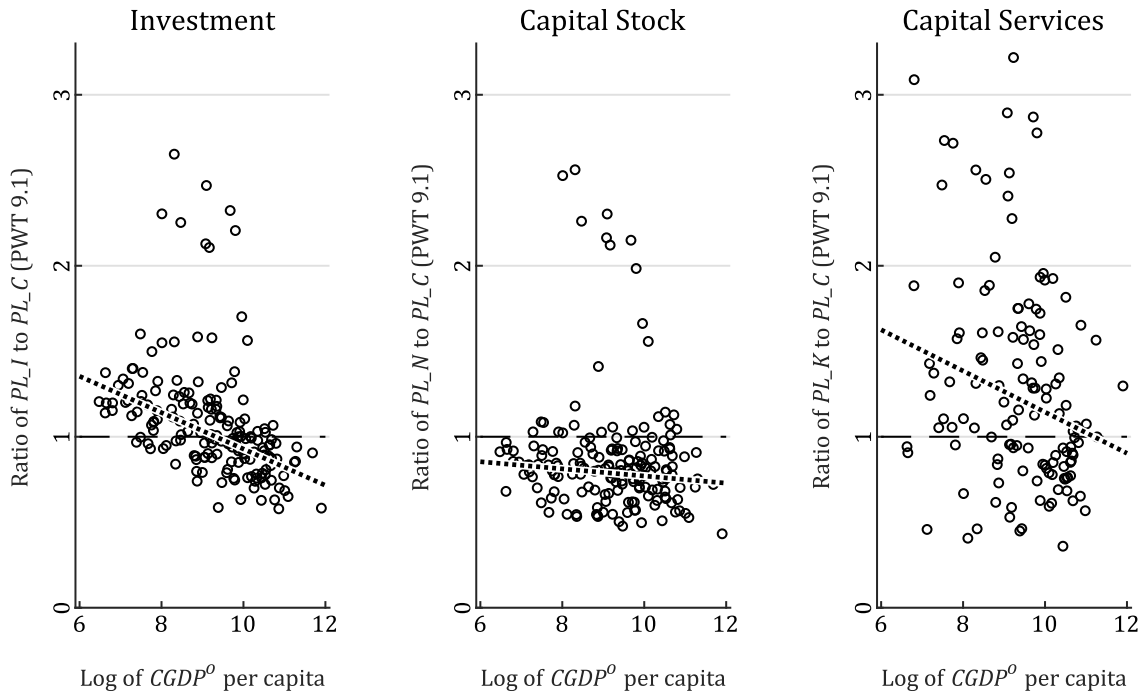


Figure 6 compares the price levels for investment, capital stock and capital services to the price of consumption. The left panel confirms the conclusion by Hsieh and Klenow (2007) that the prices of investment goods in poorer countries are high, relative to the price of consumption. This reflects the fact that many of the investment goods are tradables, whose prices are close to the exchange rate, whereas a considerable part of consumption is non-traded, the prices of which

tend to be relatively low for poorer countries. As shown by Feenstra et al. (2015) for PWT 8.1, the price level of the capital stock tends to be more similar to the consumption price for both low- and high-income countries – confirmed for 2011 in the middle panel of Figure 6. Due to its low rate of depreciation, structures form a large part of the price index of capital stock, and since they are non-traded the price level for structures tends to be lower for poorer countries, bringing the price level of the capital stock down for those countries. As discussed above, the new method gives greater weight to the tradable, short-lived assets. As shown in the right panel of Figure 6, the price of capital services tends to be lower relative to consumption prices in high-income countries as a result.

Figure 6, Ratio of price level of capital and consumption for the year 2011, PWT 9.1



Note: only countries that participated in the 2011 ICP benchmark survey are included. The price level of capital services divided by the price level of household consumption in the right panel is not shown for AZE (7.4) and MAC (3.8), whose ratios fall out of bounds of the y-axis. The dotted line represents the results of a linear regression: $\frac{p^I}{p^C} = 1.99 - 0.11 \log \frac{CGDP^o}{POP}$ (0.01) , $\frac{p^N}{p^C} = 0.98 - 0.02 \log \frac{CGDP^o}{POP}$ (0.01), $\frac{p^K}{p^C} = 2.35 - 0.12 \log \frac{CGDP^o}{POP}$ (0.04). Robust standard errors in parentheses. Number of observations: 177, 175, and 133 respectively.

In addition to a clearer relationship with income levels, the ratio of the price level of capital services to consumption in the right panel shows a great deal more variation than the ratios for investment and the capital stock. Whereas the capital stock is made comparable across countries

using data on the relative prices of investment goods, the appropriate price comparison for capital services is based on the relative rental rate. This adjusts the relative price of investment goods for differences across countries in the user cost of capital. Since we assume the same depreciation rate for a given asset in all countries, differences in the user cost of capital are due to differences in the (country-level) IRR and due to differences in the average rate of asset price inflation.

The changes to the initial capital stock and the investment deflators, as well as revisions to the PPPs and the value of gross fixed capital formation from the national accounts discussed in the previous sections, result in considerable revisions to the capital stock levels. Figure 7 reports the current capital stock in PWT 9.1 for the year 2011 compared to the capital levels reported in PWT 9.0. Most of the larger adjustments, particularly for African countries, result from revisions to the national accounts. Overall, capital stocks have increased compared to the previous release of PWT.

Figure 7, Revisions to capital stock at current PPPs for the year 2011, PWT 9.1 vs. 9.0

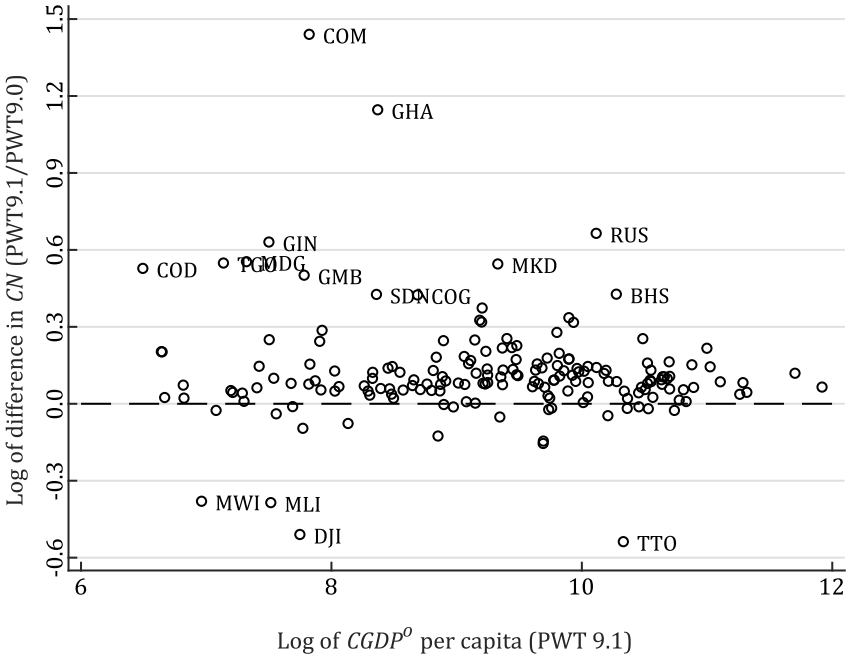
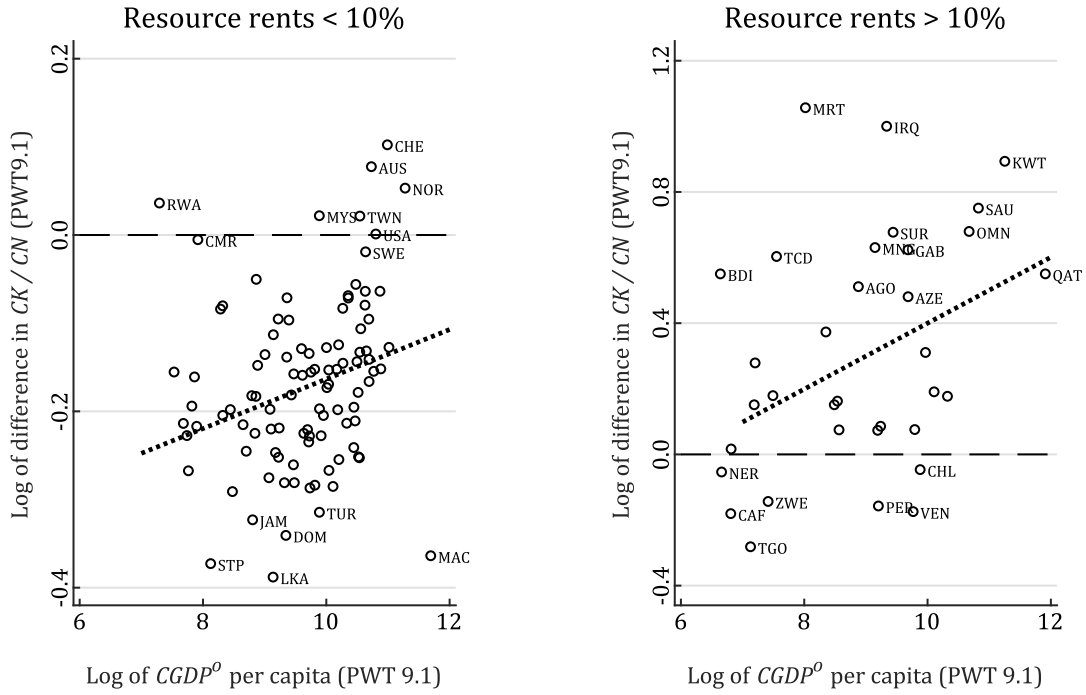


Figure 8 compares the current levels of capital services with the current levels of the capital stock. The left panel presents the results for the 101 countries where the rents from extracting natural resources like oil and gas is negligible or only a small fraction of GDP in 2011. The right panel shows the 34 countries where the resource rents exceed 10 percent of GDP for that year according to data from the World Bank. For the latter countries, the income that does not flow to labor will overestimate the factor share of capital (as discussed above) and therefore also bias capital

services upwards.[3] The left panel of Figure 8 confirms that the level of capital services, relative to the USA, is lower than the level of capital stock for most countries. The net impact of shifting from a stock- to a service-based measure of capital input is more pronounced for poorer countries, as illustrated by the results from the ordinary least squares regression. For the resource-rich countries, the shift to capital services tends to revise capital inputs upwards.

Figure 8, Difference between capital services and stocks for the year 2011, PWT 9.1

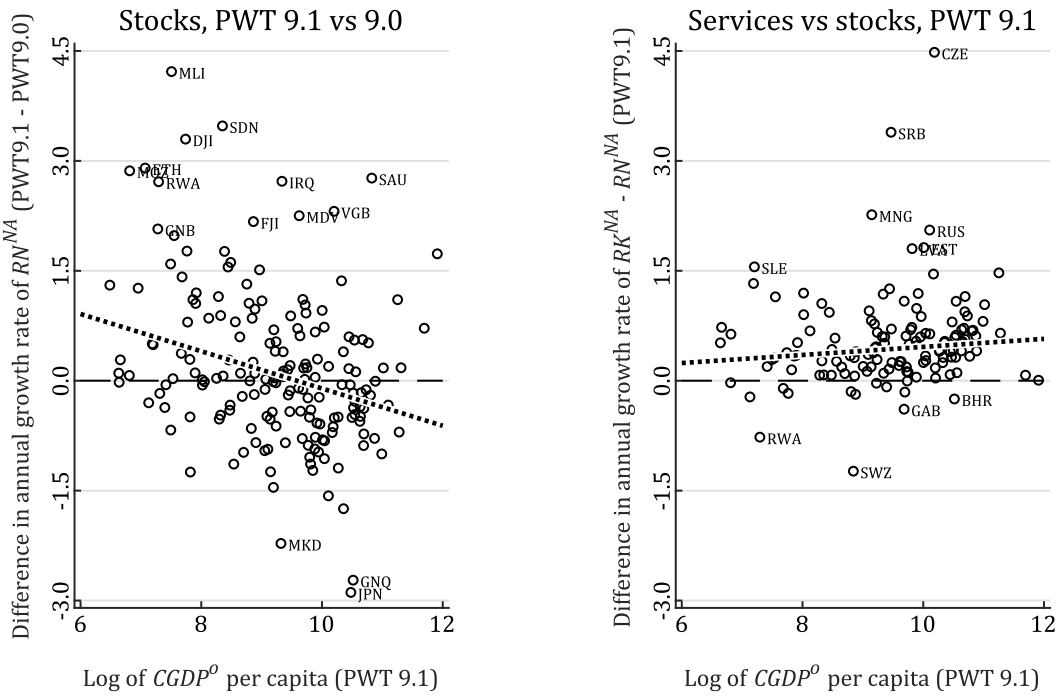


Note: both capital services (*CK*) and the capital stock (*CN*) at current PPPs, normalized to USA=1. The dotted line represents the results of a linear regression. *Left panel*: $\frac{CK}{CN} = -0.44 + 0.028 \log\left(\frac{CGDP^O}{POP}\right)$ (0.010)*; Right panel:* $\frac{CK}{CN} = 0.60 + 0.100 \log\left(\frac{CGDP^O}{POP}\right)$ (0.044). Robust standard errors in parentheses. Number of observations: 101 and 34 respectively.

Similar to the current levels of capital, growth rates for the constant series of capital stock have changed substantially compared to PWT 9.0; see the left panel of Figure 9. The right panel compares the growth rate of capital services to that of the capital stock. For most countries, capital services grow faster as investment shifts to shorter-lived asset (e.g. Communication Technology or Software) and a decline in the share of labor compensation (*LABSH*).

[3] Ideally, natural resources should be recognized as production factors in their own right. That is not yet incorporated in PWT 9.1 but see Freeman, Inklaar and Diewert (2018) for an implementation.

Figure 9, Revisions to the growth of capital inputs



Note: difference in the average annual rate of growth for RK^{NA} and RN^{NA} for the full period for which variables are observed, in percentage points. The dotted line represents the results of a linear regression. *Left panel*: $2.44 - 0.25 \log\left(\frac{CGDP^O}{POP}\right)$ (0.059); *Right panel:* $-0.089 + 0.055 \log\left(\frac{CGDP^O}{POP}\right)$ (0.033). Robust standard errors in parentheses. Number of observations: 180 and 135 respectively.

IV. TFP

In PWT 9.1 we also revise our measure of Total Factor Productivity. The most important change is that we base the productive capital input on capital services instead of the capital stock, as discussed in the previous section. In addition, for the development accounts we shift from a direct comparison with a single base country (the United States) to a multilateral comparison. By moving to a capital services framework, each of the nine capital inputs is now treated symmetrically with labor input as a relative input level, weighted by the revenue share of that factor input – see Feenstra et al. (2015) for the theoretical background. With a larger number of inputs, relying on the United States as a single base country is even less defensible, so instead we now use a base-country independent method, as discussed in more detailed in Inklaar et al. (2019).

Figure 10 shows the changes to the resulting TFP levels, comparing the original methodology from PWT 9.0, (capital stock with the USA as the base country) to our new methodology (capital

services and a multilateral index). The major downward revision primarily affected countries where a sizable share of GDP consists of rents from extracting natural resources – see the discussion to Figure 8.

Figure 10, Revisions to TFP for the year 2011, PWT 9.1

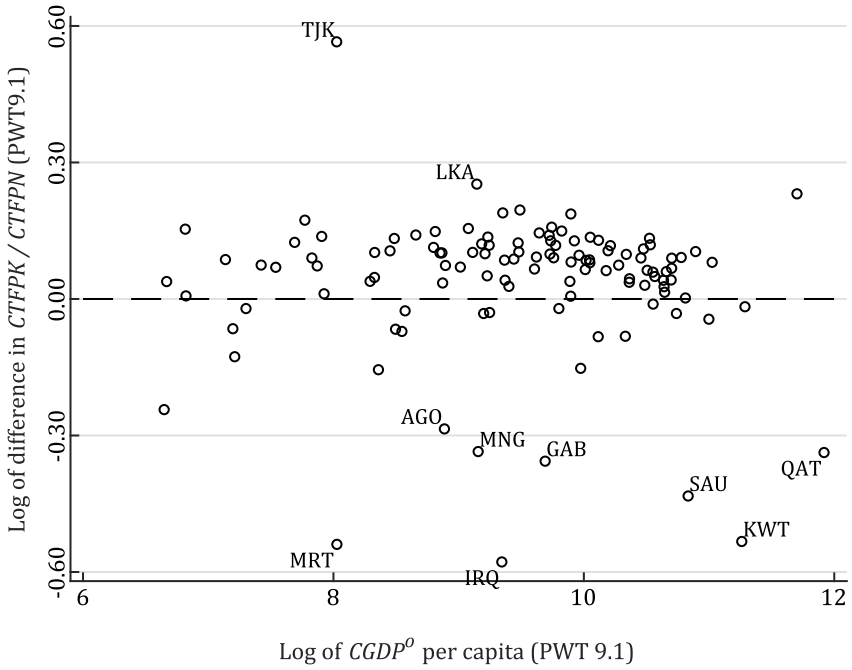
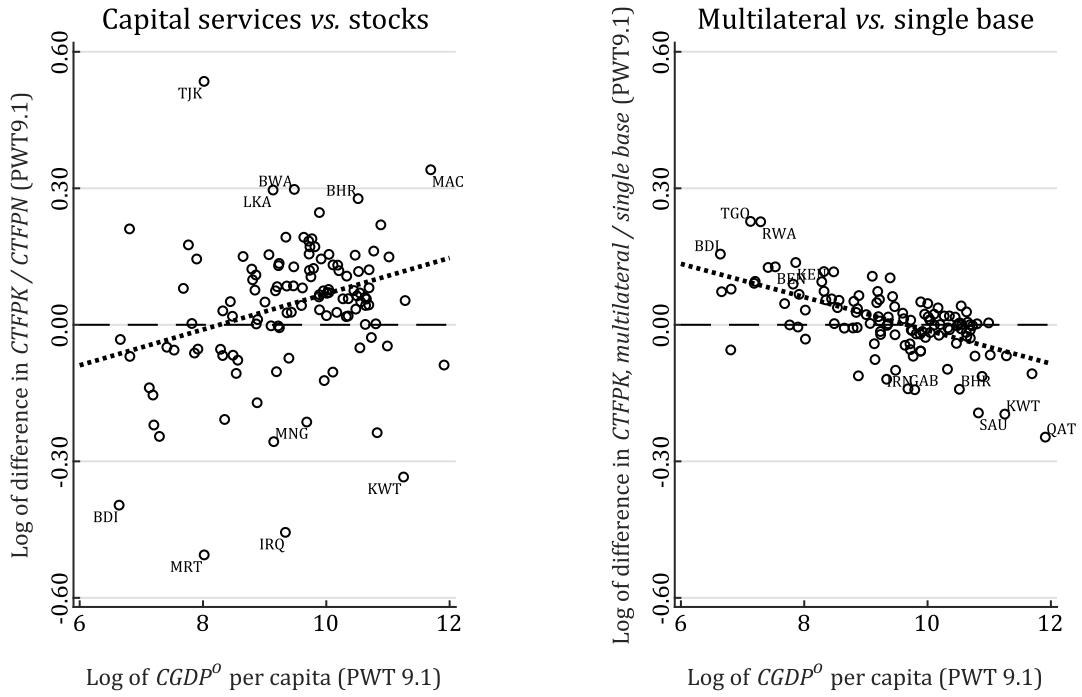


Figure 11 illustrates the direct effects of the shift to capital services (left panel) and the move to a multilateral index (right panel). Overall, the shift from capital stock to services had the greatest impact. The trend line in the left panel reveals the capital input for richer countries was revised to a greater degree (upwards) in comparison to poorer countries. The adjustment resulting from the shift towards a multilateral index also shows a significant, but negative, relation with GDP per capita. This reflects the fact that the factor input shares of the United States differ more from those in lower-income countries than in higher-income countries. The net result is that relative TFP levels tend to be higher relative to the United States based on the PWT 9.1 methodology than based on the 9.0 methodology, but with no systematic pattern across countries.

Figure 11, Sources of revisions to TFP for the year 2011, PWT 9.1



Note: revisions to the level of current TFP due to shift in capital input measure (left panel) and use of multilateral index (right panel). The dotted line represents the results of a linear regression. *Left panel:* $-0.29 + 0.034 \log\left(\frac{CGDP^O}{POP}\right)$ (0.012)*; Right panel*: $0.35 - 0.037 \log\left(\frac{CGDP^O}{POP}\right)$ (0.004). Robust standard errors in parentheses. Number of observations: 117.

V. Smaller changes

- **Purchasing Power Parities (PPP).** In the aggregation of the PPPs using the GEKS procedure we now explicitly deal with negative, zero or empty relative prices in the basic headings. If the expenditure share for this PPP is nonzero, we use the average for the other PPPs within that aggregate grouping by country and year instead. This has only a minor effect on some of the investment and government expenditure PPPs.
- **Country names.** We have renamed Swaziland to Eswatini (SWZ) and TFYR of Macedonia (MKD) to North Macedonia, following the latest UN conventions. Their ISO 3-letter codes remain the same.
- **Asset depreciation.** We now assume all investment in capital assets occur at the mid-year point, as opposed to the last day of the year, which was used for previous releases of PWT. This causes the value of newly invested assets to depreciate for 6 months during the year they were acquired.
- **Outliers price levels.** We have identified a number of new outliers in the price levels for GDP and Domestic Absorption (DA). We used the criteria discussed at length in the document

"Outliers in PWT8.0", available on the PWT website. In short, price levels for $CGDP^O$ and *CDA* are marked an outlier if the price level is extrapolated from the first or last available benchmark *and* the observed level exceeds the bounds of a predicted level, based on an OLS regression of the log of GDP per capita and the log price level of GDP and DA respectively. New outliers were identified for one or more years for Argentina (ARG), Azerbaijan (AZE), Bosnia and Herzegovina (BIH), Brunei Darussalam (BRN), Egypt (EGY), Iran (IRN), Kyrgyzstan (KGZ), Malta (MLT), Nigeria (NGA), Syrian Arab Republic (SYR), Turkmenistan (TKM), Uzbekistan (UZB), and Viet Nam (VNM).

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