# Capital Measurement and Productivity Growth Across International Databases

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# Capital Measurement and Productivity Growth Across International Databases

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**Abstract**

A country's multifactor productivity (MFP) growth, the growth of GDP that is not accounted for by growth of factor inputs, is of great interest as an indicator of living standards and technological progress. Yet different well-established databases show markedly different MFP growth rates for the same country and period. In this article, we show that differences in the measurement of capital input can account for one-third of the range of MFP growth rates across databases. Harmonizing a series of methodological choices for capital measurement substantially reduces variation across databases, but sizeable differences remain. This work highlights the continued relevance of these choices and can inform users who try to understand differences between databases and assess the robustness of differences in MFP growth across countries to measurement choices.

Productivity is a topic of enduring interest measuring growth of output, accounting for growth in inputs. Especially for a long-run perspective, we want to focus on productivity as a more enduring foundation for living standards than output, since additional inputs require giving up either leisure (due to more time spent at work) or current consumption (saving to finance investment).[2] Against this backdrop, we focus our analysis on multifactor productivity (MFP), accounting not just for growth of hours worked but also for changes in the composition of the workforce and the accumulation of capital. Under certain conditions, MFP growth is also an indicator of technological progress. Under certain conditions, MFP growth is also an indicator of technological progress. As international data on MFP growth have become increasingly widespread in recent decades, we aim to contrast results from different

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2 See e.g. Basu *et al.* (2022) for a more explicit formulation of the link between welfare and multifactor productivity along these lines.

databases and provide guidance to users on the sources of some of the differences between the databases.

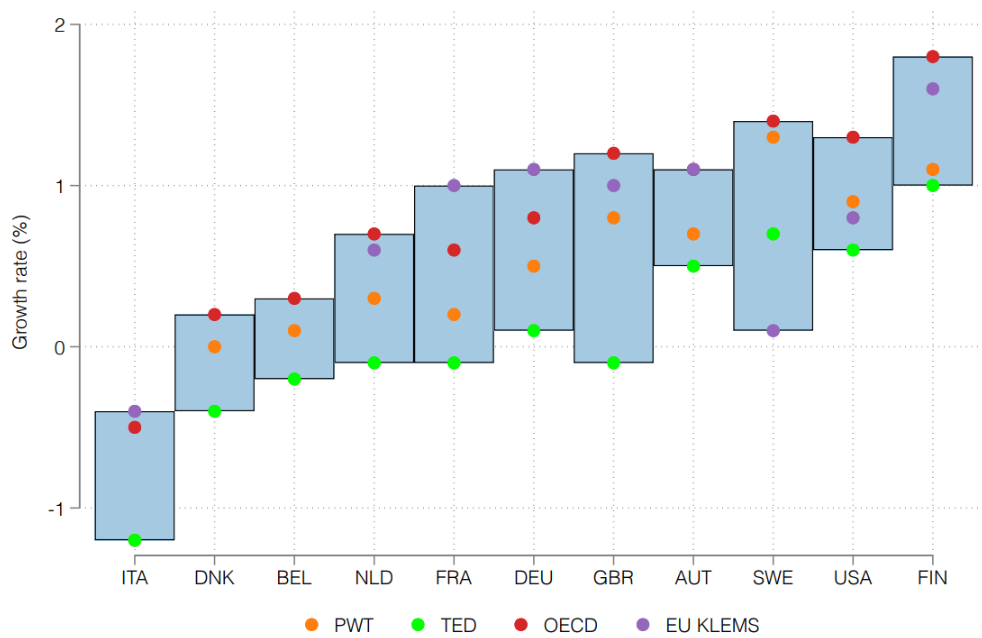
There are currently four main databases that provide data on economy-wide MFP growth for advanced economies, using detailed statistics on inputs of capital and labour. These databases are the Penn World Table (PWT), The Conference Board Total Economy Database (TED), the EU KLEMS database, and the OECD Productivity Statistics.[3] Providing data on MFP growth requires not only data on growth of gross domestic product (GDP) but also data on the input of labour (accounting for changes in the composition of the workforce) and the input of produced capital, such as buildings and machinery. The conceptual framework for growth accounting, on how to measure and aggregate data on inputs, is well-established (e.g. OECD, 2001) and many individual pieces of data are readily available for advanced economies. Yet the four databases we compare here show notably different MFP growth rates for the same country and period.

We illustrate this point in Chart 1, where we show MFP growth across the four databases for the period 2000–2007, highlighting the range across databases; Appendix Table 1 provides the growth rates for each database. We chose this period because it is recent enough to be covered by all databases yet distant enough that the precise vintage of National Accounts data used in the construction of the data will not have a substantial impact on the results. As the Chart shows, average annual MFP growth in (for example) Germany over this period could be as low as 0.1 per cent (TED) or as high as 1.1 per cent (EU KLEMS), with growth rates of 0.5 per cent for PWT and 0.8 per cent for OECD. This full percentage point difference between the fastest and slowest MFP growth rates is not atypical for the eleven countries we compare in this article. On average, the range in growth rates between the database with the fastest and slowest reported growth is 0.9 percentage points. To put this cross-database range in perspective, note that MFP growth rate over this period averaged only 0.5 per cent (across countries and databases). For countries such as France, Germany, or the UK, you would conclude that MFP growth stagnates or that it grows at a respectable 1 per cent per year depending on the choice for a particular database.

For a non-expert user of productivity data, there currently is no clear explanation for why a country for a particular period can have such widely divergent estimates of MFP growth across these databases. The aim of this article is to better understand the reasons for these differences, by comparing the different variables that go into the productivity growth

3 We use PWT version 10.01, see www.ggdc.net/pwt for details. We use the April 2022 version of TED https://conference-board.org/data/economydatabase/. We use the 2021 version of EU KLEMS, released by LUISS Lab of European Economics, https://euklems-intanprod-llee.luiss.it/. We use the OECD productivity statistics downloaded in May, 2022, available at http://www.oecd.org/sdd/productivity-stats/. The database by Bergeaud, Cette and Lecat at http://www.longtermproductivity.com/ could also have been included in the comparison, however it differs from the other productivity databases in that in distinguishes only two capital asset types. See Bergeaud *et al.* (2016).

**Chart 1: Range of Average Annual MFP Growth Across Databases, 2000-2007**




Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.
Notes: the chart shows for each country a bar ranging from the smallest to the highest average annual growth rate for the 2000–2007 period across the four databases, PWT, TED, EU KLEMS and OECD. Countries are ordered by the average growth rate across the four databases. Also included are the growth rates in each database; note that in some cases two databases show the same average growth rate. Spain has been omitted from this comparison, due to problems in the OECD capital stocks data, resulting in unreliable capital stock estimations with extreme growth rates for methods 3 and 4 in the analysis. See Appendix Table 1 for the full data.

comparison, without making value judgments on the choices made by each of the databases.

We find that the MFP growth discrepancies are not driven by differences in the growth of GDP (for instance due to data vintage differences) or the growth of hours worked between the databases but are primarily driven by differences in the measured growth of capital services. Differences in the contribution from labour composition changes also lead to differences in MFP growth, but the size of those differences is generally smaller than for capital. Furthermore, there are substantial differences in methodological choices across the databases, which motivates our empirical exercise of gradually harmonizing capital measures.

In the remainder of this article, we discuss the general growth accounting methodology of all four databases (Section 1), provide a comparison of results and methods (Section 2), illustrate how much harmonization of different methods reduces differences (Section 3) and conclude (Section 4).

## Growth Accounting Framework

For the estimation of MFP, each of the four databases follows the basic growth accounting methodology, based on the work by Solow (1957), Jorgenson (1963) and Jorgenson and Griliches (1967). In this framework the growth of MFP is defined as the growth of output not accounted for by the contribution from growth of labour and capital inputs used in production:

$$\partial MFP = \partial Y - (1-\alpha)(\partial H + \partial LC) - \alpha \sum_i w_i \partial K_i \quad (1)$$

Where $\partial MFP \equiv \log(MFP_t / MFP_{t-1})$ denotes the log growth of MFP, and likewise $\partial Y$, $\partial H$, and $\partial LC$ denote the log growth of GDP, hours worked, and the composition of labour input; all expressed in quantity/volume terms. $\alpha$ denotes the output elasticity of capital, and we assume a constant returns to scale production function, so $(1-\alpha)$ is the output elasticity of labour. Assuming cost minimization by producers and perfect competition in factor and output markets, the marginal product of an asset will equal its marginal cost. In that case, we can measure the output elasticities using the share of each input's income in total GDP. One of the main contributions of Jorgenson and Griliches (1967) was to clarify how to account for heterogeneity in labour and capital. The basic logic is the same, the marginal product of each type of labour or capital should equal marginal costs.

In equation (1), we explicitly distinguish different types of capital input, so that $\sum_i w_i \partial K_i$ reflects the weighted aggregate growth rate of the capital stocks, $\partial K$ for $i$ assets, where $w_i$ are capital cost shares. We will refer to this weighted aggregate growth of capital stocks as capital services growth throughout the remainder of this article. Note also that $\alpha$ and $w_i$ will vary over time; all four databases account for this using a Törnqvist index, where the output elasticity is measured as a two-period average cost share, which implies replacing, e.g. $\alpha$ by $\overline{\alpha}_t = \frac{1}{2}(\alpha_t + \alpha_{t-1})$.

While capital stocks by asset type are available from official statistics, productivity databases typically employ some type of harmonization procedure to estimate capital stocks that are consistent across countries and reflect capital assets relevant for production. We discuss the choices that are made by each of the databases in the next section. The most commonly employed method in capital stock measurement is the Perpetual Inventory Method (PIM), which starts from a starting capital stock for a particular asset $i$, and builds up the capital stock for succeeding years as follows:

$$K_{i,t} = (1-\delta_i)K_{i,t-1} + I_{i,t} \quad (2)$$

Where $K_{i,t}$ denotes the estimated stock in year $t$ for asset type $i$, $K_{i,t-1}$ the capital stock in the previous year, $\delta_i$ the time invariant geometric depreciation rate of asset type $i$, and $I_{i,t}$ the investment in asset type $i$ at time $t$.

The share in capital costs of capital type $w_i$ also needs to be estimated in order to calculate capital services from the capital stocks. Within the growth accounting framework, the user cost of capital is derived by multiplying a rental price, $p^K_{i,t}$ by the asset's capital stock $K_{i,t}$. This rental price reflects the price at which the investor is indifferent between buying the asset and selling it at the end of the period or renting the capital good for a one-year lease in the rental market (e.g. OECD, 2009). The cost-of-capital equation shows this relationship as a function of investment prices, depreciation, and the rate of return, in the absence of taxes:

$$\begin{aligned} p^K_{i,t} = & \, p^I_{i,t-1} \cdot r_t + p^I_{i,t} \cdot \delta_i \\ & - p^I_{i,t-1} \cdot (p^I_{i,t} - p^I_{i,t-1}) \end{aligned} \tag{3}$$

Where $p^I_{i,t}$ denotes the investment price of asset type $i$ at time $t$, $\delta_i$ the geometric depreciation rate of asset type $i$, and $r_t$ the (nominal) rate of return at time $t$. As discussed in the next section, the rate of return can be the (ex-post) rate of return that exhausts the part of GDP not accruing to labour (the internal rate of return) or an (ex-ante) assumed rate of return. A more complete expression of the rental price should also consider the tax treatment of investment, depreciation, and capital income (Hall and Jorgenson, 1967). However, none of the four databases under consideration incorporate these tax factors in their calculations, so we omit these in our further discussion.

The contribution of capital services growth in equation (1) is equal to $\alpha \sum_i w_i \partial K_i$, but for our comparison of databases, we rely on a modified decomposition that (partially) accounts for the endogeneity of capital accumulation:

$$\begin{aligned} \partial Y - \partial H = & \frac{\alpha}{1-\alpha} \left( \sum_i w_i \partial K_i - \partial Y \right) \\ & + \partial LC + \frac{\partial MFP}{1-\alpha} \end{aligned} \tag{4}$$

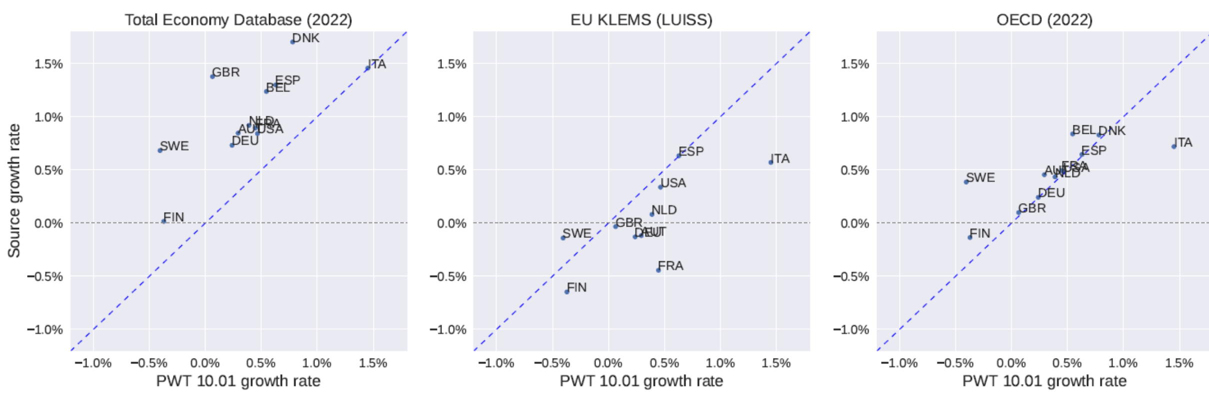
As discussed in Fernald and Inklaar (2020), this expression is useful because in many models the capital-output ratio is stationary in steady state (though possibly with a trend if there are trends in the relative price of investment goods). Slower growth in technology and labour naturally lead to a lower path for both capital and output, but, in neoclassical models, will not show up as a decline in the capital-output ratio. Thus, the capital-output ratio can help diagnose whether there are special influences that reduced capital relative to output.

All four databases in our analysis apply a growth accounting methodology that is well-described using equations (1) – (4) and we can calculate the contribution of capital services growth to labour productivity growth, $\alpha/(1-\alpha)(\sum_i w_i \partial K_i - \partial Y)$, from equation (4); henceforth, the capital contribution. Yet implementing these equations requires a series of methodological choices that have a substantial impact on the results.

## Comparing Results and Methods

In Chart 2 we show that the capital contribution varies substantially across the four databases. In this article we dig deeper into these differences and investigate the potential causes. We focus on a set of ten Western European countries and the United States, since the underlying data for these countries adheres to the same SNA definitions, with a high level of statistical quality. Furthermore, we compare the results averaged for the period 2000-2007, a relatively recent period, which

**Chart 2: Contributions of Capital Services per unit of Output to Labour Productivity Growth, Compared Against PWT 10.01**




Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.
Notes: the figure shows the average annual contribution of capital services to labour productivity growth for the period 2000–2007, based on equation (4). The blue dashed line is the 45-degree line.

means differences in the statistical source material are minimized.[4] The period is chosen to end before the Global Financial Crisis. This choice is to avoid a situation where differences in the vintage of National Accounts data need careful attention. We find that differences in capital measurement methods can account for one-third of differences in MFP growth across databases. Differences in choices on basic data, such as whether to use official estimates of capital stocks directly or estimate capital stocks using a harmonized method from official data on investment, as well as differences in labour composition change, lead to a continued wedge between the databases. Furthermore, accounting for part of the differences in MFP growth rates does not imply we can more narrowly pinpoint ‘true’ MFP growth, but rather that we better understand the sources of the differences.

Given that we compare four databases, there are six unique pairwise comparisons we can make. Since our main empirical exercise is to show how the harmonization of capital measurement affects cross-database differences, a full set of pairwise comparisons becomes even more complex. For that reason, we select PWT as our point of reference for most of this article. This is not to argue that its methodological choices are superior to those of other databases as methodological harmonization could also have been done towards other databases. Having a single point of reference can be hazardous since two databases that both differ markedly from PWT, may be very similar to each other. We will thus also include pairwise comparisons in our detailed discussion of results in Section 3.

Each of the databases has published documentation regarding the data sources, as well as the methodology used to calculate the productivity statistics. In this article we focus on the key areas in which dif-

4 An analysis for the more recent 2008–2019 period shows very similar patterns of differences between databases.

ferent methodological choices can and are being made by each database, specifically about the estimation of capital stocks and services. These choices, while motivated by economic theory and purpose of the analysis, are to some extent arbitrary and depend on subjective views on how MFP can best be measured. The current document can also be viewed as a sensitivity analysis with respect to these differences in methodological choices and differences in the sources and use of the data.[5]

Since the data source for output and labour in the current set of countries is the National Accounts (NA), the data for these variables is very similar across each of the databases, as can be seen from Chart 3, which compares average annual labour productivity growth across the databases. This confirms our expectation that this is a period for which differences due to, for example, NA revisions are of secondary importance. Given this result in Chart 3, we focus on the data for the capital stocks and investment in the main text. In Appendix Table 3 we also provide a comparison of differences in labour composition change. For most countries, the differences are smaller than for capital services though there are some remarkable results that would benefit from closer scrutiny.

The National Statistical Institutes (NSIs) for the countries in our comparison publish capital stocks by asset type in current and constant prices, which can lead to cross-country differences because the methods that NSIs use may differ. This could be a benefit, for example, if the service lives of assets would differ by countries and the NSIs would incorporate this country-specific information in their data. However, there may be too little country-specific data to motivate appropriate choices and, instead it could be that each NSI simply makes the set of measurement choices that they find most appropriate.

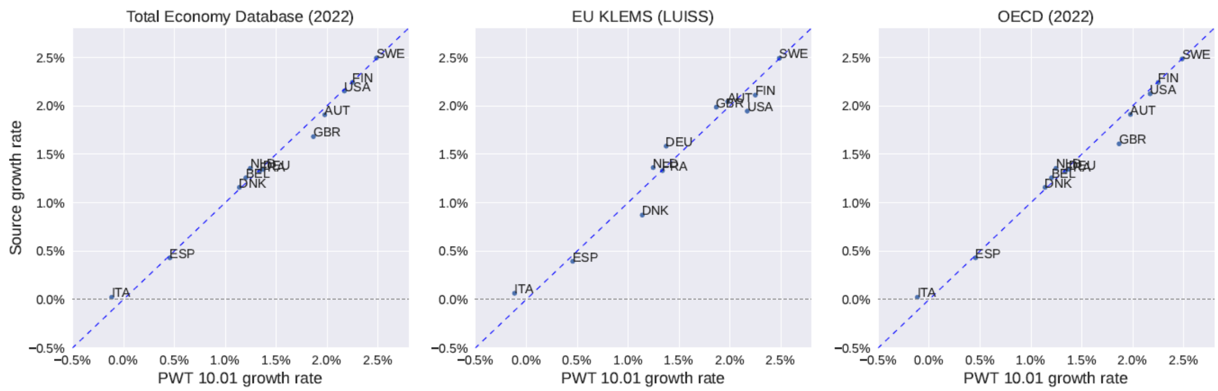
Of course, even those databases that do harmonize capital stock calculation methods will still need to rely on official statistics on investment and (typically) investment prices, so harmonization can only be taken so far. Furthermore, the official capital stock series reflect wealth capital stocks, but when doing productivity analysis, we are interested in the productive capacity of the capital stock.[6] So even when relying on official statistics for wealth stocks, as EU KLEMS does, methodological choices regarding user costs of capital will need to be made. In other words, the difference between databases is not one of 'harmonize or not' but the degree to which harmonization takes place.[7]

5 For a description of the methods of the four databases, see PWT, OECD, TED, EU KLEMS [accessed: May 2023]

6 For an overview of the difference between productive and wealth capital stocks, see OECD (2009). In brief, equation (2) provides estimates of wealth stocks, while accounting for differences in the user cost of capital using equation (3) is needed to measure productive stocks.

7 The analytical module of the EU KLEMS database does provide growth accounting estimations based on a harmonized measure of the capital stocks, but it also includes additional intangible asset types that are not part of the national accounts, which complicates a comparison with the other databases. A growing number of countries provide official statistics on MFP growth, but coverage is still much less extensive than in the databases covered here.

**Chart 3: Average Annual Labour Productivity Growth, 2000-2007**




Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

For the estimation of harmonized wealth stocks, the OECD, PWT and TCB databases typically start out from an initial capital stock and build up the time series using investment series from the national accounts. The key elements in constructing productive capital stock estimates are:

- Choice or estimation of the initial capital stock,
- The combined retirement/age-efficiency profile of assets, reflected in the depreciation rate,
- Information on investment and asset prices.

Table 1 below presents a stylized overview of the methods used by each of the productivity databases under consideration for their capital stock estimations. The first three sets of choices ('initial stocks', 'build up capital stock' and 'deflators') all affect the capital contribution primarily through the estimation of capital stocks by asset, i.e. equation (2). The final choice, on rental prices, affects the capital contribution through equation (3), through different $w_i$, and (4), through different $\alpha$.

As can be observed from Table 1, PWT, TED and OECD employ a version of the Perpetual Inventory Method (PIM) for constructing capital stocks. Table 2 gives an overview of the assets covered by each database, along with the (implied) geometric depreciation rates used. Note that OECD does not include residential structures or cultivated assets in productivity estimations. This leads to an inconsistency between the growth of output, which does include value-added growth in the residential real estate industry, and the growth of inputs, which omits the key input in the residential real estate industry.[8]

EU KLEMS relies on capital stocks from official statistics, so they do not construct a PIM-based capital stock. But for computing the user cost of capital, the depreciation is an important input. As discussed in Pionnier, Belén and Baret (2023), depreciation rates applied in official statistics vary considerably across countries, which can account for some of the cross-country

8 Additionally, none of the databases include land or inventories, which creates the same inconsistency.

**Table 1: Capital Stock Estimation, Methodology Overview**

| | PWT | TED | OECD* | EU KLEMS |
|---|---|---|---|---|
| **Initial capital stock** | 1950 capital/ output ratio with long run PIM approach* | Harberger steady-state assumption | Long run PIM approach, based on (confidential) historical GFCF data** | |
| **Build up capital stock** | Geometric depreciation rates, see Table 2 | Geometric depreciation rates, see Table 2*** | Hyperbolic age-efficiency profile; retirement profile normal distribution; average service life, see Table 2.**** | EU KLEMS takes the investment and capital stock series, including implicit deflators, directly from EUROSTAT, for the derivation of the rental price, geometric depreciation is used, see Table 2 |
| **Deflators** | Investment prices, hedonic adjustments for ICT | Investment prices, special hedonic adjustments for ICT***** | Investment prices, hedonic ICT deflators****** | |
| **Rental price** | Ex-post (internal rate of return) | Ex-post (internal rate of return) | Ex-ante (4 per cent real rate plus inflation) | Ex-post (internal rate of return) |

Source: compilation by authors based on database documentation; see footnote X for further details. [NB: see specific comments 11 for the new footnote with links to documentation]

Note: * Inklaar, Woltjer and Gallardo Albarrán (2019).

** This information was received from bilateral exchanges with the OECD Productivity Statistics team.

*** In PWT, assets are assumed to be used in production during the year in which the investment is made. To reflect this, half of current year's investment is depreciated, so equation (2) is implemented as:
$K_{i,t} = (1 - \delta_i)K_{i,t-1} + I_{i,t} - \frac{1}{2}\delta I_{i,t}$

**** OECD (2021).

***** Byrne and Corrado (2019).

****** Schreyer (2002); Colecchia and Schreyer (2002).

**Table 2: Geometric Depreciation Rates**

| Asset Code | | | | Rate (%) | | | |
|---|---|---|---|---|---|---|---|
| **OECD** | **EU KLEMS** | **TED** | **PWT** | **OECD*** | **EU KLEMS** | **TED** | **PWT*** ** |
| N111321 | IT | hard | IT | 31.2 | 31.5 | 31.5 | 31.5 |
| N111322 | CT | com | CT | 11 | 11.5 | 11.5 | 11.5 |
| N1122 | Soft | soft | SOFT | 33.3 | 31.5 | 31.5 | 31.5 |
| N1113O | OMach | nonITmach | OMach | 11.4 | 13.1 | 12.6 | 12.6 |
| N11131 | TraEq | tra | TraEq | 11 | 18.9 | 18.9 | 18.9 |
| N1111 | RStruc | str | RStruc | n.a.** | 1.1 | 2.5 | 1.1 |
| N1112 | OCon | str | OCon | 2.5 | 3.2 | 2.5 | 3.1 |
| N1114 | Cult | Not available | CULT | n.a.** | 20 | | 12.6 |
| N1124 | RD | Not available | RD | 10 | 20 | | 15 |
| N112X | OIPP | Not available | OIPP | 14.3 | 13.1 | | 15 |

IT: information technology; CT: communication technology; SOFT: software; OMach: other machinery; TraEq: transportation equipment; RStruc: residential structures; OCon: other construction; CULT: cultivated assets; RD: research and development; OIPP: other intellectual property products.

Source: compilation by authors based on database documentations; see footnote X for further details. [NB: see specific comments 11 for the new footnote with links to documentation]

* OECD reports the following average service lives in years: IT 7; CT, OMach 15; OCon 40; Soft 3; RD 10; OIPP 7.

For the purposes of this article, service lives are converted to geometric rates using the Declining Balance Rates (DBR) from Fraumeni (1997). No DBR are available for Soft, RD and OIPP, so they are assumed to be 1.

DBR's used: IT 2.1832; CT and TraEq 1.65; OMach 1.715; OCon 0.8892.

** Not available in the OECD productivity database.

*** PWT uses detailed assets in this table for its calculations. Data for the following four groups of assets are published: structures, machinery and equipment, transport equipment, and other assets.

differences in capital growth. Furthermore, EU KLEMS introduces an inconsistency by (implicitly) using one set of depreciation rates for their capital stocks and another one for the user cost of capital.

Investment at current prices and investment deflators are available from National Accounts statistics, but for information and communication technology (ICT) assets, the use of harmonized deflators based on better quality-adjusted price data for the United States is often used.

The PWT, TED, and EU KLEMS databases calculate $r_t$ from equation (3) by estimating an internal rate of return, i.e. the rate of return that exhausts the part of GDP not accruing to labour. We refer to this as the ex post method since the return is determined based on realized capital income. By contrast, the OECD employs an ex-ante approach where the real rate of return is fixed at 4 per cent and this is converted to a nominal rate of return by adding the 5-year centered moving average of changes in the national Consumer Price Index (OECD, 2021). Using the ex-post version of equation (3) ensures that factor costs sum to total output. Using the ex-ante method, capital costs can be notably lower than GDP minus labour compensation, leaving 'factorless income' (Karabarbounis and Neiman, 2019) or 'pure profits' (Hall, 1990; Barkai, 2020). If factorless income/pure profit is positive, the capital contribution will typically be lower under the ex-ante method than the ex-post method because the assumed output elasticity of capital, $\alpha$, is lower.[9]

## The Impact of Harmonizing Capital Measurement

As discussed in the introduction, we have chosen to take the 2000-2007 average of the growth accounting results for each of the databases, for a set of ten western European countries and the United States. To assess the importance of different methodological choices, we recalculate the results for each of the databases, using four levels of methodological harmonization:

M1. **No harmonization:** Calculating capital services contributions per unit of output based on the reported capital services index and labour share $(1-\alpha)$ in total factor costs from the database, using equation (4).

M2. **Recalculate capital services:** Recomputing capital services contributions based on reported capital stocks by asset and a harmonized ex-post capital services method, using equations (3) and (4).

M3. **Recalculate asset stocks:** Reestimating capital stocks using a harmonized PIM method, based on reported investment series by asset, using equation (2) and using the reported 1995 stocks as the starting stocks. From these series we calculate capital services contributions, as in M2.

9 A smaller effect is that assets with a high depreciation rate will have a relatively higher share, $w_i$, in total capital because the ex-ante rate of return is lower than the ex-post rate of return. The overall difference in capital contribution depends on the difference in growth between high-depreciation assets and low-depreciation assets.

M4. **Impose common labour shares:** Recomputing capital services contributions based on reported investment series by asset, using harmonized PIM stocks as in M3, harmonized ex-post capital services method as in M2, and using the PWT labour share $1 - \alpha$.

These four methods are best seen as cumulative harmonization steps. Our starting point, M1, is the capital contribution from each database, with M2 we harmonize the user cost equation, with M3 we also harmonize the calculation of capital stocks and with M4 we also impose common labour shares. We would thus expect that under M4, differences across databases are at their smallest as all harmonization steps are implemented at the same time.

Harmonization means that one database's methodological choice is applied to all others, which could be seen as expressing a conceptual preference for that database's choice. That is not the intention of our exercise, the intention is rather to assess the quantitative importance of each choice for cross-database differences. We use PWT's measurement choices as our point of reference for the capital services method (step 2), the PIM method and depreciation rates (step 3) and the labour shares (step 4) but could have done the same exercise using another database's choices. In summarizing our results, below, we will not only show the differences of each database vis-à-vis PWT (as the point of reference, see Table 3) but also vis-à-vis each other (Table 6).

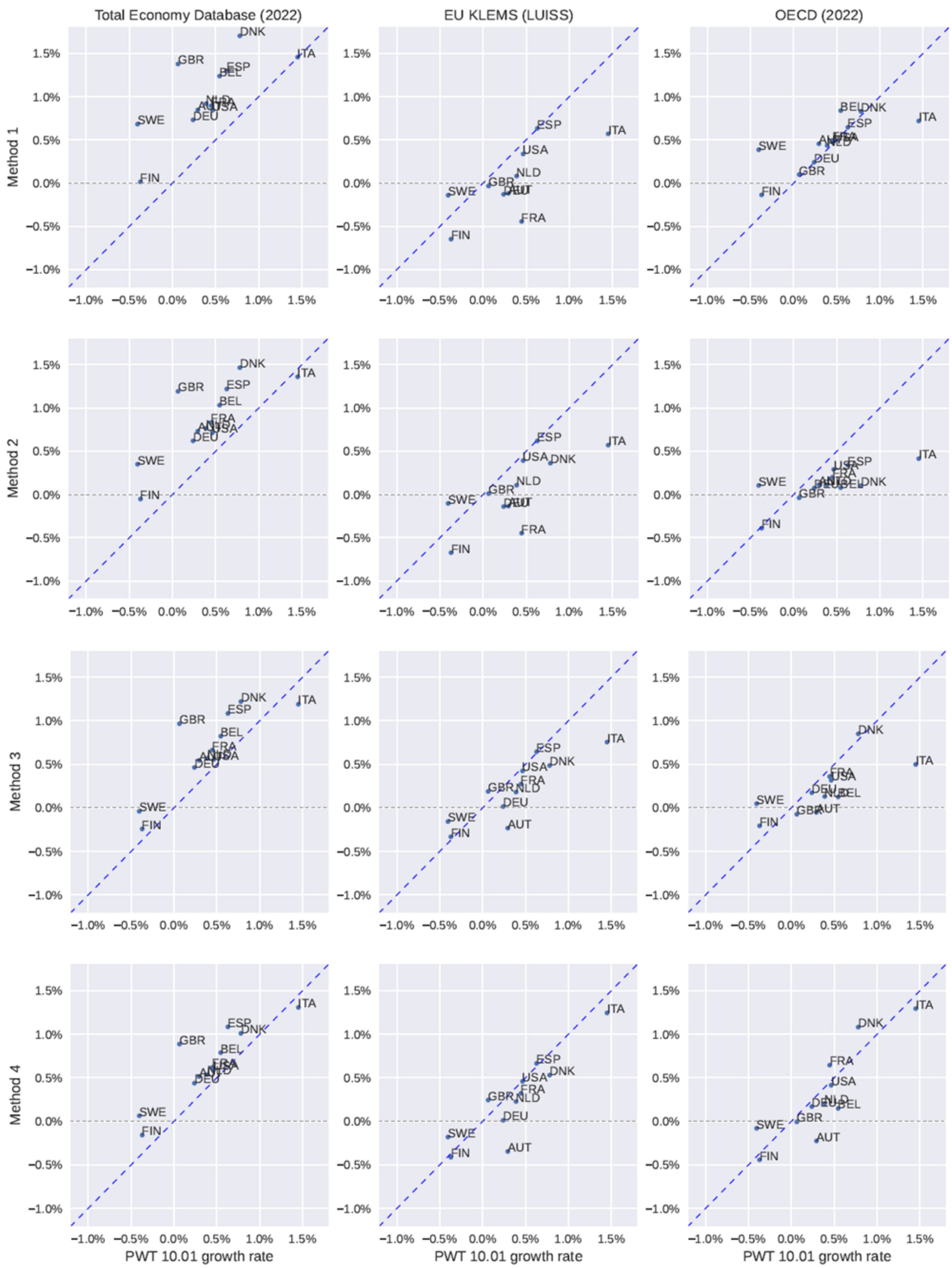
We expect that each step of further harmonization will reduce the differences between the databases. To illustrate the differences, we show in Chart 4 scatter plots with comparisons of the other three databases to PWT for each of the four harmonization steps, in Table 3 we provide summary statistics associated with each scatter plot, namely the average difference and the square root of mean squared differences.

It should be noted that OECD Productivity Data Base (PDB) does not publish the productive stocks on which their capital services estimates are based. However, investment series used in this database are available from Table 8A in the OECD National Accounts (NA) database. Therefore, we use the wealth capital stocks by asset as reported in Table 9A of the OECD NA database, for harmonization method 2. For methods 3. and 4. we take the 1995 stock values as the initial stock. These stocks include values for residential structures and cultivated assets, which are not included in OECD. Additionally, the labour share $1 - \alpha$ is not reported directly in OECD PDB. Therefore, they have been calculated from the reported growth contributions such that the M1 calculations result in MPF growth rates that are fully consistent with those reported in the database.

## Method 1: No Harmonization

The first row of Chart 4 replicates Chart 2, comparing the growth contribution of capital services per unit of output to labour productivity growth across databases. These values have been derived directly from the reported growth of output, hours worked, labour and capital services, as well as the derived or reported shares of labour compensation in value added. We refer to this as the first

**Chart 4: Capital Services Contributions at 4 Levels of Harmonization**




Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

Notes: See main text for details of the harmonization methods.

**Table 3: Capital Contribution Differences Relative to PWT (in percentage points)**

| Comparison database: | TED | | EU KLEMS | | OECD | |
|---|---|---|---|---|---|---|
| Summary statistic: | Average difference | (Mean sq. differences)0.5 | Average difference | (Mean sq. differences)0.5 | Average difference | (Mean sq. differences)0.5 |
| **Method 1** | -0.62 | 0.71 | 0.34 | 0.44 | -0.09 | 0.35 |
| **Method 2** | -0.47 | 0.55 | 0.34 | 0.46 | 0.26 | 0.45 |
| **Method 3** | -0.26 | 0.37 | 0.18 | 0.31 | 0.16 | 0.38 |
| **Method 4** | -0.25 | 0.33 | 0.13 | 0.25 | 0.06 | 0.26 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.
Note: Average difference: contribution from PWT 10.01 minus contribution from the comparison database
(Mean sq. differences)$^{0.5}$: square root of mean squared differences

method of recalculation (M1).

The estimated capital contributions in TED are systematically higher than that of PWT, but also higher than the other two databases. Most striking are the growth contributions for the UK, Denmark and Sweden where the difference in contribution exceeds 1 percentage point and changes sign for Sweden.[10] EU KLEMS reports capital contribution that are lower than those of PWT, apart from Sweden. Italy and France are the countries for which the largest differences can be observed, as seen by the vertical distance to the 45-degree reference line. Results for OECD are more in line with what PWT is reporting, although Sweden is again an outlier, changing sign from a negative contribution in PWT to a positive contribution in the OECD results. Similar to EU KLEMS, OECD also shows an almost full percentage point lower capital contribution for Italy than PWT. The results of three additional methods of recalculation are shown in the other rows of Chart 4, which are discussed in the next sections. Table 3 reports the average growth difference and the square root of mean squared differences for each method by database pairing, giving us measures of deviation from the PWT growth rates for each database.

## Method 2: Recalculation of Capital Services with Reported Stocks

In the second step we harmonize the calculation of capital services growth starting from the reported capital stocks by asset type from each of the databases. For the calculation of capital compensation by asset type, we use the PWT geometric depreciation rates mapped to the assets of the other databases, shown in Table 2. The rates reported to have been used by the other databases are reported as a reference, and they are generally quite similar. Additionally, we use investment deflators in the calculations, even though for EU KLEMS implicit stock deflators are available.

The row for Method 2 in Chart 4 and Table 3 shows that the recalculation of capital services has not brought the results of TED and PWT much closer, but the average difference did decrease somewhat. The

10 There have been considerable revisions in the latest version of the ONS data, which can be found here: https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/multifactorproductivityexperimentalestimatesreferencetables

difference in capital services contributions for EU KLEMS and PWT have stayed the same compared to Method 1, indicating EU KLEMS and PWT methodology for calculating capital services contributions are virtually identical.

The recalculation based on reported stocks has resulted in more divergence of the OECD and PWT contributions. Clearly taking the wealth capital stocks from OECD National Accounts database produces results quite different from using OECD's unpublished productive capital stocks. As noted above, OECD does not include residential structures in its measure of capital services. Therefore, part of the divergence from Method 1 to Method 2 can be attributed to the inclusion of residential structures in the capital services measure. Finally, as mentioned in section 2, OECD uses an ex-ante exogenous rate of return to calculate capital services. These results imply that PWT, TED and EU KLEMS use a similar approach to calculating capital services, which also follows from the documentation.

### Method 3: Recalculation of Capital Services Using PIM Stocks

Going one step further in the harmonization of the calculation methods, we recalculate the capital stocks based on the investment by asset from the reported 1995 capital stocks, applying the Perpetual Inventory Method (PIM) in the same way across data sources. We apply the PWT method where half of the current years' investment is depreciated and use the PWT geometric depreciation rates as reported in Table 2.

The row for Method 3 in Chart 4 and Table 3 shows that the harmonized recalculation of capital services as well as the capital stock has brought the results of the databases closer together relative to Methods 1 and 2 for TED and EU KLEMS, and relative to Method 2 for OECD. For the TED the average difference in the capital growth contribution has been reduced by 0.21 percentage points compared to Method 2, but this is not immediately clear from the chart, which suggests that this convergence is spread over all countries. For EU KLEMS the results are also moving closer to PWT, as is visible from the plot, where the countries are moving closer to the 45-degree reference line. For the OECD the results are moving closer to the Method 1 results, with Italy still being an outlier.

Thus, harmonizing the calculation of the capital stocks across databases brings the results of each database closer to PWT. For EU KLEMS this could be expected given that they use official capital stocks, directly from the NSIs, without any harmonization. For OECD this method suggests that the harmonized PIM stocks come closer to OECD's own unpublished measures of productive capital stocks. For TED the increased convergence to PWT contributions is somewhat puzzling, given that the methods as presented in Table 1, as well as the depreciation rates in Table 2, for TED and PWT are quite similar.

### Method 4: Recalculation of Capital Services Using PIM Stocks and PWT Labour Shares

In a final attempt to bring the results closer together and harmonize the methods of calculation one step further, we ap-

**Table 4: Average Share of Labour Compensation in Total Factor Costs (in %), 2000-2007**

| | PWT | TED | EU KLEMS | OECD |
|---|---|---|---|---|
| **AUT** | 57.5 | 54.9 | 66.0 | 72.0 |
| **BEL** | 61.5 | 59.7 | | 75.6 |
| **DEU** | 62.3 | 59.9 | 67.1 | 71.4 |
| **DNK** | 63.6 | 56.3 | 65.9 | 72.1 |
| **FIN** | 56.7 | 52.1 | 63.2 | 74.8 |
| **FRA** | 61.7 | 58.7 | 67.1 | 76.1 |
| **GBR** | 59.6 | 56.0 | 64.5 | 78.7 |
| **ITA** | 50.5 | 53.2 | 62.8 | 72.7 |
| **NLD** | 60.9 | 57.5 | 67.3 | 74.6 |
| **SWE** | 53.0 | 49.1 | 54.7 | 69.1 |
| **USA** | 62.0 | 65.8 | 65.0 | 77.0 |
| **Average** | 59.0 | 56.6 | 64.4 | 74.0 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.
Notes: The table shows the share of labour compensation in total costs. For PWT, TED and EU KLEMS, labour plus capital costs are assumed to be equal to GDP, for the OECD the use of an exogenous rate of return means that labour plus capital costs may be less (or more) than GDP.

ply the PWT labour shares, instead of the reported shares. The application of PWT labour shares has only a small impact on the comparative results of TED and EU KLEMS, although the capital services contribution for Italy has moved much closer to the PWT result for EU KLEMS.

For OECD, using the PWT labour share, reduces the square root of mean squared differences to 0.26 per cent, the lowest value across the four methods. This is mainly due to the effect this adjustment has on the outliers in the previous three methods. Italy has moved up to the PWT level of capital services contribution and has been completely removed as an outlier. To a lesser extent the same can be said for Sweden, comparing Method 1 and 4. Conversely, results for Austria and Denmark now diverge a bit more from PWT, as compared to Method 1, but since their results were more comparable to PWT to begin with, this has less effect on the square root of mean squared differences.

This suggests there are considerable differences in the calculations of the labour share across these databases. Table 4 shows the average share of labour compensation in value added for the 2000-2007 period, and indeed confirms this finding. As shown in the bottom row, OECD reports a labour share that is on average 15 per cent higher than PWT, for this set of countries. TED reports labour shares that are roughly similar to PWT, and EU KLEMS is in the middle between PWT and OECD.

As discussed in the previous sections, the higher OECD labour share can be explained, by the presence of factorless income in an ex-ante framework, which leads to a lower estimate of capital compensation, and conversely a higher labour share in total factor costs. EU KLEMS calculates the labour share by assuming the self-employed, on average, earn the same hourly wages as employees. For certain sectors such as agriculture, this method tends to overstate labour costs, which leads to higher labour shares. PWT uses mixed-income as a proxy for the income of the self-employed. Lastly, TED uses the same approach as PWT, but calculates the labour share as a percentage of GDP at market prices which includes net taxes on

**Table 5: Average Growth of Aggregate Investment Prices (in %), 2000-2007**

| | PWT | TED | EU KLEMS | OECD |
|---|---|---|---|---|
| **AUT** | 0.8 | 0.7 | 1.5 | 1.5 |
| **BEL** | 1.0 | 0.4 | | 1.7 |
| **DEU** | 0.0 | 0.0 | 0.3 | 0.3 |
| **DNK** | 1.3 | 0.1 | 2.1 | 2.1 |
| **FIN** | 1.9 | 2.1 | 2.3 | 2.3 |
| **FRA** | 1.8 | 1.5 | 2.3 | 2.3 |
| **GBR** | 1.9 | -0.7 | 2.2 | 2.7 |
| **ITA** | 2.0 | 1.1 | 2.5 | 2.5 |
| **NLD** | 1.7 | 0.6 | 2.2 | 2.2 |
| **SWE** | 0.8 | -0.6 | 1.4 | 1.5 |
| **USA** | 2.1 | 1.5 | 2.1 | 2.1 |
| **Average** | 1.4 | 0.6 | 1.9 | 1.9 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

products, yielding labour shares that are slightly lower than in PWT.

The TED capital contributions are generally higher than for the other databases. This can be traced to the application of alternative hedonic ICT investment deflators, which results in a significantly lower aggregate price inflation of investment as can be seen from Table 5. This in turn leads to higher capital stock growth and therefore higher capital services growth.

Comparing the results in Chart 4 and Table 3 for Methods 1 and 4, shows that increasing the harmonization of calculations reduces cross-database differences in the contribution of capital to growth. The average difference is smaller, in particular for EU KLEMS and TED, and the root mean squared difference is considerably smaller for all three comparisons. The first harmonization step, which harmonizes the capital services calculation from given stocks (Method 2 versus Method 1) has an ambiguous effect on cross-database differences, increasing the root mean squared difference for the comparison of PWT to OECD and EU KLEMS and reducing it for the comparison to TED.

The second harmonization step, which recalculates capital stocks reduces differences for all three comparisons and is the most substantial step for the comparison of PWT to EU KLEMS and TED. For those two comparisons, the third harmonization step, which imposes the same labour shares, leads to a more modest reduction in cross-database differences. This third step is very important for the OECD-PWT comparison. This is unsurprising as the OECD's labour share estimates in Table 5 differ substantially from the other two.

A downside of looking at these separate harmonization steps is that, taken in isolation, they may introduce inconsistencies. For example, the OECD uses an ex-ante rate of return to calculate capital costs and the labour share is equal to labour compensation divided by labour compensation plus capital costs. The other databases rely on an internal rate of return, which is set so that total capital cost adds up to GDP minus labour compensation. The difference in Table 4 is best understood as showing that capital costs are notably lower than GDP minus labour compensation, leaving substantial 'factorless income' (Karabarbounis and Neiman, 2019) or 'pure profits' (Hall,

**Table 6: Root Mean Squared Differences of Capital Contributions for Different Reference Databases**

| Reference: | TED | Comparison: EU KLEMS | OECD |
|---|---|---|---|
| **Method 1** | | | |
| PWT | 0.71 | 0.44 | 0.35 |
| TED | | 0.87 | 0.61 |
| EU KLEMS | | | 0.43 |
| **Method 4** | | | |
| PWT | 0.33 | 0.25 | 0.26 |
| TED | | 0.42 | 0.43 |
| EU KLEMS | | | 0.22 |
| **Difference: Method 4 – Method 1** | | | |
| PWT | -0.38 | -0.19 | -0.09 |
| TED | | -0.45 | -0.18 |
| EU KLEMS | | | -0.21 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.
Notes: The table shows root mean squared differences of the contribution of capital services growth to labour productivity between databases. The first column shows the reference database, across the rows the comparison databases are shown. The Methods refer to the harmonization steps, from no harmonization, Method 1, to the fullest harmonization (in this article), Method 4; see the main text for the full description.

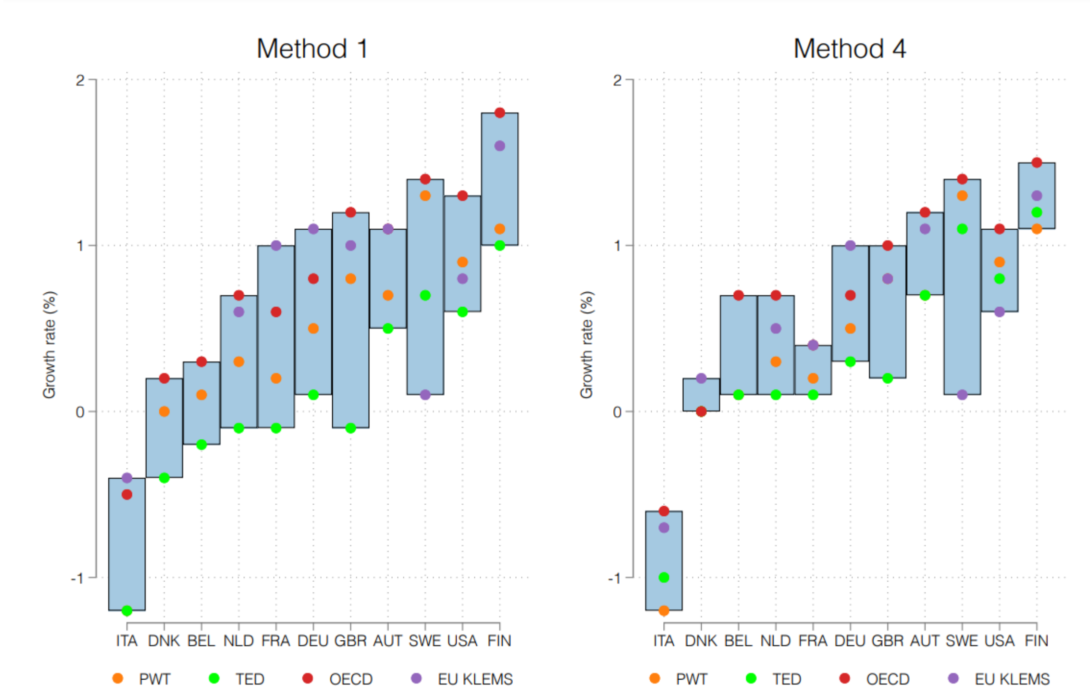
1990; Barkai, 2020). In Method 2 only the capital services calculation is changed while that change also impacts the factor shares, so both should be adjusted for a harmonized comparison between the databases.

Table 4 has PWT as the point of reference for both the harmonization steps and the comparison. In Table 6 we show how the root mean squared differences vary with different reference databases for the comparison. The first row under Method 1 shows the root mean squared differences from Table 3, comparing each database to PWT. In the second row, the comparison is made with TED contribution, in the third EU KLEMS is the point of reference. We show only the original contributions (Method 1), the final step in our harmonization (Method 4) and the difference (Method 4 – Method 1).

These results show that comparisons with TED have the largest differences to other databases, under Method 1 (0.71 points, 0.87 points and 0.61 points) and Method 4 (0.33 points, 0.42 points and 0.43 points). The large root mean squared difference that remains after our harmonization steps (i.e. Method 4) is most likely due to the large difference in investment deflators (Table 5). It is not immediately clear why the harmonization steps also have the largest impact on TED (–0.38 points, –0.45 points and –0.21 points). Excluding TED comparisons shows the smaller root mean squared differences, already in Method 1 (0.44 points, 0.35 points and 0.43 points) and they are small and comparable in Method 4 (0.25 points, 0.26 points and 0.22 points).

In closing, we return to our motivating Chart 1, which showed the range of MFP growth estimates from the different databases, i.e. Method 1. We now have more harmonized capital contribution, based on Method 4, and can compute MFP growth based on these contributions. The result is shown in Chart 5, with the ranges of MFP growth from Chart 1 on the left and the ranges based on Method 4 on the right. The range of MFP growth rates

**Chart 5: Range of MFP Growth Rates Across Databases, Method 1 versus Method 4.**




Notes: The chart shows for each country a bar ranging from the smallest to the highest average annual growth rate for the 2000–2007 period across the four databases, PWT, TED, EU KLEMS and OECD. Also included are the growth rates in each database; note that in some cases two databases show the same average growth rate. Countries are ordered by the average growth rate across the four databases. The panel on the left, labelled 'Method 1' is based on the data from Appendix Table 1, and 'Method 4' is based on Appendix Table 2.
Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

based on Method 4 is notably smaller, on average 0.6 versus the 0.9 based on Method 1. Ranges are smaller for all countries, except Belgium (where the range was small to begin with) and Sweden, where the difference is driven by the large labour composition change shown in EU KLEMS (see Appendix Table 3). Note that these smaller ranges do not imply that we can more precisely pinpoint MFP growth. Rather, we can conclude that the capital measurement choices we focus on, can account for one-third of the differences in MFP growth rates between databases. The remainder of the differences are due to differences in capital measurement we did not harmonize (e.g. investment deflators) and differences in labour composition change.

## Conclusion

As is noted by frequent users, there are considerable differences between MFP growth rates from different productivity databases. The reasons for these discrepancies are methodological, statistical, as well as country-specific in nature. The previous section has shown that differences are smaller when applying a harmonized methodology in calculating capital growth contributions to labour productivity growth. However, differences partially remain. In particular, the TED data show higher growth rates, which have been traced back to the use of alternative deflators for ICT assets.

As was mentioned in the introduction, Appendix Table 1 shows that the rankings of countries based on their average MFP growth rates is quite similar for this set of countries, despite the sizable differences in average MFP growth. Appendix Table 2 shows the same information based on the recalculated MFP growth rates using Method 4. It can be seen that after harmonization, the order of countries based on their average productivity growth rates is also quite similar across these databases.

Judging by these rankings, the user will arrive at more or less the same comparative economic performance from PWT, OECD, and TED, even though TED reports notably lower MFP growth, due to a higher capital contribution. EU KLEMS seems to be the odd one out with a few striking anomalies. The most notable example is Sweden, which PWT, OECD and TED rank as one of the fastest-growing countries while in EU KLEMS, Sweden ranks near the bottom. Appendix Table 3 shows that the contribution of labour composition for Sweden in EU KLEMS is 1.9 percentage points higher than the contribution in PWT, which explains the low MFP growth value. The difference for Germany (third place in EU KLEMS, sixth of the other databases), would also lead to very different conclusions regarding comparative economic performance.

These differences in MFP growth rates are a cause for concern, especially because it is hard for a non-expert user to trace some of the differences, let alone make a reasoned choice between databases. Each database developer has arguments and reasons for the measurement choices they make, and it is not our aim to suggest that some of those choices are better than others. Instead, our aim with this article has been to highlight some of these differences and illustrate how harmonizing some of these choices can help reduce the differences, thereby demonstrating the importance of particular measurement choices.

Of the different methodological choices, methods for estimating capital stocks and estimating the rental prices of capital seem to lead to the largest differences. We also note that the choice on ex-ante vs. ex-post user costs impacts not only rental prices but also the capital share, so taken together, this choice is quite impactful. We do not claim to be exhaustive in this analysis, as there are more detailed levels at which harmonization of capital calculations could be attempted. Furthermore, choices regarding data and methodology for labour input and labour composition also contribute to differences in measured MFP growth and we have done no more than highlight those differences. This work assesses the robustness of differences in MFP growth across countries to measurement choices, thus highlighting the continued relevance of these choices and can inform as well as caution users who try to understand differences between databases.

Yet urging caution from non-expert users seems to us an undesirable state of affairs. As indicated, in these methodological choices there is no absolute preferred option and efforts to harmonize approaches, such as through the original EU KLEMS project, have had only partial success. The overall conceptual framework for growth accounting and capital measurement has been well-established for years, so the situation where alternative, equally plausible approaches can be chosen, is likely to prevail. We would argue that the only way forward on this is through coordination between National Statistical Institutes for the next revision of the System of National Accounts. Putting this on the agenda after the current round of revisions completes in 2025 holds out hope for more coordination on capital measurement and better international comparability of MFP growth as a result.

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## Appendix

**Appendix Table 1: Average Annual MFP Growth and Country Ranking 2000–2007, Method 1**

| | PWT10.01 | | Total Economy Database (2022) | | EU KLEMS (LUISS) | | OECD (2022) | |
|---|---|---|---|---|---|---|---|---|
| | rank | average growth (%) | rank | average growth (%) | rank | average growth (%) | rank | average growth (%) |
| **SWE** | 1 | 1.3 | 2 | 0.7 | 8 | 0.1 | 2 | 1.4 |
| **FIN** | 2 | 1.1 | 1 | 1 | 1 | 1.6 | 1 | 1.8 |
| **USA** | 3 | 0.9 | 3 | 0.6 | 6 | 0.8 | 3 | 1.3 |
| **GBR** | 4 | 0.8 | 8 | -0.1 | 4 | 1.0 | 4 | 1.2 |
| **AUT** | 5 | 0.7 | 4 | 0.5 | 3 | 1.1 | 5 | 1.1 |
| **DEU** | 6 | 0.5 | 5 | 0.1 | 2 | 1.1 | 6 | 0.8 |
| **NLD** | 7 | 0.3 | 6 | -0.1 | 7 | 0.6 | 7 | 0.7 |
| **FRA** | 8 | 0.2 | 7 | -0.1 | 5 | 1.0 | 8 | 0.6 |
| **BEL** | 9 | 0.1 | 9 | -0.2 | | | 9 | 0.3 |
| **DNK** | 10 | 0 | 10 | -0.4 | | | 10 | 0.2 |
| **ITA** | 11 | -1.2 | 11 | -1.2 | 9 | -0.4 | 11 | -0.5 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

**Appendix Table 2: Average Annual MFP Growth and Country Ranking 2000–2007, Method 4**

| | PWT10.01 | | Total Economy Database (2022) | | EU KLEMS (LUISS) | | OECD (2022) | |
|---|---|---|---|---|---|---|---|---|
| | rank | average growth (%) | rank | average growth (%) | rank | average growth (%) | rank | average growth (%) |
| **SWE** | 1 | 1.3 | 2 | 1.1 | 9 | 0.1 | 2 | 1.4 |
| **FIN** | 2 | 1.1 | 1 | 1.2 | 1 | 1.3 | 1 | 1.5 |
| **USA** | 3 | 0.9 | 3 | 0.8 | 5 | 0.6 | 4 | 1.1 |
| **GBR** | 4 | 0.8 | 6 | 0.2 | 4 | 0.8 | 5 | 1.0 |
| **AUT** | 5 | 0.7 | 4 | 0.7 | 2 | 1.1 | 3 | 1.2 |
| **DEU** | 6 | 0.5 | 5 | 0.3 | 3 | 1.0 | 6 | 0.7 |
| **NLD** | 7 | 0.3 | 7 | 0.1 | 6 | 0.5 | 7 | 0.7 |
| **FRA** | 8 | 0.2 | 9 | 0.1 | 7 | 0.4 | 9 | 0.4 |
| **BEL** | 9 | 0.1 | 8 | 0.1 | | | 8 | 0.7 |
| **DNK** | 10 | 0.0 | 10 | 0.0 | 8 | 0.2 | 10 | 0.0 |
| **ITA** | 11 | -1.2 | 11 | -1.0 | 10 | -0.7 | 11 | -0.6 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

**Appendix Table 3: Growth Contribution Differences of Labour Composition (in %)**

| | Total Economy Database (2022) | EU KLEMS (LUISS) |
|---|---|---|
| **AUT** | 0.41 | 0.06 |
| **BEL** | 0.15 | |
| **DEU** | -0.15 | 0.24 |
| **DNK** | 0.30 | 0.41 |
| **FIN** | 0.28 | 0.36 |
| **FRA** | -0.04 | 0.24 |
| **GBR** | 0.02 | 0.13 |
| **ITA** | 0.04 | 0.57 |
| **NLD** | -0.19 | 0.07 |
| **SWE** | 0.1 | -1.90 |
| **USA** | -0.04 | -0.14 |
| **Average difference** | 0.08 | 0.00 |
| **(Mean sq. differences)$^{0.5}$** | 0.20 | 0.66 |
| *Excluding Sweden:* | | |
| **Average difference** | 0.04 | 0.09 |
| **(Mean sq. differences)$^{0.5}$** | 0.21 | 0.29 |

Sources: PWT version 10.01, TED version April 2022, EU KLEMS version 2021 and OECD version May 2022; see footnote 3 for further details.

Average difference: contribution from PWT 10.01 minus contribution from the comparison database. (Mean sq. differences)$^{0.5}$: square root of mean squared differences.

OECD PDB does not provide estimations of labour composition change.