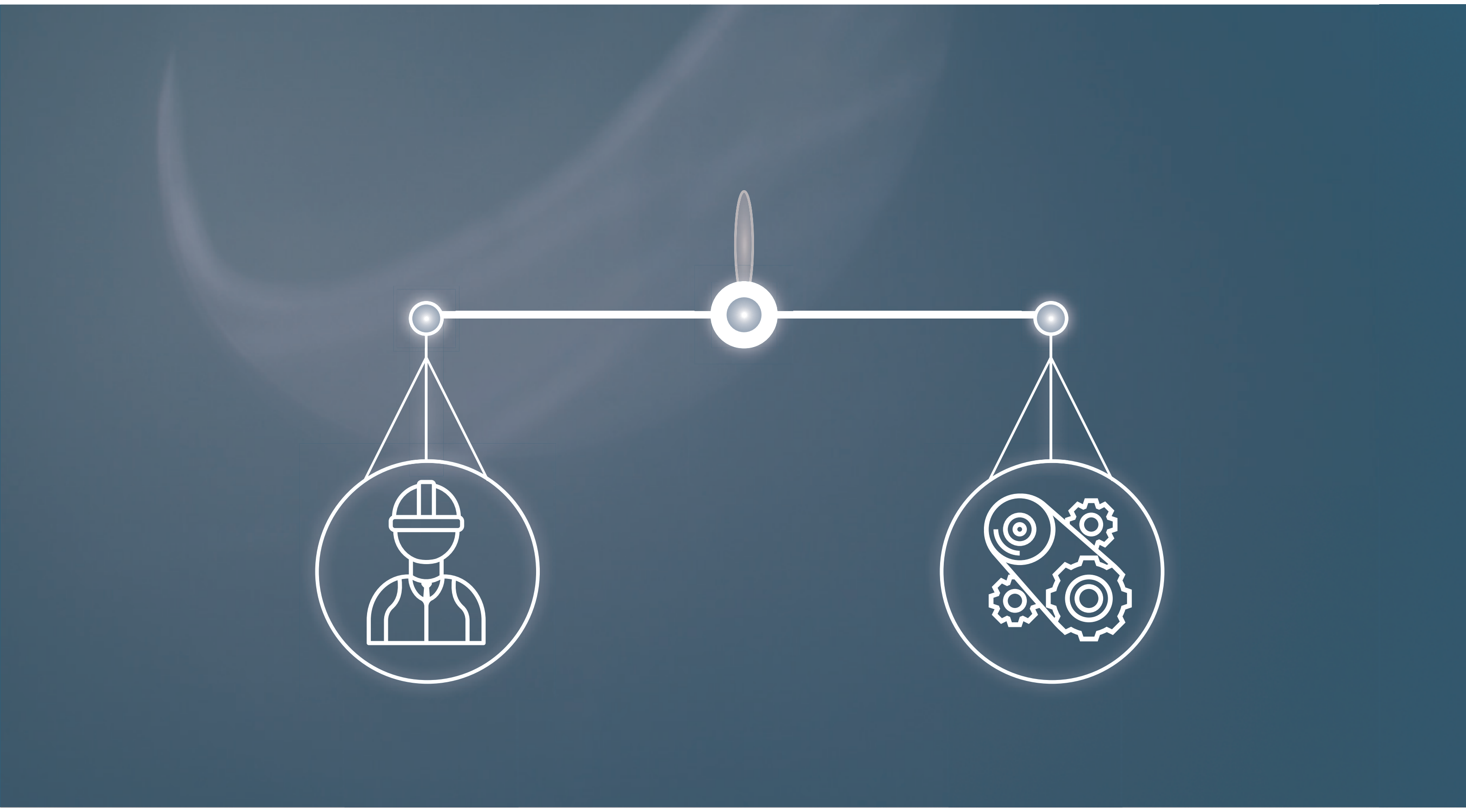
OECD PRODUCTIVITY STATISTICS

Methodological notes



OECD Productivity Statistics database

Methodological Notes

Last updated: May 7, 2021

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Acronyms

COE	Compensation of employees
GDP	Gross domestic product
ICT	Information and communication technology
MFP	Multifactor productivity
NSO	National statistics office
PDB	OECD Productivity statistics database
PIM	Perpetual inventory method
PPP	Purchasing power parities
ULC	Unit labour cost

1. Introduction

Productivity statistics gather information from multiple statistical domains into aiming to describe the efficiency with which an economy is able to turn economic inputs into economic output. In an economy, labour input (i.e. the volume and type of hours worked) and capital input (i.e. the services provided by a given volume and quality of capital) are combined in a production process to produce the goods and services that constitute a measure of output (i.e. GDP). On that basis, economic growth can be achieved by either increasing the volume or quality of the inputs, or by improving the efficiency with which those inputs are combined (i.e. multifactor productivity growth). The OECD Productivity Statistics database take a growth accounting approach through which the indicators attempt to understand the sources of growth in an economy, in particular, the contributions from labour, capital and the overall efficiency with which these inputs are used in the production process. In turn, these productivity indicators provide a useful economic yardstick, as productivity growth is considered a key source of economic growth, competitiveness and improvements in living standards.

In the OECD Productivity Statistics Database (PDB) data on output (gross value added) and on inputs (labour and capital) are combined, together with data on relative prices across countries (purchasing power parities (PPPs)), to generate consistent cross-country comparisons of productivity. This document begins with a description of the productivity indicators included in the PDB, providing the formulae underlying the indicators and their decomposition. In the sections that follow, each of hours worked measurement, capital input measurement and the use of PPPs are approached in turn.

2. Productivity measures in the OECD Productivity Statistics Database

The *OECD Productivity Statistics* (database) (PDB) contains a consistent set of productivity measures at both the total economy and the industry level. This section provides detailed information on the indicators included in the database. While the PDB presents value added based productivity indicators by relating gross value added to the labour and capital inputs used, productivity measures can be computed for different representations of the production process. One alternative approach is to relate a volume measure of gross output to primary and intermediate inputs, as used in the KLEMS methodology, which measures the contributions of capital (K), labour (L), energy (E), material inputs (M) and services (S) to output growth (OECD, 2001). This representation is not the one adopted in the PDB and will not be discussed further in this document. For further information, see the Measuring Productivity OECD Manual (OECD, 2001).

Productivity measures for the total economy

Labour input

Within the PDB, the preferred measure of labour input (L) is the total number of hours actually worked by all persons engaged in production (i.e. both employees and self-employed). Another measure of labour input, albeit less preferred, is the total number of persons employed (i.e. both employees and self-employed). The preferred source for total hours worked and total employment is the *OECD National Accounts Statistics* (database). However, this database does not provide data on hours worked for all countries, and, so, other sources are necessarily used, e.g. the *OECD Employment and Labour Market Statistics* (database). Estimates of average hours actually worked per year per person employed are also provided within the PDB (see the Section on hours worked for a detailed account).

Capital input

Capital input (K) is measured as the volume of capital services, which is the appropriate measure for capital input for productivity analysis. In the PDB, capital services measures are based on productive capital stocks derived using the perpetual inventory method (PIM). The PIM calculations are carried out by the OECD, using common assumptions for given assets for all countries (e.g. age-efficiency profile, retirement patterns and average service lives), and by correcting for differences in the national deflators used for information and communication technology (ICT) assets. The investment series by asset type used in the PIM calculations are series of gross fixed capital formation by asset type sourced from national accounts statistics produced by national statistics offices (NSOs). Schreyer, Bignon and Dupont (2003) provide a detailed description of the computation of capital services in the PDB. Schreyer (2002) and Colecchia and Schreyer (2002) provide further information about the calculation of the OECD "harmonised" deflators for the ICT assets.

From 2015, the classification of assets adopted in the PDB is in line with the System of National Accounts 2008 (2008 SNA). Capital services are computed separately for eight non-residential fixed assets $k = 1, 2, \dots, 8$, i.e. computer hardware, telecommunications equipment, transport equipment, other machinery and equipment and weapons systems, non-residential construction, computer software and databases, research and development and other intellectual property products. The volume index of total capital services is computed by aggregating the volume change of capital services of all individual assets using a Törnqvist index that applies asset specific user cost shares as weights:

$$\ln\left(\frac{K^t}{K^{t-1}}\right) = \sum_{k=1}^{8} \frac{1}{2}\left(v_k^t + v_k^{t-1}\right) \ln\left(\frac{K_k^t}{K_k^{t-1}}\right) \qquad (1)$$

where:

$$v_k^t = \left(\frac{u_k^t K_k^t}{\sum_{k=1}^{8} u_k^t K_k^t}\right)$$

and u_k^t is the user cost per unit of capital services provided by asset k at time t (see Schreyer et.al., 2003). Thereby, v_k^t is the user cost share of asset k, $\frac{1}{2}\left(v_k^t + v_k^{t-1}\right) \ln\left(\frac{K_k^t}{K_k^{t-1}}\right)$ is the contribution of asset k, to total capital services in year t and K_k^t is the quantity of capital services provided by asset k in year t.

Therefore, the volume index of total capital services presented above accounts for changes in the volume of capital of different asset types and their relative marginal productivities as captured by their user costs shares. The volume index of capital services can be then represented as the addition of changes in the volume of capital stock and changes in capital composition, where the latter is commonly used a measure of changes in capital quality as it captures changes in the relative marginal productivities of the different assets.

$$\ln\left(\frac{K^t}{K^{t-1}}\right) = \ln\left(\frac{KSTOCK^t}{KSTOCK^{t-1}}\right) + \ln\left(\frac{QK^t}{QK^{t-1}}\right) \qquad (2)$$

Aggregate volume indices of capital services are also computed for ICT assets (computer hardware, telecommunications equipment and computer software and databases) and non-ICT assets (transport equipment, other machinery and equipment and weapons systems, non-residential construction, research and development and other intellectual property products), using the appropriate user costs shares as weights. The aggregate volume indices of ICT and non-ICT capital services are given by:

$$\ln\left(\frac{K_{ict}^t}{K_{ict}^{t-1}}\right) = \sum_{i=1}^{3} \frac{1}{2}\left(\gamma_i^t + \gamma_i^{t-1}\right) \ln\left(\frac{K_i^t}{K_i^{t-1}}\right)$$

where i represents an ICT asset and

$$\gamma_i^t = \left(\frac{u_i^t K_i^t}{\sum_{i=1}^{3} u_i^t K_i^t}\right)$$

$$\ln\left(\frac{K_{nict}^t}{K_{nict}^{t-1}}\right) = \sum_{j=1}^{5} \frac{1}{2}\left(\gamma_j^t + \gamma_j^{t-1}\right) \ln\left(\frac{K_j^t}{K_j^{t-1}}\right)$$

where j represents a non-ICT asset and

$$\gamma_j^t = \left(\frac{u_j^t K_j^t}{\sum_{j=1}^{5} u_j^t K_j^t}\right)$$

Cost shares of labour and capital inputs

The total cost of inputs is the sum of the labour input cost and the total cost of capital services. The national accounts record the income of the self-employed as mixed income. This measure includes the compensation of both labour and capital received by the self-employed but separate estimates of the two components are not generally measurable. As such, in the PDB, total labour input costs for total persons employed (i.e. employees and self-employed) are computed as the average remuneration per employee multiplied by the total number of persons employed. The preferred source for data on compensation of employees and for the number of employees as well as the total number of persons employed is the *OECD National Accounts Statistics* (database).

The labour input cost is calculated as follows:

$$w^t L^t = \left(\frac{COE^t}{EE^t}\right) E^t$$

where $w^t L^t$ reflects the total remuneration for labour input in period t, COE^t is the total compensation of employees in period t, EE^t is the number of employees in period t, and E^t the total number of employed persons, i.e., employees plus self-employed, in period t.

Total capital input cost is computed as the sum of the user costs of each capital asset type k given by $u_k^t K_k^t$, where u_k^t is the user cost per unit of capital services provided by asset type k.

The total cost of inputs is then given by

$$C^t = w^t L^t + \sum_{k=1}^{8} u_k^t K_k^t \qquad (3)$$

and the corresponding cost shares of labour and capital are

$s_L^t \equiv \frac{w^t L^t}{C^t}$ for labour input,

$s_K^t \equiv \frac{\sum_{k=1}^{8} u_k^t K_k^t}{C^t}$ for total capital input,

$s_{K_{ict}}^t \equiv \frac{\sum_{i=1}^{3} u_i^t K_i^t}{C^t}$ for capital input derived from ICT assets i=1,2,3,

$s_{K_{nict}}^t \equiv \frac{\sum_{j=1}^{5} u_j^t K_j^t}{C^t}$ for capital input derived from non-ICT assets j=1,…,5.

Labour productivity

At the total economy level, labour productivity is measured as Gross domestic product (GDP) at market prices per hour worked. However, PDB also presents measures of labour productivity computed as GDP per person employed. For analytical purposes, hours worked-based labour productivity measures are preferred to person-based labour productivity.

Multifactor productivity

The underlying production function assumes "Hicks neutral" technical change (A), as it is represented as an outward shift of the production function that affects all factors of production proportionately:

$$Q = A\,f(L, K)$$

Differentiating this expression with respect to time and using a logarithmic rate of change, multifactor productivity (MFP) growth (the rate of change of the A) is measured as the rate of change of the volume measure of output (Q) minus the weighted rates of change of volumes of inputs (X). In simple terms, growth in MFP can be described as the change in the volume of output that cannot be explained by changes in the quantity of capital and labour inputs used to generate that output. In the PDB, MFP growth is then measured as follows:

$$\ln\left(\frac{MFP^t}{MFP^{t-1}}\right) = \ln\left(\frac{Q^t}{Q^{t-1}}\right) - \ln\left(\frac{X^t}{X^{t-1}}\right) \qquad (4)$$

where Q is output measured as GDP at market prices and at constant prices; X relates to total inputs used and the rate of change of these inputs is calculated as a weighted average of the rate of change of the volume of labour and capital inputs, with their respective cost shares as weights. Aggregation of these inputs is by way of the Törnqvist index:

$$ln\left(\frac{X^t}{X^{t-1}}\right) = \frac{1}{2}\,(s_L^t + s_L^{t-1})\,ln\left(\frac{L^t}{L^{t-1}}\right) + \frac{1}{2}\,(s_K^t + s_K^{t-1})\,ln\left(\frac{K^t}{K^{t-1}}\right) \qquad (5)$$

Contributions to GDP growth

In the growth accounting framework, GDP growth can be decomposed into the contributions of each production factor plus MFP:

$$\ln\left(\frac{Q^t}{Q^{t-1}}\right) = \frac{1}{2}\,(s_L^t + s_L^{t-1})\ln\left(\frac{L^t}{L^{t-1}}\right) + \frac{1}{2}\,\left(s_{K_{ict}}^t + s_{K_{ict}}^{t-1}\right)\ln\left(\frac{K_{ict}^t}{K_{ict}^{t-1}}\right) + \frac{1}{2}\,\left(s_{K_{nict}}^t + s_{K_{nict}}^{t-1}\right)\ln\left(\frac{K_{nict}^t}{K_{nict}^{t-1}}\right) + \ln\left(\frac{MFP^t}{MFP^{t-1}}\right) \qquad (6)$$

where:

$\frac{1}{2}(s_L^t + s_L^{t-1})\ln\left(\frac{L^t}{L^{t-1}}\right)$ is the contribution of labour input to GDP growth,

$\frac{1}{2}\left(s_{K_{ict}}^t + s_{K_{ict}}^{t-1}\right)\ln\left(\frac{K_{ict}^t}{K_{ict}^{t-1}}\right)$ is the contribution of ICT capital input to GDP growth,

$\frac{1}{2}\left(s_{K_{nict}}^t + s_{K_{nict}}^{t-1}\right)\ln\left(\frac{K_{nict}^t}{K_{nict}^{t-1}}\right)$ is the contribution of non-ICT capital input to GDP growth,

$\ln\left(\frac{MFP^t}{MFP^{t-1}}\right)$ is the contribution of MFP to GDP growth, which in this representation equals MFP growth.

It is also possible to reformulate this decomposition to account for the contribution of changes in the volume of productive capital stock and changes in capital composition (or capital quality). Equation (6) above can be also represented as:

$$\ln\left(\frac{Q^t}{Q^{t-1}}\right) = \frac{1}{2}\left(s_L^t + s_L^{t-1}\right)\ln\left(\frac{L^t}{L^{t-1}}\right) + \frac{1}{2}\left(s_K^t + s_K^{t-1}\right)\ln\left(\frac{K^t}{K^{t-1}}\right) + \ln\left(\frac{MFP^t}{MFP^{t-1}}\right) \quad (7)$$

Bringing equation (2) into equation (7):

$$\ln\left(\frac{Q^t}{Q^{t-1}}\right) = \frac{1}{2}\left(s_L^t + s_L^{t-1}\right)\ln\left(\frac{L^t}{L^{t-1}}\right) + \frac{1}{2}\left(s_K^t + s_K^{t-1}\right)\ln\left(\frac{KSTOCK^t}{KSTOCK^{t-1}}\right) + \frac{1}{2}\left(s_K^t + s_K^{t-1}\right)\ln\left(\frac{QK^t}{QK^{t-1}}\right) + \ln\left(\frac{MFP^t}{MFP^{t-1}}\right) \quad (8)$$

Contributions to labour productivity growth

By reformulating the decomposition of output (GDP) growth presented above, it is possible to decompose labour productivity growth (LP) into the contribution of capital deepening and MFP. Capital deepening is defined from the concept of capital intensity. Capital intensity in PDB is defined as capital services per hour worked (i.e. capital input per unit of labour input), and represents the extent to which capital is used as compared with labour. Capital deepening is then defined as changes in capital intensity, i.e. changes in the ratio of capital services per unit of hour worked.

$$\ln\left(\frac{LP^t}{LP^{t-1}}\right) = \frac{1}{2}\left(s_K^t + s_K^{t-1}\right)\left[\ln\left(\frac{K^t}{K^{t-1}}\right) - \ln\left(\frac{L^t}{L^{t-1}}\right)\right] + \ln\left(\frac{MFP^t}{MFP^{t-1}}\right) \quad (9)$$

where:

$\ln\left(\frac{LP^t}{LP^{t-1}}\right) = \ln\left(\frac{Q^t}{Q^{t-1}}\right) - \ln\left(\frac{L^t}{L^{t-1}}\right)$ is labour productivity growth,

$\ln\left(\frac{K^t}{K^{t-1}}\right) - \ln\left(\frac{L^t}{L^{t-1}}\right)$ is capital deepening (i.e. growth in capital services per hour worked),

$\frac{1}{2}\left(s_K^t + s_K^{t-1}\right)\left[\ln\left(\frac{K^t}{K^{t-1}}\right) - \ln\left(\frac{L^t}{L^{t-1}}\right)\right]$ is the contribution of capital deepening to labour productivity growth,

$\ln\left(\frac{MFP^t}{MFP^{t-1}}\right)$ is the contribution of MFP growth to labour productivity growth.

It is also possible to reformulate the decomposition of labour productivity growth to show the contributions of ICT capital and non-ICT capital:

$$\ln\left(\frac{LP^t}{LP^{t-1}}\right) = \frac{1}{2}\left(s_{K_{ict}}^t + s_{K_{ict}}^{t-1}\right)\left[\ln\left(\frac{K_{ict}^t}{K_{ict}^{t-1}}\right) - \ln\left(\frac{L^t}{L^{t-1}}\right)\right] + \frac{1}{2}\left(s_{K_{nict}}^t + s_{K_{nict}}^{t-1}\right)\left[\ln\left(\frac{K_{nict}^t}{K_{nict}^{t-1}}\right) - \ln\left(\frac{L^t}{L^{t-1}}\right)\right] + \ln\left(\frac{MFP^t}{MFP^{t-1}}\right) \quad (10)$$

where:

$\frac{1}{2}\left(s_{K_{ict}}^{t} + s_{K_{ict}}^{t-1}\right)\left[\ln\left(\frac{K_{ict}^{t}}{K_{ict}^{t-1}}\right) - \ln\left(\frac{L^{t}}{L^{t-1}}\right)\right]$ is the contribution of ICT capital deepening to labour productivity growth,

$\frac{1}{2}\left(s_{K_{nict}}^{t} + s_{K_{nict}}^{t-1}\right)\left[\ln\left(\frac{K_{nict}^{t}}{K_{nict}^{t-1}}\right) - \ln\left(\frac{L^{t}}{L^{t-1}}\right)\right]$ is the contribution of non-ICT capital deepening to labour productivity growth.

A final decomposition highlights the link between labour productivity and changes in the capital stock-to-output ratio K/Y and changes in capital composition (i.e. capital quality). By adding and subtracting $s_{K}^{t}\ln\left(\frac{Q^{t}}{Q^{t-1}}\right)$ from the right side of equation (9), growth in labour productivity can be reformulated as:

$$\ln\left(\frac{LP^{t}}{LP^{t-1}}\right) = \frac{1}{\frac{1}{2}\left(s_{L}^{t} + s_{L}^{t-1}\right)}\ln\left(\frac{MFP^{t}}{MFP^{t-1}}\right) + \frac{\frac{1}{2}\left(s_{k}^{t} + s_{k}^{t-1}\right)}{\frac{1}{2}\left(s_{L}^{t} + s_{L}^{t-1}\right)}\left(\ln\left(\frac{KSTOCK^{t}}{KSTOCK^{t-1}}\right) - \ln\left(\frac{Q^{t}}{Q^{t-1}}\right)\right) + \frac{\frac{1}{2}\left(s_{k}^{t} + s_{k}^{t-1}\right)}{\frac{1}{2}\left(s_{L}^{t} + s_{L}^{t-1}\right)}\ln\left(\frac{QK^{t}}{QK^{t-1}}\right) \qquad (11)$$

where:

$\frac{1}{\frac{1}{2}\left(s_{L}^{t}+ s_{L}^{t-1}\right)}\ln\left(\frac{MFP^{t}}{MFP^{t-1}}\right)$ is the contribution of MFP to labour productivity growth. Note that the contribution of MFP to growth in labour productivity is not anymore equal to growth in MFP as in the current growth accounts for LP.

$\frac{\frac{1}{2}\left(s_{k}^{t}+ s_{k}^{t-1}\right)}{\frac{1}{2}\left(s_{L}^{t}+ s_{L}^{t-1}\right)}\ln\left(\ln\left(\frac{KSTOCK^{t}}{KSTOCK^{t-1}}\right) - \ln\left(\frac{Q^{t}}{Q^{t-1}}\right)\right)$ is the contribution of the capital-output ratio to labour productivity growth.

$\frac{\frac{1}{2}\left(s_{k}^{t}+ s_{k}^{t-1}\right)}{\frac{1}{2}\left(s_{L}^{t}+ s_{L}^{t-1}\right)}\ln\left(\frac{QK^{t}}{QK^{t-1}}\right)$ is the contribution of capital quality to labour productivity growth.

Unit labour costs and their components

Unit labour costs (ULCs) measure the average cost of labour per unit of output produced. They are calculated as the ratio of total labour costs (in national currency, current prices) to real output (in national currency, constant prices). At the total economy level, real output is measured as GDP at market prices and constant prices. Equivalently, ULCs may be expressed as the ratio of total labour costs per hour worked in current prices to real GDP per hour worked in constant prices, i.e., labour productivity.

In principle, the appropriate numerator for ULC calculations is total labour costs of all persons engaged. In practice, however, this information is not readily available for most countries. As such, OECD total labour cost estimates used in calculating ULCs are based on adjusted estimates of compensation of employees (COE), compiled according to the 2008 SNA.

Compensation of employees as defined in the SNA excludes labour compensation for the self-employed which is covered in the item *mixed income*. Estimates of the component of mixed income are set equal to compensation of employees per hour worked by employees. This assumption may be more or less valid across different countries and industries.

Unit labour costs are therefore compiled as follows:

$$\frac{COE^t \frac{H^t}{HE^t}}{Q^t}$$

where COE^t reflects the total compensation of employees in period t, H^t is the total number of hours worked by all persons employed in period t, HE^t is the total number of hours worked by employees in period t and Q^t is GDP at market prices and constant prices in period t.

Productivity measures at industry level

The conceptual approach used to estimate productivity at industry level follows that for the total economy. However the same quantity and quality of data that are available for the whole economy estimates are not always available at the detailed industry level. Therefore, some approximations are necessary and, so, some differences may prevail between the whole economy estimates and those produced at industry level.

In PDB, productivity measures at industry level are computed for 14 economic activities, each defined in accordance with the International Standard Industrial Classification of All Economic Activities (ISIC) Rev.4.

Labour input

Labour input is measured as total hours worked by all persons engaged in production, i.e. employees plus self-employed, broken down by industry. Another measure of labour input presented in PDB is total number of persons employed (i.e. number of employees and numbers of self-employed).

Labour productivity

At the industry level, labour productivity is measured as gross value added at basic prices per hour worked and growth rates are determined using constant price estimates of gross value added. The PDB also present measures of labour productivity by industry derived as gross value added at basic prices per person employed. For analytical purposes, hours worked-based labour productivity measures should be preferred to person-based labour productivity.

Contributions to labour productivity growth

The contribution of an economic activity to hours worked-based labour productivity growth of a group of economic activities (e.g. total business sector, total business services) is compiled using a Törnqvist index as follows:

$$Cont(i,t) = \frac{1}{2}\left[\left(\frac{Q_{cur,i,t}}{Q_{cur,tot,t}} + \frac{Q_{cur,i,t-1}}{Q_{cur,tot,t-1}}\right)\theta_t(Q_{con,i}) - \left(\frac{L_{i,t}}{L_{tot,t}} + \frac{L_{i,t-1}}{L_{tot,t-1}}\right)\theta_t(L_i)\right]$$

where:

i is an economic activity,

tot is an aggregate of economic activities including economic activity i,

$Qcur$ is gross value added at current prices,

$Qcon$ is gross value added at constant prices,

L is the number of hours worked,

$\theta_t(x)$ is the annual growth rate of x between time $t-1$ and t.

The database also presents contributions to labour productivity growth by economic activity on an employment (persons) basis.

Unit labour costs and their components

Unit labour costs (ULCs) measure the average cost of labour per unit of output produced. They are calculated as the ratio of total labour costs (in national currency, current prices) to real output (in national currency, constant prices). For main economic activities, real output is measured as gross value added at basic prices and constant prices. Equivalently, ULCs may be expressed as the ratio of total labour costs per hour worked in current prices to real gross value added per hour worked, i.e. labour productivity.

Total labour costs used for the calculations of ULCs by economic activity are computed as described above for the total economy. ULCs by economic activity are compiled as follows:

$$\frac{COE^{i,t}\,\dfrac{H^{i,t}}{HE^{i,t}}}{Q^{i,t}}$$

where i reflects the economic activity, COE^t reflects the total compensation of employees in period t, $H^{i,t}$ is the total number of hours worked by all persons employed in industry i in period t, $H^{i,t}$ is the total number of hours worked by employees in industry i in period t and $Q^{i,t}$ is gross value added at basic and constant prices of industry i in period t. The database presents ULCs by economic activity on an employment (persons) basis.

3. Measuring hours worked

Definitions

In the national accounts framework, for the purposes of productivity measurement, labour input is most appropriately measured as the total number of hours actually worked by all persons engaged in production (2008 SNA, para 19.47). It is instructive to consider the relationship between this concept and related measures of working time (see also Table 1):

- *Hours actually worked* – the hours actually spent on productive activities;
- *Hours usually worked* – the typical hours worked during a short reference period such as a week over a longer observation period;
- *Hours paid* – the hours worked for which remuneration is paid;
- *Contractual hours of work* – the number of hours that individuals are expected to work based on work contracts;
- *Overtime hours of work* – the hours actually worked in excess of contractual hours; and
- *Absence from work hours* – the hours that persons are expected to work but do not work.

Table 1. Relationship between different concepts of hours worked

Overtime hours of work				Hours concept	Absences from work			
Irregular overtime		Regular overtime			Irregular absence		Regular absence	
Unpaid	Paid	Paid	Unpaid		Unpaid	Paid	Paid	Unpaid
				Contractual hours				
				Hours actually worked				
				Hours usually worked				
				Hours paid for				

Note: Establishing the relationship between normal hours and the five other concepts is not possible, as normal hours are established on a case-by-case basis.

Source: ILO (2008), Measurement of working time, 18th ICLS.

Because productivity analysis relates the inputs used in producing a given output, the underlying concept for labour input should include all hours used in the production of that output, whether paid or not, and so should exclude those hours not used in production, even if some compensation is received for those hours. As such the relevant concept for measuring labour input is *hours actually worked*. The productive or non-productive characteristic of an activity is determined by its inclusion in, or exclusion from, the System of National Accounts (SNA) production boundary. *Hours actually worked* are defined as by the International Labour Organisation (ILO, 2008) and the 2008 SNA in same way:

- the hours spent directly on productive activities or in activities in relation to them (maintenance time, cleaning time, training time, waiting time, time spent on call duty, travelling time between work locations);

- the time spent in between these hours when the person continues to be available for work (for reasons that are either inherent to the job or due to temporary interruptions); and
- short resting time.

Conversely, *hours actually worked* should exclude:

- annual leave and public holidays;
- longer breaks from work (e.g. meal breaks);
- commuting time (when no productive activity is performed); and
- educational activities other than on-the-job training time.

Data sources

The majority of countries use multiple sources to compile estimates of average hours worked per person, in particular for employees, often using *labour force surveys* as a main or secondary source in combination with other main and/or secondary data sources, such as *population census*, *business* statistics and *administrative records* (Ward, Marianna and Zinni, 2018).

- *Labour force survey*: The labour force survey (LFS) is the most comprehensive and well-established source for information on the composition and characteristics of the labour force. LFS include questions on the number of hours actually and usually worked in the reference period, i.e. questions concerning the differences between the time usually spent working and the time actually worked during the reference week. Additional LFS questions concerning working time components such as hours worked at home, commuting time, short breaks, overtime and absences from work are also often available. International harmonisation is achieved by complying with definitions set out by the International Labour Organisation (ILO, 1982 and 2013), although sample selection, survey techniques, survey responses and the implementation of ILO concepts may vary between countries. An advantage of the LFS is that it covers a broad range of employment situations, including the self-employed, unpaid family workers and informal employment, as well as collecting information on multiple-job holdings, hours usually and actually worked, and paid and unpaid overtime. Its main limitation from the perspective of national accounting, and hence, productivity analysis, is the often limited consistency with output and value-added measures, in particular, by industry, as the LFS is a household survey for which the stratification process may not adequately capture the homogenous strata required in productivity analysis. In addition, in many countries, the LFS does not cover some groups of the population such as persons below or above certain age thresholds (which varies by country), those living and working in communal establishments (such as prisons or long-term care facilities), collective households (such as religious institutions) and the armed forces, all of whose output is included, at least in theory, in estimates of GDP. In addition, the sampling structure of LFS is based on the population usually residing in the country and includes workers in non-resident production units, whereas non-resident cross-border workers working in resident production units are excluded. There may also be biases in LFS responses, reflecting the self-reporting nature of LFS, and these biases, that may also be cultural, appear to be significant with respect to responses on hours actually worked.

- *Population census*: The population census (PC) is a comprehensive source covering the whole population of a country, making it a useful tool to benchmark household surveys, including the LFS. The main disadvantages are the low frequency of data collection, which is typically carried out every five or ten years, and the possibility that unregistered migrants may not be captured.
- *Business statistics*: Business statistics (BS) include establishment and/or enterprise surveys, business census, and dedicated labour cost surveys. Another important data source is the statistical business register (SBR) which is typically sourced from multiple primary data sources, including business surveys and a variety of administrative data. BS typically provide detailed data on employment and hours worked following a detailed industrial classification of firms that is generally consistent with their classification in national accounts output and value-added data – indeed structural business statistics are an important input to, and building block for, the national accounts. One of the main limitations of BS, however, is that they sometimes exclude establishments or enterprises below a certain employment or turnover threshold and certain categories of firms, such as unincorporated businesses, self-employed persons and informal labour. A further limitation of some business statistics, such as dedicated labour cost surveys, is that they often provide information on hours paid or contractual hours only, and not information on absences from work and unpaid overtime, and, so, do not align with the concept of hours actually worked required to measure labour input in productivity analysis.
- *Administrative data sources*: Administrative data sources (AS) are typically collected by government bodies – but also increasingly by private data providers (e.g. associations for specific groups) – based on some form of statutory or voluntary registration. For example, statistics from social security institutions and tax administrations can provide information on all persons required to pay income tax or social insurance contributions. Social security records, tax registers, compulsory business registration systems, resident permit registers, migration statistics, and statistics on the armed forces, are the administrative sources most commonly used by countries in compiling estimates of labour input. AS may include information on wages, entrepreneurial income, taxes, etc. as well as a series of demographic variables describing age, gender, and family ties. The main advantage of AS is that they are generally comprehensive, at least with regards to the population that they purport to cover, and do not entail additional collection costs to the national statistical offices (NSOs) as compared to surveys. Like BS however, AS often struggle to capture informal labour.
- *Other sources*: Statistical offices may use other complementary sources to estimate labour input that do not fall neatly into any of the above categories. Among others these can include time-use surveys, surveys on households' living conditions, tourism surveys, and surveys of insurance companies.

Table 2 summarises the main strengths and limitations of the primary sources typically used to compute hours worked and employment estimates in national accounts.

Table 2. Primary sources used to compute national accounts estimates of hours worked and employment

Primary data source	Main strengths	Main limitations
Labour force survey	• Covers employees, self-employed, unpaid family workers, government and NPISH workers • Includes information on the characteristics of employment: age, gender, education, industry, occupation • Provides information on hours actually worked • Harmonised concepts across countries (ILO concepts) • Typically counts the number of persons	• It is a household survey and so may have limited consistency with output and value added measures collected in business surveys, especially by industry • Concept of employment typically not be in line with the resident (domestic) concept in national accounts • There may be reporting biases in reported hours worked • Excludes people living in collective households, although this is unlikely to significantly affect numbers of persons employed
Business statistics (establishment surveys, business census, labour cost surveys)	• Information consistent with output data • Covers production units operating in the territory: domestic concept of employment	• Typically excludes information on agriculture and government sectors - although these are covered in comparable surveys • May exclude small enterprises below a certain employment or turnover threshold and certain categories of firms, such as unincorporated, self-employed and informal. • Information on hours paid or contractual hours, excludes absences and unpaid overtime • Not necessarily harmonised across countries, although when presented as structural business statistics comparability is generally improved
Population census	• Can be used as a benchmark	• Low frequency of data collection (typically every 10 years)
Administrative sources (e.g. social security registers, tax registers)	• To complement data on employment and labour income/compensation	• There is often restricted access (micro data) • Difficult to capture the informal economy
Time use surveys	• To complement and compare data on hours worked	• Low frequency data • Limited international comparability

Source: OECD elaboration, updated in May 2021.

For the purposes of productivity analysis, consistency of total hours worked with national accounts concepts needs to be ensured (OECD, 2009; Ward et al., 2018). This implies adjusting the coverage of activities covered by the labour input measures to those covered in GDP, i.e. adapting the geographical and economic boundaries of employment and hours worked to the national accounts production boundary. The notion of economic territory used to compute GDP refers to the domestic concept, so that when compiling labour input measures, resident persons working non-resident units should be excluded while non-resident persons working in resident-units should be included.

Methods

In essence, there are two main approaches to compute estimates of total hours actually worked:

- The *direct method*, which consists of annualising average actual weekly hours worked derived from continuous surveys in all weeks of the calendar year (i.e. multiplying the number of self-reported actual hours worked in the reference week by the number of working weeks in a year). This method often relies on a single source, generally the LFS, and assumes that full- and part-week absences and extra hours worked in the main and/or additional job/s are well captured in self-reported actual hours worked averaged over the year.

- The *component method*, which starts from estimates of contractual, paid or usual hours per week from establishment surveys, administrative sources or, indeed, the LFS, with adjustments for absences (holidays, sickness, maternity leave, etc.) and (paid and/or unpaid) overtime. This is an indirect approach, as its starting point is not the target concept (hours actually worked) and, rather, requires a series of explicit adjustments (i.e. accounting for each component) to align with the concept, which is why it is often referred to as the component method.

For labour force surveys with fixed monthly reference weeks (i.e. where the survey is not conducted continuously in all weeks of the month or the quarter but in a given week of the month), the direct method consists of averaging hours worked during those 12 reference weeks after applying adjustments for special events, such as holidays, falling outside each reference week. This is the method applied, for example, in Australia and Canada. As discussed in Ward et al. (2018), this is a *direct method with adjustments* that resembles a component approach, as it corrects for annual leave and public holidays, which are the most important reasons for work absences, followed by sickness leave, and the most important reason, after differences in usual hours, to explain cross-country differences in annual working time.

Hours worked in the OECD Productivity Statistics (database)

In the PDB, the main requirement is that the most internationally comparable hours worked data are used (OECD, 2007). The preferred source for total hours worked is countries national accounts, which are presented in the *OECD National Accounts Statistics* (database), both for the total economy and for aggregate economic activities. However, long time series of hours worked are not available for a number of countries; in which case, the Secretariat estimates hours worked using the *OECD Employment and Labour Market Statistics* (database). Total economy estimates of average hours actually worked per year and per person employed are currently available on an annual basis, for 36 OECD member countries and some key partner economies as follows:

- Actual hours worked are primarily sourced from the *OECD National Accounts Statistics* (database) for Australia, Belgium, Canada, Costa Rica, the Czech Republic, Denmark, France, Germany, Hungary, Iceland, Ireland, Israel, Italy, Korea, Luxembourg, Mexico, the Netherlands, Norway, the Slovak Republic, Slovenia, South Africa, Spain, Switzerland, and the United States.
- Actual hours worked are sourced from the *OECD Employment and Labour Market Statistics* (database) for Chile, Japan, New Zealand, the Russian Federation and Turkey.
- Since January 2019, actual hours worked for Austria, Estonia, Finland, Greece, Latvia, Lithuania, Poland, Portugal, Sweden and the United Kingdom are estimated by the OECD Secretariat applying a simplified component method on EU LFS data, as described and following the recommendations in Ward et al. (2018). This working paper presents compelling evidence that average hours actually worked derived from a direct method without any adjustment come with a systematic upward bias, in large part due to self-reporting and recall issues, affecting international comparisons of labour input or productivity.

- For some countries, longer time series and/or more recent estimates of total hours worked are derived using the *OECD Economic Outlook: Statistics and Projections* (database), the *OECD Main Economic Indicators* (database) and national sources.

Measuring capital

Definitions

The measurement of capital stocks is key to both the national accounts and productivity measurement (OECD, 2009). Capital stocks feature at two key points in the national accounts: as part of the compilation of balance sheets, and as a tool to derive estimates of depreciation/consumption of fixed capital (CFC). Capital stocks are also a core component in the productivity measurement framework, constituting an input into the construction of capital services, which in turn enter into the growth accounting framework as a measure of capital input and therefore in the estimation of multifactor productivity (MFP). Capital stocks, therefore, have a dual nature, both as a storage of wealth as presented in balance sheets, and as a source of capital services in the analyses of production and productivity. As shown in Table 3, the former are referred to as *net wealth capital stocks* and the latter as *productive capital stocks*.

Given the practical issues surrounding the use of company and business surveys to measure the stock of capital assets, the most widely used method across NSOs for the measurement of capital stocks is the direct application of the *Perpetual Inventory Method* (PIM). The PIM allows for the estimation of the net wealth and productive capital stocks from the associated investment flows. It does this by accumulating past purchases of capital assets (i.e. gross fixed capital formation - GFCF), adjusted for retirement, and using an age-price profile (i.e. adjustments for losses in the market value, when the aim is to estimate the net wealth stock), or an age-efficiency profile (adjusting for losses in the productive capacity or efficiency of the assets, when the aim is to estimate productive capital stocks).

This section first defines the two concepts of capital and described the information required for their compilation. It then focuses on the most important capital concept in the context of productivity analysis: the measurement of capital services.

Table 3. Two concepts of capital

	Income and wealth perspective	Production and productivity perspective
Basic flow	Investment	Investment
Aggregation across assets of different age based on	Depreciation profile (age-price profile)	Age-efficiency profile
Resulting stock for each class of assets	Net capital stock by asset type	Productive capital stock by asset type
Derived flow	Depreciation (consumption of fixed capital)	Capital services by type of asset
Aggregation across different classes of assets based on	Market prices	Price of capital services (user cost of capital)
Resulting stocks	Total net capital stock	Productive stock for each type of asset
Derived measures	Balance sheet entry, national wealth, net measures of income	Capital services

Source: Adapted from Measuring Capital OECD Manual: Second Edition (OECD, 2009).

Net and gross wealth capital stocks

Perhaps the best known measure of capital stock is that used to value assets on a company, industry or nation's balance sheets, that is, the gross and net (wealth) capital stock measures described in the 2008 SNA. This concept of capital stock relates with the capacity of capital goods to act as a storage of value or wealth, and as such it is not conceptually appropriate for productivity analysis. The stock of assets surviving from past periods constitute the gross wealth capital stock. The stock of assets surviving from past periods and corrected for depreciation (i.e. corrected for both retirement and losses in assets' market value due to ageing), constitute the net wealth capital stock. The gross and net wealth capital stocks are valued as if the capital goods (used or new) were acquired on the date to which a balance sheet relates, and, as such, they are designed to reflect the wealth of the owner of the assets at a particular point in time.

Unlike the productive capital stock, the purpose of wealth capital stocks measures is not to track the role of capital as a factor of production but to track the role of capital as a set of assets with market value – the gross and net wealth capital stocks appear on the balance sheets in the SNA. This reflects the fact that the implicit weighting for the different assets used in building up wealth measures of total capital stock is based on the market prices of the different assets. However changes in the relative productivity of the different assets are not necessarily consistent with changes in the relative market price of the assets. As explained below, for productivity analysis it is the former measure (and weighting of different asset types) that is relevant.

Productive capital stock

The concept of productive capital stock relates to the capacity of capital goods to be used as a factor input in the production process. To better understand this, one can conceive that for any given type of asset (e.g. trucks, computers, R&D) there is a flow of productive services drawn from the cumulative stock of past investments (i.e. capital services). Indeed, the *productive capital stock* is estimated as the cumulative sum of past investment volumes, adjusted for retirement and losses in efficiency or productive capacity (as opposed to losses in the market value of an asset as assumed in the measurement of net wealth capital stocks). It is therefore necessary to apply a retirement pattern and an age-efficiency profile when cumulating volumes of past investments of each asset over time. For example, a 10-year old lorry should be given a lower weight compared with a new lorry when past purchases of lorries are added up to construct a measure of today's productive stock of lorries. Moreover, lorries are scrapped after a certain number of years and investments that date back by say 30 years would not enter today's productive stock. Unlike gross or net wealth capital stock measures, aggregate measures of productive capital stock weigh different types of assets by their relative productivity using the user costs of each capital asset type. The resulting aggregate constitutes a measure for the potential flow of productive services that all fixed assets can deliver in production, i.e. capital services.

Measuring capital input for productivity analysis: capital services

Estimates of capital services in the PDB are based on a common computation method for all countries (Schreyer et al., 2003). This approach estimates *productive capital stocks* and *capital services* for different asset types for all countries applying the same assumptions (age-efficiency function, retirement profile, average service life) for any given asset irrespective of the country. From 2015, the classification of assets adopted in the PDB is in line with the 2008 SNA asset boundary, with the exception of dwellings, which are currently excluded from the productive capital stocks and capital services estimation in PDB.

In the PDB, the assumptions underlying the estimation of *productive capital stocks* are as follows (Schreyer et al., 2013):

- hyperbolic age-efficiency profile for all assets, assuming a beta coefficient of 0.75 for non-residential construction and 0.5 for all other asset types
- a retirement profile represented by a normal distribution with a standard deviation of 25% around the average service life of the asset; the distribution is truncated at an assumed maximum service life of 1.5 times the average service life.
- average service lives are currently assumed for the different asset types: 7 years for computer hardware, 15 years for telecommunications equipment, other machinery and equipment and weapons systems and transport equipment, 40 years for non-residential construction, 3 years for computer software and databases, 10 years for research and development and 7 years for other intellectual property products.

The approach further uses harmonised deflators for investment in computer hardware, telecommunications equipment and computer software and databases (i.e. ICT assets), for all countries, to sort out comparability problems that exist in national practices for deflation for this group of assets (Schreyer, 2002; Colecchia and Schreyer, 2002).

Estimated the productive capital stocks by asset type, one can proceed to estimate the growth in capital services from each asset type and construct a volume index of total capital services (i.e. growth rate of total capital services). Conceptually, capital services reflect a “quantity” or “physical concept”, not to be confused with the market value (or wealth concept) of capital. To illustrate this, take the example of a taxi. The capital services provided by the taxi relate to the number of trips, distance driven, and comfort of the taxi, rather than the market value of the vehicle, which would instead relate to the net wealth capital stock concept. As a result, the price of the capital services that the vehicle provides to the taxi owner when used in the production of transport services differs from the market value of the vehicle. The measurement of the price of capital services, i.e. the user cost of capital, is the core difference between aggregate measures of net wealth stocks and capital services.

The methodology underlying aggregate measures of capital services relies on the work of Jorgenson (1963) and Jorgenson and Griliches (1967). In their framework, the volume of capital services provided by a given asset is assumed to be proportional to the asset’s productive capital stock. With a time-invariant proportionality factor, at the individual asset level, the growth rate of the asset’s capital services is equal to growth rate of the asset’s productive capital stock. The next step towards the construction of total capital services is to aggregate across different asset types (and industries). The aggregation process relies on the construction of asset-specific weights.

As explained above, the aggregation of net wealth capital stocks across asset types (and industries) is based on the market value of each asset. In contrast, an aggregate measure of capital services is computed by aggregating the volume change of capital services of all individual assets using asset-specific user cost shares as weights. Ideally, statisticians would use observed rental prices of capital goods, i.e. the price paid in the market to use the capital good for one period. In practice, most capital goods are owned by their users and rental transactions are not observed. In such cases, rental prices have to be imputed as the implicit rent that capital goods’ owners “pay” to themselves. This implicit rent is estimated as the *user cost of capital*.

The user cost of capital is the minimum price at which the owner of the capital good would be willing to rent the asset during one period of time. It corresponds to a fraction of the purchase price of a new asset where the percentage share is computed as the sum of three components. The first component is a nominal rate of return representing the opportunity cost of the financial capital tied up to the asset. The choice of the nominal rate of return is an important decision in the construction of user costs (see chapter 8 of the Measuring Capital OECD Manual; OECD, 2009). The second component is the depreciation rate of a new asset. It is derived from the combined age-price/retirement profile of the asset. The third component is the expected change in the price of the asset during the period where it is used as a factor of production. This reinforces the need for an accurate measurement of changes in asset prices, which is particularly challenging for ICT assets. Further details about the construction of user costs of capital are available in OECD (2009).

In PDB, the user cost of capital of asset i at time t is estimated as follows:

$$u_{it} = p_{it-1} * (r_t + \delta_{it} - \zeta_{it})$$

where u_{it} is the user cost of one unit of asset i in period t, p_{it-1} is the purchase price of asset i at time $t-1$, r_t is the expected nominal rate of return (ENRR), ζ_{it} is the expected rate of change of the asset price, and δ_{it} is the depreciation rate of a new asset i.

In PDB, the ENRR is currently computed as $(1 + r) * (1 + \Delta CPI_t) - 1$, following Diewert (2001) (page 15), the annex 1 in Schreyer et al. (2003), and Schreyer (2010) (page 33), where r is the constant (time-invariant) real interest rate and ΔCPI_t stands for the 5-year centred moving average of changes in the national Consumer Price Index (CPI). The asset-specific depreciation rate δ_{it} is derived from the combined age-efficiency/retirement profile of the asset. The expected rate of change of the asset price ζ_{it} is estimated as the 5-year centred moving average of change in the price of the asset.

With the estimates of the productive capital stocks and the user costs for the different asset types, the growth rate in the aggregate volume of capital services is obtained through a Törnqvist index:

$$\ln\left(\frac{K_t}{K_{t-1}}\right) = \sum_i \frac{1}{2}(v_{it} + v_{it-1})\ln\left(\frac{K_{it}}{K_{it-1}}\right)$$

where $v_{it} = \frac{u_{it}K_{it}}{\sum_i u_{it}K_{it}}$ and u_{it} is the user cost of capital of asset i in period t.[1]

The user costs of capital capture the heterogeneity in the productive capacity of capital goods. This constitutes a major difference with the market prices (market values) of capital goods considered in wealth measures of capital. To illustrate this, one can take the example of short-lived capital assets such as computer hardware. This type of asset typically presents high depreciation rates and a rapid decline in the asset price over time. These will contribute to raise the asset's user cost and the associated user costs' shares relative to their market value shares. Therefore, if the composition of investment shifts towards short-lived assets over time (typically ICT and intellectual property assets),

[1] This is based on the assumption that $K_{it} = \lambda_i * KSTOCK_{it}$ where K_{it} is the flow of capital services of asset i in period t, $KSTOCK_{it}$ is the corresponding productive capital stock, and λ_i is a time-invariant proportionality factor. In this case, the growth rates of capital services and the productive capital stock are equal for each asset: $\frac{dlnK_{it}}{dt} = \frac{dlnKSTOCK_{it}}{dt}$. In practice, the proportionality factor λ_i is set equal to 1.

the aggregate measure of capital services grows faster than the aggregate measures of net wealth capital stocks.

Cross-country productivity comparisons

Definition

In order to compile internationally comparable estimates of productivity, it is necessary to find a way of converting GDP and gross value added measures in national currencies to a comparable base. The tool used to perform this function in the PDB, as in other similar measurement efforts, is the purchasing power parities (PPPs). PPPs are the rates of currency conversion that equalise the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, PPPs are price relatives, which show the ratio of the prices in national currencies of the same good or service in different countries. In this sense, they are spatial price comparisons.

Levels of GDP in a given year, when converted with PPPs, measure the size of economies in volume terms and so provide a more meaningful measure of the relative size of countries than simple exchange rate based comparisons. Indeed, exchange rates reflect so many more influences than the direct price comparisons that are required to make volume comparisons. Furthermore, they tend to exhibit large movements over short periods of time, implying rapid changes in living standards which cannot have possibly occurred.

PPPs produced at the OECD are intended for whole economy cross-country comparisons of GDP and consumption across countries. They are derived through a collection of prices of final demand components and, as such, while they provide a sound basis for whole economy comparisons, they should not be used for cross-country comparisons across industries, especially for economic activities whose prices are determined internationally.

GDP and its components, converted using PPPs, provide a snapshot of relative volumes in a particular year. For many analytical purposes, the interest is in the evolution of GDP volumes between countries and over time. There are at least two ways of setting up such a comparison, each with its specific interpretation and use.

Current PPPs and expenditures (comparison at current international prices)

One approach for combining spatial and temporal observations is to use a sequence of current PPPs, i.e. a new set of price data for every period, compiled, weighted and aggregated to yield rates of currency conversion for total GDP and its expenditure components. With current PPPs, prices and price structures are allowed to vary over time. Volume levels of GDP are then obtained by applying these current PPPs, for every period, to GDP measures at current national prices. For a given year, (spatial) comparisons between countries are straightforward – volumes are measured with the same price structure. Comparisons of the resulting series over time, however, incorporate several effects: relative volume changes, changes in relative prices between countries and, possibly, changes in definitions and methodologies. The approach can also be described as comparisons at *current international prices or current PPPs*.

Constant PPPs and expenditures (comparison at constant international prices)

A second approach is to generate time series at constant prices and constant PPPs. With constant PPPs, a single year is chosen for the comparison of GDP levels and all other observations are obtained by applying relative rates of GDP growth, consistent with those derived in national currencies. This procedure ensures transitivity over space and time. The approach can also be described as comparisons at *constant international prices or at constant PPPs*. The key conceptual difference between using current and constant PPPs is that the former capture changes in volume as well as changes in weights, whereas the latter only capture volume changes. Put differently, even if the volumes of goods and services remain identical over time, a GDP comparison based on current PPPs may change over time if prices and price structures shift. Ignoring such shifts over longer periods can generate a biased picture of economic developments. This factor comes into play when some countries are large producers and exporters of products with marked price changes, for example Norway, which is an important oil exporter. Another consequence of fixing price structures to a base year is the sensitivity of results to the choice of the base year.

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