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THE OECD POTENTIAL OUTPUT ESTIMATION METHODOLOGY

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ABSTRACT/RESUMÉ

The OECD Potential Output Estimation Methodology

This paper describes the methodology used in the OECD Economics Department to produce historical estimates and short-run projections of potential output. These estimates are used mainly in the *OECD Economic Outlook*, in country surveys and as starting point for long-run scenarios. Total-economy potential output is modelled using a constant-returns-to-scale Cobb-Douglas production function with fixed factor shares. The three main inputs are labour, fixed capital excluding housing and labour efficiency, the latter obtained as a decomposition residual. The trend unemployment rate is estimated by Kalman filtering within a forward-looking Phillips curve. Other trend components are obtained by HP-filtering but labour efficiency and the labour force participation rate are cyclically adjusted before filtering to help alleviate the end-point problem associated with filters. This pre-filtering cyclical adjustment is especially helpful at cyclical turning points. It helps to lower the cyclicality of potential output as well as the extent of future revisions.

JEL codes: E20, E32

Keywords: Potential output, potential growth, labour efficiency, output gap, NAIRU, capital stock

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La méthodologie de l'OCDE pour estimer la production potentielle

Ce document décrit la méthodologie utilisée au Département des affaires économiques de l'OCDE pour estimer la production potentielle historique et ses prévisions à court terme. Ces estimations sont utilisées surtout dans les *Perspectives Économiques de l'OCDE*, dans les études économiques par pays et comme point de départ des scénarios à long terme. La production potentielle de l'économie totale est modélisée à l'aide d'une fonction de production Cobb-Douglas à rendements d'échelles constants et aux parts de facteur fixes. Les trois intrants principaux sont le travail, le capital fixe excluant les logements et l'efficience du travail, ce dernier étant obtenue en tant que résidu de décomposition. Le taux de chômage tendanciel est issu du filtre de Kalman appliqué à une courbe de Phillips incluant les anticipations d'inflation. Les autres composantes de la production potentielle sont obtenues par application d'un filtre HP mais l'efficience du travail et le taux de participation tendanciel sont ajustés pour le cycle avant l'application du filtre pour atténuer le problème de point final associé aux filtres. Cet ajustement cyclique avant filtrage est particulièrement utile aux points tournants du cycle économique. Il aide à réduire la cyclicité de la production potentielle ainsi que l'importance des révisions futures.

Codes JEL: E20, E32

Mots-clés: Production potentielle, croissance potentielle, efficience du travail, écart de production, NAIRU, stock de capital

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The OECD Potential Output Estimation Methodology

by Thomas Chalaux and Yvan Guillemette[1]

1. Introduction

1. The OECD Economics Department estimates potential output for member and selected non-member economies regularly. Historical series, real-time estimates and two-year ahead projections for, as of now, 47 countries[2] are produced as part of the twice-yearly *OECD Economic Outlook*. Real-time estimates and projections of potential output growth help to guide the demand-side growth projections. Output gaps derived from potential output series are useful cyclical indicators in assessing inflationary pressures and they enter the calculation of structural fiscal balances, which in turn help to assess fiscal sustainability. In a separate bi-annual exercise, the potential output series estimated as part of the *OECD Economic Outlook* are extended forward to produce long-term economic scenarios, which serve, among other uses, to illustrate the potential medium and long-run effects of supply-side reforms.

2. The OECD's approach to estimating potential output has evolved over the years, as described in numerous papers published on this topic, among which Giorno et al. (1995[1]), Cotis, Elmeskov and Mourougane (2005[2]) and Beffy et al. (2006[3]). The current approach uses a production function with filtered components, augmented with cyclical adjustments to the pre-filtered components to alleviate the end-point problem associated with filtering. The pre-filter cyclical adjustment was described in Turner et al. (2016[4]) for the G7 countries, but has since been extended to other countries. This cyclical adjustment contributes to making OECD potential output estimates less sensitive to the economic cycle than European Commission and International Monetary Fund estimates (Guillemette and Chalaux, 2018[5]).

3. This paper describes the complete methodology used to estimate potential output in the OECD Economics Department. It brings together some previously published material with a description of parts of the process that had never been formalised, in particular the production of capital stock series for countries lacking official estimates. The paper is structured as follows: section 2 provides an overview of the approach and the next three sections go over each of the inputs in greater depth: trend labour efficiency in section 3, trend employment in section 4 and the productive capital stock in section 5. Section 6 previews future developments of the methodology.

[1] The authors would like to thank Robert Grundke, Vincent Koen, Nigel Pain, Véronique Salins and David Turner for comments and discussions on previous versions of the paper, and Veronica Humi for assistance in preparing the document for publication.

[2] In addition to the 36 OECD member countries, potential output estimates are currently produced for eight non-OECD G20 countries (Argentina, Brazil, China, India, Indonesia, Russia, Saudi Arabia and South Africa) and three accession or partner countries (Colombia, Costa Rica and Romania).

2. Overview of the production function approach

4. Potential output is defined for the total economy using a common production function, namely a constant-returns-to-scale Cobb-Douglas function with Harrod-neutral labour-augmenting technical progress. The Cobb-Doulas function is a special-case of the constant elasticity of substitution (CES) function where the elasticity of substitution between labour and capital is equal to one. One of the first efforts by the Secretariat to model the supply-side of OECD economies in a consistent way was for the supply block of the now-defunct INTERLINK model. At this time, a general CES function was used and the elasticity of substitution between labour and capital (bundled with an energy component) in the business sector was estimated empirically. It came out at one exactly for three of the G7 countries and lower than one for the others (Helliwell et al., 1985[6]). Subsequent estimations put the elasticity of substitution at one for all G7 countries except Japan, but the use of a lower value for Japan did not materially affect the main results of supply-side modelling (Turner, Richardson and Rauffet, 1996[7]). From then on, the Cobb-Douglas function became the standard for potential output work as it is well-known in the profession and considerably simplifies some analyses and expositions. For its part, the assumption that technical progress is purely labour-augmenting is conventional and has no practical impact on the estimation of historical potential output given the assumption of fixed factor shares, discussed below.[3]

5. The assumed production function can be represented as the following, using mnemonics as they appear in the ADB and EO databases:[4]

$$GDPV = (EFFLAB * ET\_NA)^{\alpha} * (KTPV\_AV)^{(1-\alpha)} \qquad [1]$$

where *GDPV* is real GDP; *EFFLAB* represents labour efficiency, *ET_NA* denotes total employment according to the national accounts concept; *KPTV_AV* measures the whole-economy stock of capital excluding residential structures; and α denotes the share of national income accruing to labour, assumed to be 0.67 and constant in all countries. Equations throughout this paper refer to country-specific time series at the annual frequency; for simplicity the country index is omitted and the time index t is used only when lagged variables are present. *GDPV* and *ET_NA* are available in National Accounts, while *KPTV_AV* is estimated from national statistics on investment and capital stocks (see section 5). *EFFLAB* is obtained as a residual by inverting [1]. Therefore, unlike the other variables, it is conditional on the assumed functional form of the production function.

6. The assumption of a fixed labour income share (also called wage share) used to be regarded as a 'stylised fact' in macroeconomics.[5] With rare exceptions, the labour income

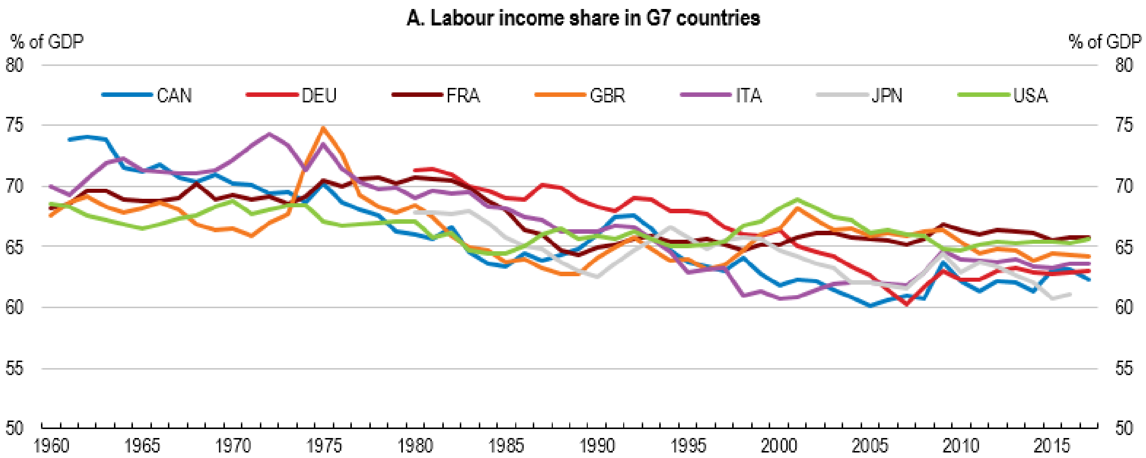
[3] A common alternative is for technical progress to increase the productivity of both labour and capital proportionally, in which case it is typically referred to as total factor productivity (TFP). The two concepts are related via a simple monotonic transformation.

[4] ADB stands for Analytical DataBase and is the internal and research-oriented database of the OECD Economic Department. The EO database is the one used in the production of the *OECD Economic Outlook*. A subset of the full EO database is published on stats.oecd.org with each version of the *OECD Economic Outlook*.

[5] Following the work of Douglas (1930[20]) and Bowley (1937[21]), who respectively analysed wage data for the US and the UK in the early 1920's, the stability of the labour share of income became a fundamental feature of macro-economic models (amongst the others "stylised facts of growth" proposed by Kaldor (1957[22])).

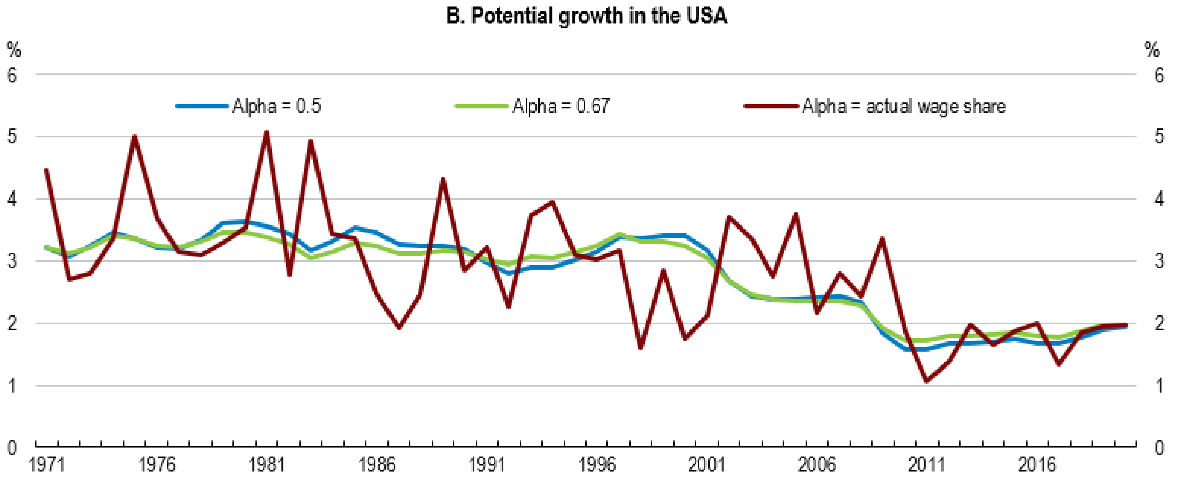
share in the United States has remained between 65% and 70% since 1960 (Figure 1, Panel A).[6] In other countries, such as Canada, the labour income share appears to have declined since the 1960s, a trend which has generated a rich literature (see for example Schwellnus et al. (2018[8]), Pak and Schwellnus (2019[9]), Karabarbounis and Neiman (2013[10]), Growiec, McAdam and Mućk (2018[11]), Schneider (2011[12]), Krämer (2010[13]) or Bentolila and Saint-Paul (2003[14])). For the purposes of potential output estimation, the value of α does not have a large impact on either the level or growth rate of potential output, although it impacts the breakdown of potential growth between different components. For instance, using a labour income share of 50% for the United States instead of 67% changes potential output growth in some years by, at most, one or two tenths of a percentage point. Using the actual labour income share computed from the National Accounts yields a similar trend for potential growth but with much greater volatility (Figure 1, Panel B). The common and fixed labour income share assumption may be changed in a future methodological revision (see Section 6), but one practical difficulty is obtaining comparable and timely estimates for non-OECD countries.

Figure 1. Labour income shares in G7 countries and illustrative impact on US potential output growth



6 The stability of the labour income share has been considered as "a bit of a miracle" (Keynes, 1939[23]), a "mystery" (Schumpeter, 1939[24]), or a "mirage" (Solow, 1958[25]).

Figure 1. Labour income shares in G7 countries and illustrative impact on US potential output growth (*contd.*)



Note: In Panel A, the labour income share is computed by adding gross operating surplus and mixed income to the wages of employees and dividing by current GDP.
Source: Analytical Database (ADB) of the OECD Economics Department and authors' calculations.

7. Total employment (*ET_NA*) can be decomposed into the product of: the size of the working-age population, considered to be those aged 15 to 74 (*POP1574*)[7]; their labour force participation rate (*LFPR1574*); an adjustment factor to correct for any inconsistency between the national accounts and the labour force definitions of total employment (*CLF*); and (one minus) the rate of unemployment (*UNR*):

$$ET\_NA = POP1574 * \frac{LFPR1574}{100} * CLF * \left(1 - \frac{UNR}{100}\right) \quad [2]$$

Combining [1] and [2], the representation of output becomes:

$$GDPV = \left[EFFLAB * POP1574 * \frac{LFPR1574}{100} * CLF * \left(1 - \frac{UNR}{100}\right)\right]^{\alpha} * KTPV\_AV^{(1-\alpha)} \quad [3]$$

The level of potential output (*GDPVTR*) is obtained by substituting each variable in [3] by its estimated trend component, with the exception of the capital stock:

$$GDPVTR = \left[EFFLABS * POPS1574 * \frac{LFPRS1574}{100} * CLFS * \left(1 - \frac{NAIRU}{100}\right)\right]^{\alpha} * KTPV\_AV^{(1-\alpha)} \quad [4]$$

where *EFFLABS*, *POPS1574*, *LFPRS1574*, *CLFS* and *NAIRU* are the trended counterparts of *EFFLAB*, *POP1574*, *LFPR1574*, *CLF* and *UNR*, respectively. Re-aggregating the potential employment component (*ETPT*), [4] can be re-written as:

$$GDPVTR = (EFFLABS * ETPT)^{\alpha} * (KTPV\_AV)^{(1-\alpha)} \quad [5]$$

[7] Historically, the working-age population has more commonly been defined as the population between 15 and 64. The OECD Economics Department added the 65 to 74 age group some years ago in the context of work on long-run scenarios, to better take account of the trend toward longer careers.

8. Trend labour efficiency (*EFFLABS*) is computed by cyclically adjusting the raw labour efficiency measure (*EFFLAB*) and then applying a Hodrick-Prescott (HP) filter (see section 3). Trend population (*POPS1574*) and the trend labour force adjustment factor (*CLFS*) – used to reconcile the National Accounts employment measure with the Labour Force Survey measure – are obtained by HP-filtering. The trend participation rate (*LFPRS1574*) is obtained by cyclically adjusting the actual rate before applying a HP filter (see section 4). The trend unemployment rate (*NAIRU*) is estimated using a Kalman filter within the context of a Phillips curve equation with anchored inflation expectations (see section 4). The capital stock measure (*KTPV_AV*) remains unadjusted, the idea being that the value of the capital stock reflects its maximum potential contribution to the economy (full utilisation, see section 5).

9. Most of the series used in estimating potential output come from the OECD Economic Outlook database, which in turn sources the necessary data mainly from National Accounts (for GDP, total historical population, capital stock and investment) or Labour Force Surveys (for labour force and unemployment). The age breakdown of the historical total population (to calculate the working-age population) as well as population projections are from the United Nations or Eurostat (see section 4). Data on capacity utilisation, commodity prices and current account balances, which are used in the cyclical adjustment of labour efficiency, come from national business surveys, the Hamburg Institute of International Economics and Balance of Payments, respectively (see section 3). The structural unemployment rate (*NAIRU*) is estimated internally (see section 4). All computations are based on annual historical data. However, real-time estimates and projections, which are done by country desks considering the latest high-frequency data, are also used in parts of the potential output estimation process. Automatic interpolation converts annual potential output series to the quarterly frequency for internal purposes, but these series are not published as they contain no additional information relative to the annual series.

10. Every effort is made to apply a consistent framework and methodology to all countries. One way in which this is accomplished is by having a single team in the Economics Department, called the 'supply team', responsible for estimating potential output for all countries. At the same time, this team interacts with country desks throughout the duration of the projection round to discuss the supply estimates and, if necessary, make country-specific adjustments. A dose of judgement therefore remains part of the approach. To take one example, a lambda (smoothness parameter) of 100 is typically used when smoothing annual series using the HP filter. However, different values can be used depending on the length and volatility of the series concerned, or if country specialists think that an alternative value results in a superior structural/cyclical decomposition according to their priors and other available information. Furthermore, manual adjustments can be made to projections of potential output components to take into account forthcoming policy reforms, on a case-by-case basis. Established procedures ensure regular back-and-forth between the supply team and country desks to enforce methodological consistency while respecting country specificities.

3. Trend labour efficiency

11. As mentioned previously, labour efficiency is a concept that is not directly observable or measurable. It is defined as the residual from [1] or, equivalently, from [3]. More explicitly, it can be expressed as:

$$EFFLAB = exp\left[\frac{\log(GDPV)}{\alpha} - log\left\{\left(1-\frac{UNR}{100}\right) * POP1574 * \frac{LFPR1574}{100} * CLF\right\} - \frac{(1-\alpha)}{\alpha} * log(KTPV\_AV)\right] \quad [6]$$

where *exp()* and *log()* are, respectively, the exponential and logarithmic functions.

12. Trend labour efficiency (*EFFLABS*) must be extracted from raw labour efficiency. A conventional method for extracting the trend component of a cyclical series is filtering. However, a well-known problem with filtering is that the resulting trend series tends to be unduly sensitive to the end-point of the source series. At cyclical turning points, when raw labour efficiency growth is especially strong (in a boom) or weak (in a recession), the trend series based on a filter will also tend to be too strong or weak relative to estimates made later on once more data have become available. In other words, trend labour efficiency estimates made at a cyclical turning point tend to be heavily revised later on.

13. One way of alleviating the problem is to extend the series to be filtered with projected values. Given the tendency of forecasters to assume some mean reversion, this approach should in principle yield a more 'balanced' end-point. In the case of labour efficiency, this requires projections for *GDPV*, the components of *ET* as well as *KTPV_AV* in [1]. However, this introduces an awkward circularity: if one motivation for estimating potential output is to anchor demand-side forecasts, then relying on those same forecasts to estimate potential output rather defeats the purpose of the exercise. Moreover, evaluations of OECD forecasting performance have shown that, beyond a 6-month horizon, GDP projections often perform no better than naïve forecasts, are very poor at predicting turning points and are systematically biased upward, all problems shared with other macro forecasters (Pain et al., 2014[15]; Turner, 2017[16]). Alleviating the end-point problem using projections would therefore tend to introduce an upward bias into trend labour efficiency projections.

14. To address this problem, Turner et al. (2016[4]) introduce a pre-filtering cyclical adjustment to the raw labour efficiency series. The idea is to exploit the correlation between labour efficiency and cyclical indicator(s) external to the methodology and available on a timely basis, to cyclically adjust labour efficiency before applying the filter. This adjustment helps lessen eventual revisions to trend labour efficiency as new data become available and is particularly important around economic turning points.[8]

15. Capacity utilisation, the investment ratio and the currency account balance are used to construct cyclical indicators when available and historically well correlated with labour efficiency. A capacity utilisation gap is defined as the difference between capacity utilisation and its sample average. An investment gap is defined as the share of investment in GDP minus its 10-year moving average. And a current account balance gap is calculated as the current account balance as a percentage of GDP minus its 5-year moving average. Commodity prices are also considered for countries where commodities account for at least 30% of total exports. In commodity-exporting countries, high commodity prices typically boost economic activity, with no corresponding increase in short-run employment or capital stock. The burst of activity therefore ends up mostly in the labour efficiency residual and would in turn affect the trend estimate. A commodity prices gap is obtained by computing country-specific aggregates of five nominal commodity price indices expressed in US dollars (agricultural raw materials; minerals, ores and metals; crude oil; food; and tropical

[8] Turner et al. (2016[4]) found that the revisions to the labour efficiency gap in G7 countries for 2007 and 2009 averaged 1.8 percentage points when using a simple HP filter, and 1.3 percentage points when applying the pre-filter cyclical adjustment.

beverages) using the country's commodity export shares, deflating the resulting aggregate by the US GDP deflator to obtain a real-valued series, and subtracting its 5-year moving average.

16. First, a naïve labour efficiency gap ($EFFLABGAP$) is computed by HP-filtering the raw series given by [6] and subtracting the filtered series from the raw series:[9]

$$EFFLABGAP = log(EFFLAB) - HP\{log(EFFLAB)\} \quad [7]$$

This naïve labour efficiency gap is then regressed on its first lag as well as the set of cyclical indicators (gaps) (X_i) just described and $k \leq 2$ of their lags:

$$EFFLABGAP_t = c + \alpha * EFFLABGAP_{t-1} + \sum_i \sum_{j=0}^{k\leq 2} \beta_{i,j} * X_{i,t-j} + \varepsilon_t \quad [8]$$

where *c* is a constant term and *ε* a residual. Only the indicators and lags with statistically significant coefficients are kept in the final equation.

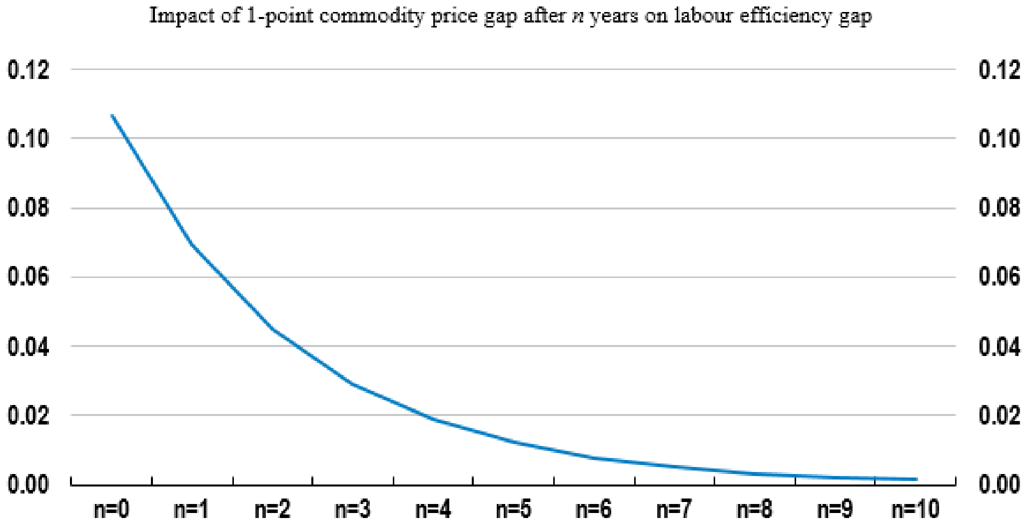
17. Because [8] includes a lagged dependent variable, whose estimated coefficient ($\hat{\alpha}$) is almost always statistically significant, the impact of each cyclical indicator (X_i) on the labour efficiency gap is computed via an impulse-response function. Letting $\gamma_{i,n}$ represent the impact of a change in indicator *i* after *n* years, and assuming that one contemporaneous cyclical indicator (with coefficients $\beta_{1,0}$) and two of its lags (with coefficients $\beta_{1,1}$ and $\beta_{1,2}$) are retained in [8] for the sake of example, then:

$$\begin{aligned}
\gamma_{1,0} &= \hat{\beta}_{1,0} \\
\gamma_{1,1} &= \hat{\alpha} * \gamma_{1,0} + \hat{\beta}_{1,1} = \hat{\alpha} * \hat{\beta}_{1,0} + \hat{\beta}_{1,1} \\
\gamma_{1,2} &= \hat{\alpha} * \gamma_{1,1} + \hat{\beta}_{1,2} = \hat{\alpha}^2 * \hat{\beta}_{1,0} + \hat{\alpha} * \hat{\beta}_{1,1} + \hat{\beta}_{1,2} \\
\gamma_{1,3} &= \hat{\alpha} * \gamma_{1,2} = \hat{\alpha}^3 * \hat{\beta}_{1,0} + \hat{\alpha}^2 * \hat{\beta}_{1,1} + \hat{\alpha} * \hat{\beta}_{1,2} \\
\gamma_{1,4} &= \hat{\alpha} * \gamma_{1,3} = \hat{\alpha}^4 * \hat{\beta}_{1,0} + \hat{\alpha}^3 * \hat{\beta}_{1,1} + \hat{\alpha}^2 * \hat{\beta}_{1,2} \\
&\vdots \\
\gamma_{1,n} &= \hat{\alpha} * \gamma_{1,n-1} = \hat{\alpha}^n * \hat{\beta}_{1,0} + \hat{\alpha}^{n-1} * \hat{\beta}_{1,1} + \hat{\alpha}^{n-2} * \hat{\beta}_{1,2}
\end{aligned} \quad [9]$$

The impact of cyclical indicators on the labour efficiency gap typically declines quickly with time and largely dies out after 4 years, as shown for example by the impulse response function for the commodity price gap in Argentina (Figure 2). Therefore, in practice, $\gamma_{i,n}$ is only computed up to year 4.

[9] Forecasts for the necessary variables originate either from preliminary projections by country desks (*GDPV* and *UNR*), or from estimations described in the next subsections (*LFPR1574*, *CLF* and *KTPV_AV*). Population projections come from the United Nations or from Eurostat.

Figure 2. Impulse response function for the commodity price gap in Argentina



Note: In the case of Argentina, [8] includes the contemporaneous commodity gap and a lagged dependent variable only.

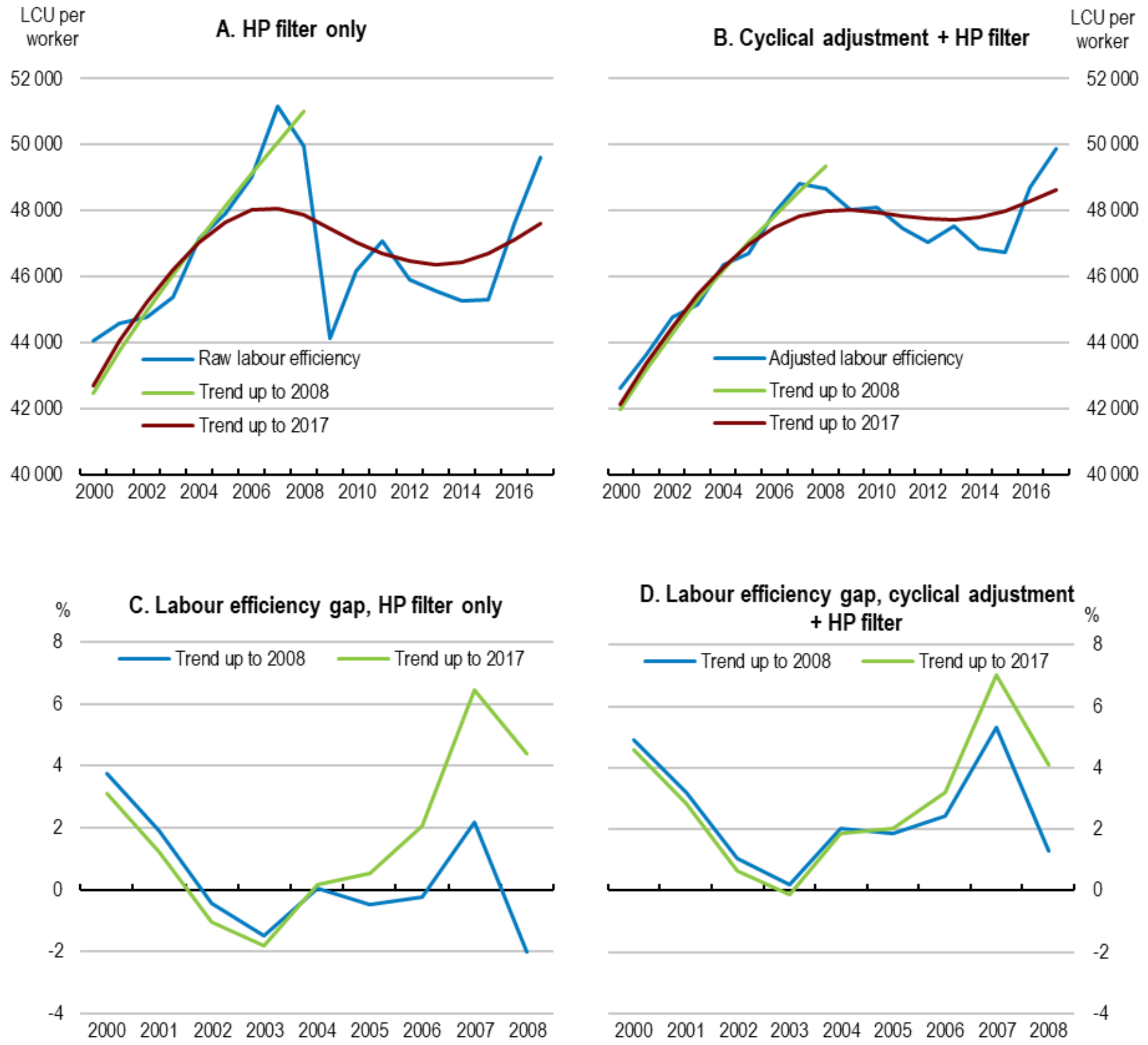
18. Next, the cyclically-adjusted estimate of labour efficiency ($EFFLAB\_ADJ$) is obtained by applying the estimated correlations above to the raw labour efficiency series:

$$EFFLAB\_ADJ_t = exp(log(EFFLAB_t) - \sum_i \sum_{n=0}^{4} \gamma_{i,n} * X_{i,t-n}) \quad [10]$$

where the $\gamma_{i,n}$ are the impulse-response coefficients derived in [9]. Finally, this cyclically adjusted labour efficiency series is HP-filtered to obtain the final trend labour efficiency estimate ($EFFLABS$).

19. Figure 3 illustrates the impact of the cyclical adjustment step using Finland as an example. Applying a HP filter to raw labour efficiency up to 2008, just before the global financial and economic crisis, puts the level of trend labour efficiency at the end-point (in 2008) substantially above the estimate for that year obtained when re-applying the same procedure but adding the data since the crisis and up to 2017 (Panel A). Consequently, between the two vintages, the labour efficiency gap estimate for 2008 reverses sign, going from -2% in the 2008 vintage to over 4% in the 2017 vintage (Panel C). The issue is that 2007/08 was a cyclical peak for the Finnish economy. When applying the HP filter up to 2008, the end-point is severely distorted, putting the trend rate of labour efficiency much too high. Therefore, when considering additional years of data, the 2008 estimate is revised down substantially.

Figure 3. Trend labour efficiency in Finland



Source: OECD Economic Outlook No. 104 database and authors' calculations.

20. Applying the cyclical adjustment reduces the amplitude of the labour efficiency series substantially. Consequently, when applying the filter up to 2008, the end-point (i.e. the trend labour efficiency estimate for 2008) is much closer to the estimate for that year based on filtering the series up to 2017 (Panel B). Equivalently, the 2008 vintage estimate of the 2008 labour efficiency gap, at around 1.5%, is much closer to and has the same sign as the 2017 vintage estimate, around 4% (Panel D). The revision is still large given the extreme nature of the cyclical turnaround, but it is cut by more than half relative to using the HP filter only, from 6.4 to 2.8 percentage points (Table 1). While it is not possible to say with certainty that one trend labour efficiency series is 'better' than the other, given that the 'true' series is unobservable, the information contained in the investment and capacity utilisation series as to the state of the economic cycle seemingly helps to better pin down the underlying strength of the Finnish economy.

21. The two-step method with a pre-filtering cyclical adjustment is applied to all 47 countries covered in the OECD *Economic Outlook* with the exception of China (Table 1). In the China case, none of the external cyclical indicators available has a statistically significant coefficient in regression [8]. The cyclical adjustment step is therefore omitted and trend labour efficiency is obtained by simple HP-filtering. Table 1 shows the year for which the revision to the labour efficiency gap is largest when comparing the estimate that would have been made in that year with a simple HP filter, versus using the full series to 2017 (for Finland this corresponds to 2008 as shown in Figure 3). The size of the revision is in the next column and, for countries where a cyclical adjustment is applied, the last column shows the corresponding revision with the two-step method.

Table 1. Indicators used in cyclical adjustment of labour efficiency and impact on largest revision to the labour efficiency gap

Country	Capacity utilisation gap	Investment rate gap	Current account balance gap	Commodity prices gap	Year of maximum revision with HP filter only	Labour efficiency gap revision, % points	
						HP filter only	Cyclical adjustment + HP filter
ARG		✓	✓		2005	-13.1	-9.7
AUS		✓			2005	2.4	2.3
AUT	✓				2008	3.2	1.1
BEL	✓		✓		2008	2.5	1.6
BRA	✓				2014	9.1	4.6
CAN	✓	✓			2007	3.2	1.2
CHE	✓				2008	2.7	1.1
CHL				✓	2008	5.5	5.3
CHN					2005	-10.5	
COL	✓			✓	2008	7.6	1.4
CRI				✓	2011	2.7	1.0
CZE	✓				2008	5.3	1.1
DEU	✓				2008	3.4	1.7
DNK	✓				2007	3.4	1.6
ESP		✓			2014	-3.0	-2.2
EST	✓	✓			2007	11.1	4.9
FIN	✓	✓			2008	6.5	3.5
FRA	✓	✓			2007	3.2	2.2
GBR	✓	✓			2007	4.3	3.4
GRC			✓		2008	10.9	8.6
HUN	✓				2008	7.2	2.9
IDN	✓				2005	-9.5	-9.2
IND	✓				2014	-3.6	-3.9
IRL	✓				2007	4.4	3.9
ISL		✓			2008	4.6	2.6
ISR		✓			2005	-3.8	-3.8
ITA	✓	✓			2014	-4.1	-2.4
JPN	✓				2007	2.6	0.7
KOR		✓			2011	2.8	2.9
LTU		✓			2008	9.2	5.0
LUX	✓				2007	6.0	5.0
LVA	✓	✓			2007	11.4	5.0
MEX	✓				2008	4.2	3.2
NLD	✓				2008	3.7	3.0
NOR	✓				2007	3.9	1.9

Table 1. Indicators used in cyclical adjustment of labour efficiency and impact on largest revision to the labour efficiency gap *(cont'd.)*

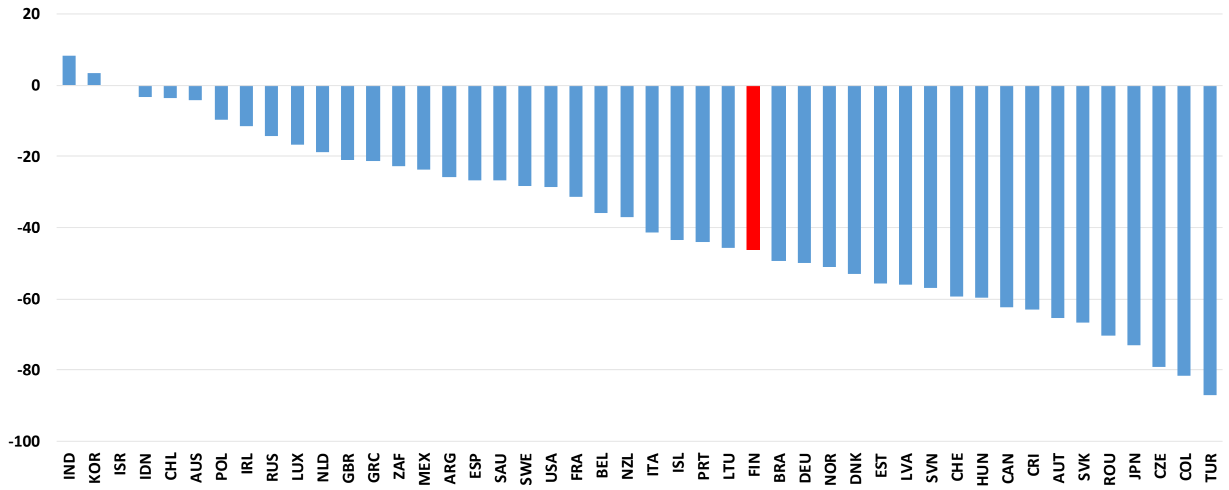
Country	Capacity utilisation gap	Investment rate gap	Current account balance gap	Commodity prices gap	Year of maximum revision with HP filter only	Labour efficiency gap revision, % points	
						HP filter only	Cyclical adjustment + HP filter
NZL		✓			2005	2.7	1.7
POL			✓		2016	-2.1	-1.9
PRT	✓	✓			2014	-4.3	-2.4
ROU	✓		✓		2008	-11.5	-3.4
RUS				✓	2008	9.1	7.8
SAU			✓	✓	2015	9.0	6.6
SVK	✓				2008	4.8	1.6
SVN	✓		✓		2008	8.8	3.8
SWE	✓				2007	5.3	3.8
TUR		✓	✓		2007	6.5	0.8
USA	✓				2007	2.1	1.5
ZAF				✓	2013	4.4	3.4

Note: The 'year of maximum revision with HP filter only' is found by computing, for all years between 2005 and 2016, the labour efficiency gap obtained by estimating trend labour efficiency with a HP filter using data up to that year, and comparing it to the gap obtained when filtering the same series up to 2017. The revision between the two estimates is shown in the next column. In the case of Finland, this revision corresponds to the vertical distance between the two lines in 2008 in Figure 3, Panel C. The last column shows the revision between the same two years when the labour efficiency gap is calculated using the two-step method. In the case of Finland, this revision corresponds to the vertical distance between the two lines in 2008 in Figure 3, Panel D.

22. With the exception of India, Korea and Israel, the addition of a pre-filter cyclical adjustment lowers the size of the maximum revision, by 2¼ percentage points on average, or some 40% of the HP-only revision, in the admittedly extreme cases chosen, which for most countries corresponds to the period just before the great recession. And the Finnish example shown above is not an exception – Finland is roughly middle-of-the-range when looking at reductions in maximum revisions across countries (Figure 4). The lack of a cyclical adjustment for China, the three countries for which the adjustment does not lower the maximum revision and the wide range of maximum reductions across other countries indicate that further work on this cyclical adjustment is desirable. So this aspect of the methodology will continue to be refined and, in time, it should be possible to apply the step to all countries.

Figure 4. Reduction in maximum revision

Per cent of maximum revision with HP filter only



Note: The bars correspond to the per cent difference between the last two columns of Table 1.

23. The procedure just described yields a trend labour efficiency series for the historical period. For the current year and the two-year projection horizon, trend labour efficiency is obtained by applying a simple autoregressive rule to the series' growth rate for the two preceding years:

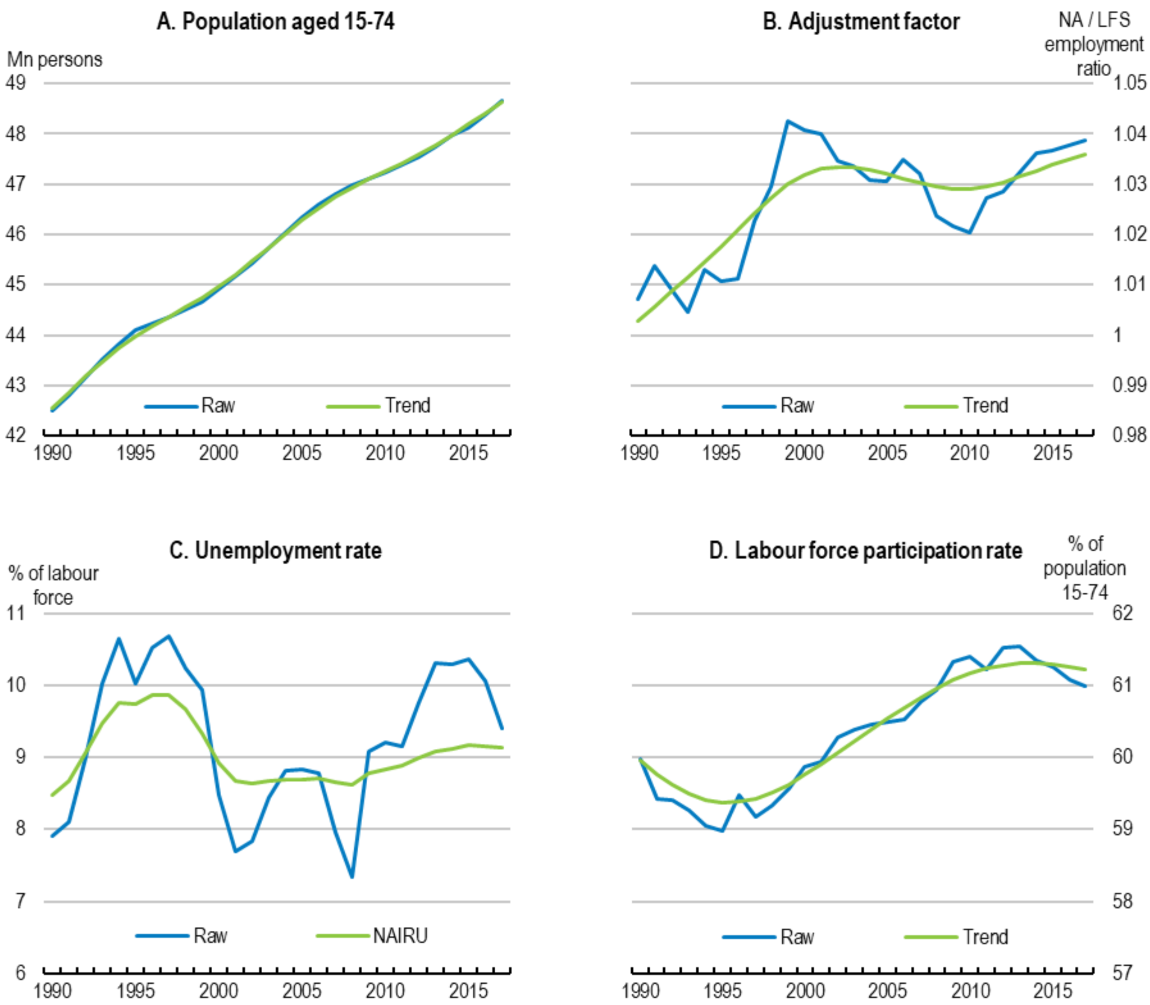
$$g(EFFLABS_{t+1}) = g(EFFLABS_t) + 0.7 * \Delta(g(EFFLABS_t)) \quad [11]$$

where *g*() computes the annual growth rate. This default rule is also subject to judgemental modifications, for instance when country specialists estimate that recent structural reforms are about to bear fruit and might raise trend labour efficiency growth above what the rule would project. Otherwise, the rule gradually tapers off any recent change in the trend labour efficiency growth rate.

4. Trend employment

24. Total employment can be decomposed into four subcomponents, as shown in [2]. Trend employment is obtained by computing a trend measure for each of the four subcomponents and re-aggregating them. Figure 5 shows the raw and trend measures for components of total employment in France as an example.

Figure 5. Trend employment components in France



Source: OECD Economic Outlook No. 104 database and authors' calculations.

4.1. Trend working age population

25. The working-age population estimate (*POP1574*) is obtained in several steps. The starting point is the historical total population series available from National Accounts. This source is used to ensure that the *Economic Outlook* definition of GDP per capita is consistent with national sources. However, National Accounts do not provide population projections, which are needed for the two-year projection horizon of potential output and the long-term scenarios, nor do they include an age/sex breakdown of the total population, which is needed to compute the working-age population series (*POP1574*). Therefore, obtaining a complete set of age/sex-specific historical population estimates and projections that correctly add up to the National Accounts historical series proceeds in two steps. First, the historical series for total population is extended forward using projected total population

growth rates from Eurostat or the United Nations.[10] Second, the age/sex decomposition (for both history and projections) is obtained by applying the age/sex proportions of the EU/UN sources to the total population series. *POP1574* is then computed by aggregating the relevant age groups. Trend working age population (*POPS1574*) is obtained by applying a HP filter to the working-age population series with projections up to 2080. Because projections are included, the end-point problem is not an issue and, in any case, working-age population exhibits little cyclicality in most countries.

4.2. Trend unemployment rate (NAIRU)

26. Unemployment (*UN*) and labour force (*LF*) series are sourced from national Labour Force Surveys and used to compute the unemployment rate (*UNR* = *UN* / *LF* * 100).[11] The trend unemployment rate, also called the non-accelerating inflation rate of unemployment (*NAIRU*), is then estimated using a Kalman filter embedded within a forward-looking Phillips curve, as described in detail in Rusticelli, Turner and Cavalleri (2015[17])[12]:

$$\Delta\pi_t = \theta * (\pi_{t-1} - \pi^e) + \alpha(L)\Delta\pi_{t-1} + \beta * (NAIRU_{t-1} - UNR_{t-1}) + supply\ shocks_{t-1} + \varepsilon_t \quad [12]$$

where π is the core inflation rate, π^e is expected inflation, usually set to the official inflation target, L is a distributed lag of changes in past inflation and ε is a residual. Supply shocks include country-specific variables which have a temporary effect on inflation like import price inflation and changes in indirect taxes.

27. The forward-looking Philipps curve framework provides a stronger statistical relationship between inflation and the unemployment gap and unemployment gap estimates that are more robust to end-point revisions than the previous Phillips curves used in $NAIRU$ estimation (Guichard and Rusticelli, 2011[18]). For some non-OECD countries, a Kalman-filter based $NAIRU$ is not yet available, so it is instead estimated by HP-filtering the unemployment rate, including short-run projections to alleviate the end-point problem.

28. Projections of the NAIRU for the two-year horizon assumes that it would gradually stabilise, if that is not already the case:

$$\Delta NAIRU_t = 0.7 * \Delta NAIRU_{t-1} \quad [13]$$

[10] The latest Eurostat population projections are normally used for European Countries and the latest United Nations population projections for other countries.

[11] Labour-force based series for Argentina and India are not available from the *OECD Economic Outlook* database and are sourced instead from the IMF *World Economic Outlook* or the International Labour Organisation's databases.

[12] It has been argued that the unemployment gap ($NAIRU - UNR$) may be higher than indicated by the unemployment rate itself because of a rise in part-time employment (and more specifically involuntary part-time employment) in many OECD countries. However, in the framework presented here, the Kalman filter sets the $NAIRU$ series so that the resulting unemployment gap best 'explains' the evolution of inflation. Using a different measure of unemployment would have minimal effect in this framework because, while the $NAIRU$ would adjust, the resulting gap estimate would essentially be the same. Incorporating alternative measures of labour market slack would require a different framework.

4.3. Trend labour force participation rate

29. The labour force (*LF*) series is sourced from national Labour Force Surveys and used to compute the labour force participation rate (*LFPR1574 = LF* / *POP1574* * 100). The trend labour force participation rate is then estimated in two steps that mirror what is done for trend labour efficiency. First, a preliminary estimate of the labour force participation gap (*LFPRGAP*) is computed relative to the labour force participation rate smoothed by a HP filter. Second, this preliminary estimate is regressed on the contemporaneous and up to two lags of the unemployment gap (*GAPUNR = NAIRU - UNR*) to isolate the cyclical component in the preliminary labour force participation gap:

$$LFPRGAP_t = c + \alpha * LFPRGAP_{t-1} + \sum_{j=0}^{k\leq 2} \beta_j * GAPUNR_{t-j} + \varepsilon_t \quad [14]$$

where *c* is a constant term and *ε* is a residual. Next, the estimated coefficients, if statistically significant, are used to compute the cumulative impacts of $GAPUNR$ on $LFPRGAP$ according to an impulse-response function as in the case of labour efficiency. The impulse-response coefficients thus obtained (γ_n) are then used to adjust the raw labour force participation rate (*LFPR1574*) and obtain a cyclically-adjusted measure (*LFPR1574_ADJ*) as in the case of trend labour efficiency:

$$LFPR1574\_ADJ_t = LFPR1574_t - \sum_{n=0}^{4} \gamma_n UNRGAP_{t-n} \quad [15]$$

Again, given the rapid decay of the impulse-response function, the impacts of the unemployment gap on the labour force participation gap are considered only up to year 4.

30. Unlike in the case of labour efficiency, for which the cyclical adjustment step omits projected values of labour efficiency, in the case of labour force participation the cyclical adjustment is applied to the series including projections made by the desk. The justification is that the labour force participation rate is much less cyclical than labour efficiency, doing it this way avoids having to extend the trend labour force participation rate over the two-year projection horizon. Thus, when the HP filter is applied to $LFPR1574\_ADJ_t$ to obtain the final measure of the trend labour force participation rate (*LFPRS1574*), the projections are obtained at the same time.

31. The cyclical adjustment step to the labour force participation rate is applied to 40 of the 47 countries (Table 2). For the reason just mentioned – lower cyclical sensitivity – the pre-filter cyclical-adjustment step is not as critical to estimating the trend labour force participation rate as it is to trend labour efficiency. This can be seen by considering, like in the case of labour efficiency, the year in which the cyclical adjustment steps makes the largest difference to how much the labour force participation gap is revised between that year and the estimate with the full sample to 2017. The revision is reduced in three quarters of the countries, but only by an average of 0.2 percentage points.

Table 2. Impact of cyclical adjustment to labour force participation rate on the largest revision to the labour force participation gap

Country	Year of maximum revision with HP filter only	Labour force participation gap revision, % points	
		HP filter only	Cyclical adjustment + HP filter
ARG	2006	0.7	
AUS	2011	0.6	0.5
AUT	2006	-0.7	-0.7
BEL	2010	0.5	0.6
BRA	2014	-0.7	-0.7
CAN	2008	0.8	0.6
CHE	2013	-0.5	-0.5
CHL	2009	-1.3	-1.2
CHN	2010	-0.7	
COL	2008	-2.4	-2.4
CRI	2015	1.5	1.6
CZE	2012	-0.7	-0.6
DEU	2005	-1.1	-1.1
DNK	2009	1.0	0.6
ESP	2011	1.6	1.3
EST	2005	-1.1	-1.1
FIN	2008	0.8	0.7
FRA	2013	0.3	0.2
GBR	2008	0.2	0.1
GRC	2010	1.0	0.7
HUN	2013	-1.5	-1.0
IDN	2010	0.6	
IND	2006	1.5	
IRL	2008	2.6	1.6
ISL	2008	1.1	0.2
ISR	2008	-0.4	-0.4
ITA	2011	-0.5	
JPN	2014	-0.6	-0.4
KOR	2013	-0.7	-0.8
LTU	2008	-1.6	-1.6
LUX	2012	0.5	0.4
LVA	2005	-1.6	-1.5
MEX	2013	0.8	0.8
NLD	2009	0.8	0.8
NOR	2009	0.9	0.8
NZL	2008	1.0	0.4
POL	2008	-1.4	-0.7
PRT	2016	-0.7	-0.7
ROU	2005	-1.0	
RUS	2005	-0.8	-0.9

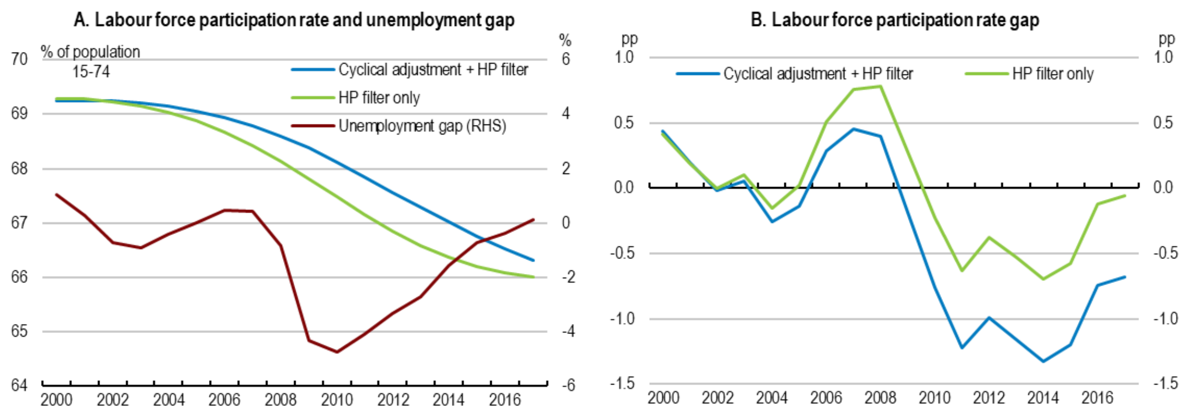
Table 2. Impact of cyclical adjustment to labour force participation rate on the largest revision to the labour force participation gap (*cont'd.*)

Country	Year of maximum revision with HP filter only	Labour force participation gap revision, % points	
		HP filter only	Cyclical adjustment + HP filter
SAU	2015	-2.0	-2.0
SVK	2014	-0.3	
SVN	2010	1.3	1.0
SWE	2012	-0.3	-0.2
TUR	2009	-1.7	-1.7
USA	2008	0.9	0.5
ZAF	2005	-1.0	-0.4

Note: The 'year of maximum revision with HP filter only' is found by computing, for all years between 2005 and 2016, the labour force participation gap obtained by estimating the trend labour force participation rate with a HP filter using data up to that year, and comparing it to the gap obtained when filtering the same series up to 2017. The revision between the two estimates is shown in the next column. The last column shows the revision between the same two years when the participation gap is calculated using the two-step method.

32. Nevertheless, there are cases in which the cyclical adjustment step can be helpful. In the United States for example, the unemployment rate almost doubled after the great recession. The two-step method yields a higher trend labour force participation rate over the past decade and a half than applying the HP filter only (Figure 6, Panel A). In addition, the labour force participation gaps resulting from the two-step procedure seem more consistent with the estimated unemployment gaps, in the sense that there are fewer years in which the two gaps have opposite signs.[13] For instance, the HP-only method yields a positive participation gap in 2009, whereas the two-step method yields a negative gap (Figure 6, Panel B). More generally, the two-step method indicates greater labour market slack (a more negative labour force participation gap) in the post-crisis period.

Figure 6. Trend labour force participation rate in the United States



13 For the United States over the 1965-to-2017 period, adding the cyclical adjustment step lowers by eight the number of years with conflicting signs on the two gaps.

Source: OECD Economic Outlook No. 104 database and authors' calculations.

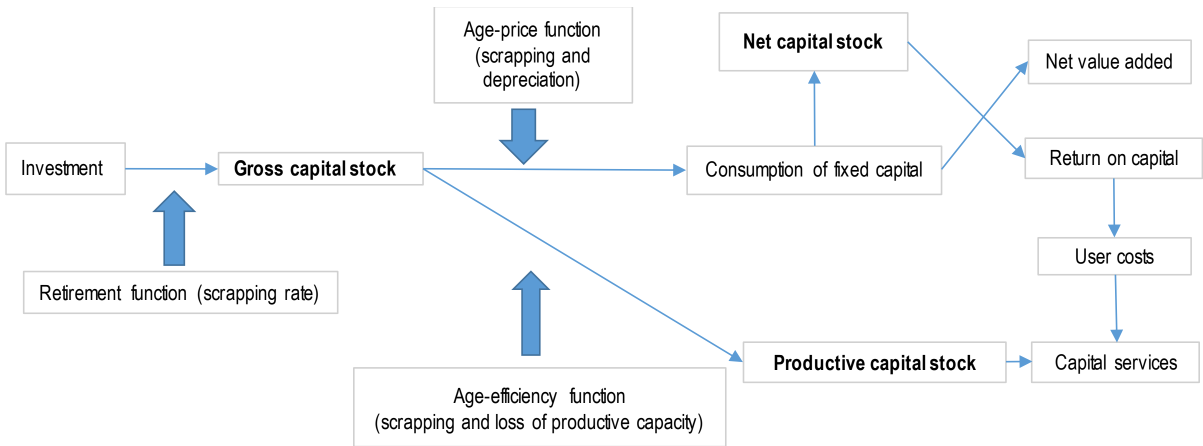
4.4. Trend adjustment factor

33. The adjustment factor (*CLF*) is computed as the ratio of total employment from the National Accounts (*ET_NA*) to that of the Labour Force Survey (*ET*) (*CLF* = *ET_NA* / *ET*).[14] For countries missing one of the two series (17 out of 47), usually the National Accounts measure, this adjustment factor is set to 1. The trend adjustment factor (*CLFS*) is obtained by a simple HP-filter. Again, the end-point problem is a minor concern, as both employment measures should respond to the economic cycle in similar ways.

5. Productive capital stock

34. Different capital stock measures are possible (Figure 7). Two are well-established and are part of the System of National Accounts 1993 revision: the gross capital stock is the sum of assets surviving from past investments, valued at the reference period; while the net capital stock subtracts depreciation from the gross measure and is the concept entering the balance sheets of institutional sectors and private companies. They are both measures of wealth, but do not track the role of capital as a factor of production. For example, a machine can lose value from a pure accounting point of view, but retain its productive capacity. A third measure, the productive stock of capital, is equal to the gross capital stock corrected for the loss of productive efficiency. It is the appropriate measure for production analysis as it assesses the flow of productive services provided by an asset that is employed in production (Schreyer, Bignon and Dupont, 2003[19]).

Figure 7. Capital stock measurement



Note: The definitions of consumption of fixed capital, net value added, return on capital or user costs can be found in the OECD Glossary of Statistical Terms.
Source: OECD (2009), *Measuring Capital – OECD Manual 2009: Second edition*, OECD Publishing, Paris.

35. The capital stock concept used in potential output estimation includes non-residential structures and equipment in the total economy (including the government

[14] The discrepancy between the two sources is typically less than 10% (i.e. *CLF* < 1.1), with the notable exception of Luxembourg, where cross-borders workers are counted in only one of the two measures.

sector's) but excludes housing (residential structures). The idea is that housing does not contribute to productive capacity as much as non-residential structures and equipment, hence the 'productive capital stock' nomenclature. This adjustment is disputable, however, since housing does add to GDP in the form of housing services.

36. As pointed out in section 2, the capital stock is the only sub-component of potential output that is not cyclically adjusted and/or filtered. As such, its size at any given time is considered to reflect its potential contribution to economic output, with less than full utilisation being reflected instead in the residual (labour efficiency). This treatment is disputable on the basis that some of the variables entering the computation of the capital stock do have a cyclical component, for instance investment and the scrapping rate, which may respectively fall and rise during a downturn such as the great recession. Unlike inactivity or unemployment, however, forgone investment or scrapped capital are not idle resources that could be brought into production if the economy rebounded. They do represent a real reduction in the economy's productive capacity.

37. The source of the capital stock series depends on the country (Table 3). The OECD Statistics and Data Directorate (SDD) computes detailed productive capital stock series for, currently, 20 of the 47 individual countries covered in the *OECD Economic Outlook*. These are countries for which national sources provide sufficient detail on investment and prices for age-efficiency functions to be estimated for various types of asset in six or seven different sectors. The capital stock for South Africa is sourced directly from the South African Reserve Bank, but the concept is not fully consistent with the other countries. For the 25 remaining countries, the productive capital stock estimate is computed using the perpetual inventory method (PIM).

Table 3. Sources of capital stock estimates

Data from Statistics and Data Directorate (derived from National Accounts)	AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN, KOR, NLD, NZL, PRT, SWE, USA
Economics Department estimate using the PIM with housing investment	EST, CHL, COL, CZE, GRC, HUN, ISL, ISR, LUX, LVA, MEX, NOR, POL, SWE, SVK, SVN
Economics Department estimate using the PIM without housing investment	ARG, BRA, CHN, CRI, IDN, IND, RUS, SAU, TUR
Obtained from national sources	ZAF

38. The basic logic of the PIM is to sum all past investment while applying a decay factor, the latter encompassing only the scrapping rate (when capital assets are withdrawn from the capital stock at the end of their service lives) when computing the gross stock, a combination of scrapping and depreciation rates when computing the net stock (the 'age-price' function), or a combination of scrapping and loss of productive capacity when computing the productive stock (the 'age-efficiency' function).[15] The following dynamic equation shows the basic PIM framework:

$$K_t = K_{t-1} * (1 - \theta_t) + I_t \quad [16]$$

[15] See OECD (2009[26]) for the theoretical foundations and full methodological details used by the OECD Statistics and Data Directorate to estimate such decay factors.

where K is the capital stock volume (gross, net, productive), I the flow of investment and θ the geometric decay rate (scrapping, age-price, age-efficiency). In *OECD Economic Outlook* mnemonics, K is *KTPV_AV*, θ is *RSCRP* and I is equal to *ITV* - *IHV* (total investment minus housing investment).

39. An official housing investment series (*IHV*) is available for 16 countries (Table 3). For these countries, the PIM is applied straightforwardly. For the nine countries for which a housing investment series is unavailable, the share of housing investment is assumed equal to the weighted average housing investment share of the 16 countries where this information is available. For all 25 PIM countries, the rate of decay of the capital stock (*RSCRP*) is assumed equal to a weighted average of the scrapping rate for the 20 countries covered by SDD.

40. Applying [16] necessitates a value for the initial capital stock. The geometric nature of θ allows an approximation of this initial stock (at time t=0) using past investment flows:

$$K_{t=0} \approx [I_{t=-1} + (1-\theta_{t=0}) * I_{t=-2} + (1-\theta_{t=0})^2 * I_{t=-3} + \cdots] \quad [17]$$

Under the plausible assumption that the long-run growth rate of investment equals the long-run growth rate of GDP, estimated here to be the compound 10-year average growth and noted g, then $I_t = I_{t-1} * (1+g_t)$, and [17] can be rewritten as:

$$\begin{aligned}&[I_{t=0-1} + (1-\theta_{t=0}) * I_{t=0-2} + (1-\theta_{t=0})^2 * I_{t=0-3} + \cdots] \\ &\quad = I_{t=-1} * [1 + (1-\theta_{t=0}) * (1+g_{t=0}) + (1-\theta_{t=0})^2 * (1+g_{t=0})^2 + \cdots] \\ &\quad = I_{t=-1} * \frac{(1+g_{t=0})}{(\theta_{t=0}+g_{t=0})}\end{aligned} \quad [18]$$

The unknown investment level in the year preceding $t = 0$, $I_{t=-1}$, is estimated by multiplying the 10-year average investment rate by GDP. It is therefore necessary to choose a year for the initial capital stock at least 10 years past the first available investment data point. Once $K_{t=0}$ has been estimated, [16] can be used to build the complete capital stock series.

41. For the two-year projection horizon, the productive capital stock is computed with equation [16], using investment projections by country desks. The scrapping rate and, when needed, the housing investment share, are projected with a rule similar to that of the NAIRU in [13].

6. Future developments

42. The methods used to estimate potential output described in this paper are subject to continuous evaluation and adjustment. For instance, the coefficients relating external cyclical indicators to labour efficiency or participation are regularly re-estimated on up-to-date datasets. New indicators can be introduced or functional forms modified when experimentations yield improvements on the existing approach. This process is one of refinements within the existing framework.

43. More fundamentals revisions to the framework in future are likely to be driven by the desire to enrich the long-run scenarios produced regularly by the Economics Department which, for consistency, are based on the same production function as that used in potential output estimation. For instance, there is evidence that labour income shares have been declining in many countries. While this has limited implications for historical potential output growth or output gap estimates, as illustrated for the United States in

section 2, it has greater implications for its decomposition into components, which in turn affects long-run projections. So one possible evolution of the potential output framework might be to switch from fixed to variable income shares (which could be done by keeping the Cobb-Douglas functional form but letting α in [1] be a variable). This would allow additional channels through which technology, demographics and policies could affect future output. Pak and Schwellnus (2019[9]) for instance identified a number of policy influences on the evolution of labour income shares which could be interesting to exploit in the context of long-run scenarios.

44. More ambitiously, another possible revision to the framework would be to add natural capital as an additional factor of production to the Cobb-Douglas production function. This would allow for a richer decomposition of the historical sources of growth, as well as a channel for the influence of climate change on future economic developments.

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