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ABSTRACT/RÉSUMÉ

An investigation into improving the real-time reliability of OECD output gap estimates

Estimates of the output gap ought to be a useful guide for macroeconomic policy, both for assessing inflationary pressures and fiscal sustainability, but their reliability has been called into question by the large revisions which they are often subject to, particularly around turning points. Revisions to OECD published estimates of the output gap around the period of the financial crisis have been exceptionally large, with by far the largest contribution to these revisions coming from the labour-efficiency gap. The current paper investigates a modification to the standard OECD production function method for deriving potential output, which involves an additional cyclical adjustment in the derivation of trend labour efficiency. The additional adjustment helps to reduce the occurrence of large end-point revisions and of sign switches between the initial and final estimates of the labour-efficiency gap. The variables which are most often found to be useful in providing this cyclical adjustment of labour efficiency are manufacturing capacity utilisation and the investment share. However, for a few countries additional variables – house prices and credit – have been used to provide the cyclical adjustment, although this raises an issue as to whether the cyclical adjustment should be limited to a core set of variables to ensure the method remains reasonably homogenous across countries. Recent improvements to the specification of the Phillips curve, which imply a tighter fit between the unemployment gap and inflation, should also reduce end-point revisions to the unemployment gap in future.

JEL Classification: E32; E5; E6; E3

Keywords: potential output, end-point revisions, production function, financial crisis, labour efficiency, manufacturing capacity utilisation, total factor productivity, output gap.

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Améliorer la fiabilité en temps réel des estimations d'écarts de production de l'OCDE : une investigation

Les estimations de l'écart de production devraient être un guide utile à la politique macroéconomique, à la fois pour mesurer les pressions inflationnistes et la viabilité de la politique fiscale, mais leur validité et leur fiabilité ont été mises en question par les larges révisions dont elles ont souvent fait l'objet, particulièrement autour des points de retournements. Les révisions concernant les estimations de l'écart de production publiées par l'OCDE autour de la période de la crise financière ont été exceptionnellement larges, en majeure partie à cause de révisions aux écarts de productivité (efficience du travail). Cette étude examine une modification de la méthode usuelle utilisée par l'OCDE pour le calcul de la production potentielle, basée sur une fonction de production, qui rajoute un ajustement cyclique additionnel au niveau du calcul de l'efficience du travail. Cet ajustement additionnel permet de réduire l'occurrence de larges révisions dues à la sensibilité des filtres aux points terminaux et du changement de signe entre les estimations initiales et finales des écarts de productivité. Les variables s'avérant les plus utiles pour cet ajustement cyclique sont le taux d'utilisation des capacités du secteur manufacturier et la part de l'investissement dans le PIB. Cependant, pour quelques pays, des variables additionnelles comme les prix des logements et le crédit ont été utilisées pour effectuer cet ajustement cyclique, quoique cela soulève la question de savoir si l'ajustement cyclique devrait être limité à un noyau de variables de base pour assurer l'homogénéité de la méthode entre pays. Des améliorations récentes sur la spécification de la courbe de Phillips, dont découle une correspondance plus stricte entre écarts de chômage et inflation, devraient aussi permettre de réduire les révisions des écarts du chômage dans le futur.

Classification JEL: E32; E5; E6; E3

Mots clés : Production potentielle, révisions dues aux points terminaux, fonction de production, crise financière, efficience du travail, taux d'utilisation des capacités du secteur manufacturier, productivité multifactorielle, écart de production.

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AN INVESTIGATION INTO IMPROVING THE REAL-TIME RELIABILITY OF OECD OUTPUT GAP ESTIMATES

David Turner, Maria Chiara Cavalleri, Yvan Guillemette, Alexandre Kopoin, Patrice Ollivaud and Elena Rusticelli[1]

1. Introduction and summary

1. Estimates of the output gap ought to be a useful guide for macroeconomic policy, both for assessing inflationary pressures and fiscal sustainability, but their reliability has been called into question by the large revisions to which they are often subject, particularly around turning points. The current paper reviews the real-time reliability of OECD published estimates of the output gap for the G7 economies over the period immediately preceding and following the financial crisis, before considering modifications to the existing OECD production function method for estimating potential output, which might reduce the extent of such revisions. A companion paper (Rusticelli et al., 2016) considers an altogether different methodology by estimating potential output as a multi-variate filter.

2. The current paper is organised as follows. The OECD production function framework for potential output is described in Section 2, where it is shown that the output gap is essentially a linear combination of three component gaps: a labour-efficiency gap, an unemployment gap and a labour-force gap. Section 3 examines revisions to successive vintages of published OECD output gaps for the major seven OECD economies since 2004 and so including the period around the financial crisis. In Section 4, modifications to the current OECD method of deriving the labour-efficiency gap are described and their effectiveness in reducing end-point revisions evaluated. In Section 5, the method of estimating the unemployment and participation gaps are described, including recent innovations which are conceptually similar to those proposed for the labour-efficiency gap, and which may help to reduce end-point revisions in the future. A final section considers the importance of minimising revisions to output gap estimates, but argues this should not be the only criterion used to judge their usefulness.

3. The main findings are as follows:

- Revisions to OECD published estimates of the output gap around the period of the financial crisis have been exceptionally large; across the G7 countries revisions to the output gap for the

1. The authors are members of the Macroeconomic Analysis Division of the OECD Economics Department. They would like to thank Jonathan Millar as well as participants at an Economics Department seminar for useful comments, Sylvie Toly and Jeroen Meyer Zu Schlochtern for statistical support and Veronica Humi for assistance in preparing the document. OECD Working Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the author(s).

immediate pre-crisis period have typically been 2–3 percentage points and sometimes larger. The magnitude and systematic nature of revisions around the crisis strongly suggest that end-point problems associated with filtering around turning points have been the main contribution to the largest revisions.

- Revisions to potential output are much more important than revisions to GDP in explaining output gap revisions for the G7 countries over the period considered.

- The output gap can be decomposed into component production function gaps and by far the largest contribution to the revision of aggregate output gaps comes from revisions to the labour-efficiency gap, although revisions to the unemployment gap also made a significant contribution for some countries.

- The paper investigates a modification to the standard OECD method of deriving the labour-efficiency gap which exploits correlations with other macroeconomic variables – usually survey measures of manufacturing capacity utilisation or the share of investment in GDP – which are available on a timely basis. This allows labour efficiency to be cyclically adjusted and so provide more stable series prior to trend labour efficiency being derived with a Hodrick Prescott (HP) filter. The additional cyclical adjustment helps to reduce large end-point revisions relative to just using an HP filter. In a comparison exercise examining the period around the time of the crisis, the effect of the additional adjustment is to substantially reduce the frequency of large end-point revisions and of sign switches between the initial and final estimates of the labour-efficiency gap.

- The variables most often found to be useful in providing a cyclical adjustment of labour efficiency across the G7 countries are manufacturing capacity utilisation and the investment share. However, for a few countries – notably the United States and United Kingdom – these variables are only poorly correlated with labour efficiency and so provide a poor cyclical adjustment. For these countries, additional variables – house prices and credit – have been used to provide the cyclical adjustment. This is, however, less satisfactory, both because it involves country-specific solutions and because these variables need to be de-trended before being used and there are different ways this might be done which could impact on the final estimate of the gap. More generally, if the method is to be extended to all OECD countries, it raises the issue as to whether the variables used to provide the cyclical adjustment should be limited to a core set of variables to ensure the method remains reasonably homogenous across countries.

- While the additional cyclical adjustment to labour efficiency is mainly designed to limit end-point revisions, it can lead to a change in the historical profile of the gap where the cyclical adjustment variables suggest there has been a prolonged period of boom or slump. Among the G7, the clearest example is Japan for which the adjustment generates a more sustained negative gap over the period of the "lost decade", but the adjustment also generates a more negative gap for most G7 countries over the period since the financial crisis. However, with the exception of Japan, the additional adjustment only makes a minor difference to estimates of the gap over the sample outside the end-points.

- The OECD method uses a Kalman filter embedded within a Phillips curve equation to derive the unemployment gap. Recent improvements to the specification of the Phillips curve which imply a tighter fit between the unemployment gap and inflation should reduce end-point revisions in future. Similarly, the use of the unemployment gap in the derivation of the labour-force participation gap should better anchor estimates of the trend labour force and so reduce end-point revisions. While these methodological improvements may contribute to reducing revisions in the

future, they do not contribute to reducing revisions to historical output gaps, particularly over the crisis period, and indeed may have exacerbated them.

2. The OECD production function framework for calculating potential output

4. The OECD approach to estimating potential output uses a production function framework which is described here in a stylistic form, with further details, including variable definitions, documented in Appendix 1. It is assumed that GDP (Y) can be represented as a 2-factor Cobb-Douglas production function, in terms of employment (N) and the capital stock (K), with labour-augmenting technical progress (E) defined as a residual to ensure that:

$$y = \alpha (n + e) + (1- \alpha) k, \quad [1]$$

where lower case letters denote logs and α is the wage share.

5. Potential output is then defined in terms of [1] but substituting potential employment, n*, for n and trend labour efficiency, e*, for e:[2]

$$y^* = \alpha (n^* + e^*) + (1- \alpha) k, \quad [2]$$

so that the output gap is defined as the difference between GDP and potential output:

$$y - y^* = \alpha [(n - n^*) + (e - e^*)] \quad [3]$$

6. In order to derive potential employment, the trend labour force and structural unemployment rate are separately estimated. Given that employment is the difference between the labour force (LF) and unemployment (U), then to a reasonable approximation, providing the unemployment rate (UR = U/LF) is not very high, n = lf - UR. Taking also the equivalent expression for potential employment (n*= lf* - UR*), and substituting them both into [3] allows the output gap to be expressed as the approximate sum of the three component gaps in labour efficiency, unemployment and the labour force: [3]

$$y - y^* = \alpha [(e - e^*) + (lf - lf^*) - (UR - UR^*)]. \quad [4]$$

7. The substance of the potential output methodology is then concerned with calculating e*, UR* and lf*. A key problem is that if a simple filter, such as the HP filter, is applied to the actual data to derive the corresponding potential/trend series, then there is a risk of an end-point problem, whereby the filtered values may subsequently be subject to large revisions as new data become available. Such revisions may be particularly large if the series ends near a cyclical turning point. One common approach to try to limit such revisions is to extend the sample of the series being filtered with forecast values, although in practice this approach is of limited value given that forecasters are typically poor at forecasting turning points.

2. Labour efficiency is closely related to the perhaps more familiar concept of total factor productivity (TFP) so that tfp = α e.

3. This decomposition of the output gap is not precise, both because of the log approximation in the expression which is used linking the logged labour force and unemployment rate and because in practice there are sometimes other complications in the data. One example of such a data complication is the need to relate national accounts measures of employment to a labour force survey measure (see Appendix 2 for details). Nevertheless, expression [4] does hold as a reasonable approximation for nearly all countries and, in any case, is useful here as an expository device.

3. An examination of revisions to OECD output gaps

8. There are a number of reasons why output gap estimates are revised: revisions to the underlying data, especially GDP; changes in the methodology used to derive potential output between vintages; and instability in any given method used to derive potential output, particularly concerning end-point estimates, which arise as the data sample is extended.

9. GDP revisions will affect estimates of the output gap, but their magnitude and the fact that they typically only apply to recent quarters means that they are unlikely to undermine the usefulness of output gaps for policy purposes. Moreover, if the GDP revisions are substantial and over a long period (as for example might be associated with a major revision to the definition of National Accounts), then most of them would likely be absorbed in revised potential, so that the output gap may be minimally changed.[4] A decomposition analysis of output gap revisions for the G7 countries since 2004 suggests that in cases where the output gap was revised by more than two (one) percentage points, the main contribution was from a revision to potential output in 90% (85%) of cases (see Appendix 2 for details). Moreover, the magnitude of the correlation coefficient between revisions to the output gap and revisions to potential output is 0.82, whereas between revisions to the output gap and revisions to GDP it is only 0.12.

10. There have also been major changes to the OECD's production function methodology which have had an impact on output gap estimates including: switching between a measure of capital services and capital stock; a number of changes to the method of estimating equilibrium unemployment, notably to provide a closer link to inflation (Rusticelli et al., 2015); and a set of changes designed to produce a more uniform approach across a broader range of countries[5] and to link the estimates of potential output to longer-term projections (Johannsson et al., 2013). The introduction of the last and most far-reaching of these changes in May 2012 led to the largest average revision across all G7 countries between successive vintages of output gap estimates over the period examined in Appendix 1.[6]

11. Revisions to output gap estimates tend to be markedly larger around cyclical turning points (Koske and Pain, 2008; Orphanides and Van Norden, 1999) which is borne out by a comparison of successive OECD published output gap estimates for the G7 economies covering the immediate pre-crisis period until 2014 (Appendix 1). Output gap revisions tended to be positive especially for the immediate pre-crisis years, consistent with a tendency to revise potential output downwards following the crisis. In particular, the potential output estimates published in 2008 implied that output was close to potential in the preceding years, so output gaps were small. In the following years, downward revisions to potential output led to positive output gap revisions typically by about 2-3 percentage points for G7 economies in 2007, with even larger revisions for Italy but lower for Canada (Table 1). Relatedly, there are numerous

4. The largest GDP revision to the G7 countries over this period was almost certainly associated with the introduction of the 2008 System of National Accounts (SNA08). For the United States the *Financial Times* reported "US economic history will be rewritten this week, as the most far-reaching methodological changes in years will add the equivalent of a country the size of Belgium to output in the world's largest economy." However, the effect on output gap estimates is likely to have been more trivial: deriving an output gap as the difference between GDP and an HP filter of the same series (lambda equal to 100), then comparing US output gap estimates using the newly introduced SNA08 data with the previous vintage of GDP (based on the 1993 SNA), results in an average absolute revision to the output gap over the previous decade of about 0.1 percentage point and a maximum revision of less than 0.3 percentage points.

5. This involved dropping average hours, the use of standardised parameters for the wage share across countries and the introduction of human capital into the production function.

6. Taking the average of all absolute output gap revisions across successive vintages of estimates across all G7 countries, the largest revision occurs between *Economic Outlook* numbers 91 and 90, corresponding to the major change in potential output methodology discussed in the text.

examples of the output gap estimates switching sign during the immediate pre-crisis period, typically from negative to positive (Appendix 1).

Table 1. Revisions to published G7 output gaps for 2007 and 2009

	2007 Output gap			2009 Output gap		
	Initial estimate	Most recent estimate	Revision	Initial estimate	Most recent estimate	Revision
United States	0.4	2.6	2.2	-5.1	-4.6	0.6
Japan	0.5	2.5	2.0	-5.5	-5.1	0.4
Germany	0.5	2.3	1.8	-5.2	-5.2	0.1
France	0.3	2.3	2.0	-4.5	-2.8	1.7
United Kingdom	0.2	3.4	3.1	-6.4	-3.7	2.6
Italy	-1.2	3.0	4.2	-5.5	-4.0	1.5
Canada	0.2	1.2	1.1	-5.5	-4.0	1.5
Average			2.3			1.2

Note: The "initial estimate" for 2007 (2009) is taken from the May 2008 (2010) *OECD Economic Outlook* when outturn data for 2007 (2009) would first have been available. The most recent estimate is taken from the November 2015 *OECD Economic Outlook*.

Source: May 2008 and November 2015 *OECD Economic Outlooks*.

12. Revisions are still substantial in the immediate post-crisis period and mostly in the direction of making the output gap less negative (again consistent with a lowering of potential), although they are typically smaller than for the immediate pre-crisis period and less systematic across countries. Among the G7 countries, the upwards revision to the 2009 output gap is: largest for the United Kingdom, at 2½ percentage points; between 1½ and 1¾ percentage points for France, Italy and Canada; only a half percentage point for the United States and Japan; and negligible for Germany (Table 1).

13. Whilst it seems likely that revisions to actual GDP and methodological changes have contributed to these output gap revisions, their large magnitude and systematic nature across countries and through time, both immediately before and after the crisis, suggest that methodological issues associated with filtering end-points are dominant over this period. Such revisions are of particular concern given their magnitude and because they come at a time where an accurate reading of the cycle is particularly important from a policy perspective.

14. A decomposition analysis of output gap revisions in terms of component gaps is hampered by changes in methodology which occurred between the initial and most recent estimates.[7] Nevertheless, such decomposition suggests that the component which consistently contributes most to crisis output gap revisions is the labour efficiency gap (Figure 1), especially in the immediate pre-crisis period. Revisions to the unemployment gap make a significant contribution for some countries, whereas large revisions to the participation gap are less frequent. It is not particularly surprising that the largest contribution to output gap revisions comes from the labour efficiency gap, given that labour efficiency is more volatile than either the labour force or unemployment rate; on average across the G7, the standard deviation of annual changes in (logged) labour efficiency is three times that of annual changes in (logged) labour force and 2½ times that of annual changes in the unemployment rate over the period 1985-2014. Accordingly, the remainder of the

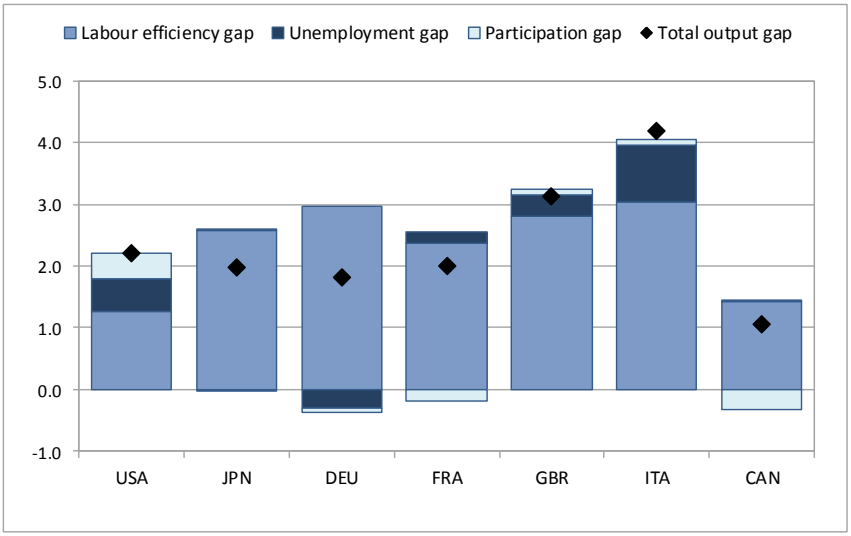
7. The changes in methodology include revised wage share parameters, the dropping of average hours worked as a measure of labour input and changes in the definition of capital used in the production function. For the purpose of the decomposition shown in Figure 1 the 'hours gap', which was part of the initial estimate but is not available for the final estimate, has been absorbed in the labour efficiency gap.

paper examines alternatives to the standard OECD methodology which might help reduce such end-point revisions, with a particular focus on the derivation of the labour-efficiency gap in the next section.

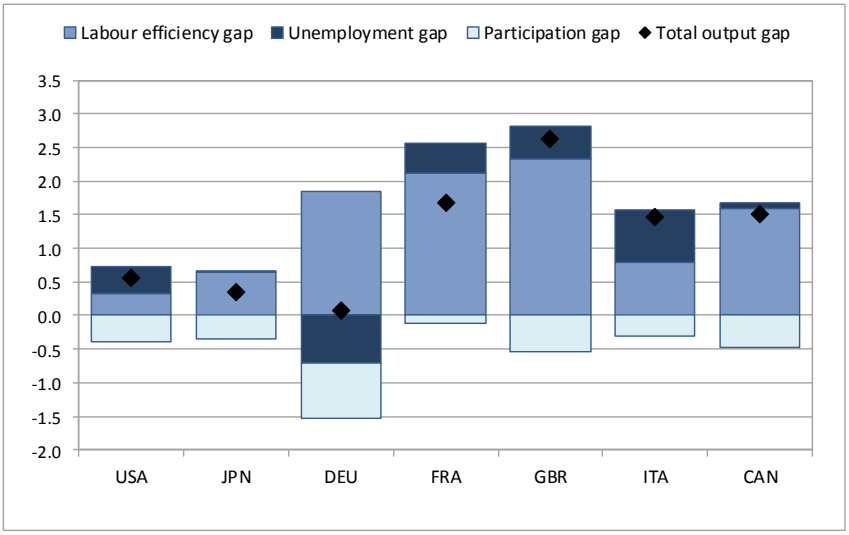
Figure 1. Production function component contributions to revisions of the output gap

Difference between initial and final estimates (percentage points)

A. 2007



B. 2009



Note: The chart decomposes revisions to the output gap for 2007 and 2009 between the 'initial' and 'final' estimates, as defined in Table 1, into the three component gaps based on equation (4). The decomposition is only approximate for reasons discussed in the text.

4. Estimating the trend labour efficiency gap

15. In the standard OECD approach to estimating potential output, 'raw' (logged) labour efficiency is calculated as a residual from [1] and then trend labour efficiency is computed by passing an HP filter through this series. To try to limit the problem of end-point revisions, historical values of labour efficiency are extended by using forecast values.[8] However, as previously noted, forecasters are generally poor at predicting turning points, which casts doubt on the usefulness of this extension.

4.1 A cyclical adjustment to labour efficiency prior to filtering

16. The approach to limiting end-point revisions in the calculation of trend labour efficiency investigated here exploits correlations between labour efficiency and other macroeconomic variables which are available on a timely basis. This procedure is described in a series of stages and illustrated for the case of Japan, although summary results are also presented for the other G7 economies.

- *First stage*: Take an HP filter of raw logged labour efficiency, e, to give a series, e^{HP}, from which a preliminary labour efficiency gap can be derived as $(e - e^{HP})$.

- *Second stage:* Regress this preliminary estimate of the labour efficiency gap on a set of variables Xn (n=1,2,…), which are correlated with the cycle and can be contemporaneous or lagged one, or occasionally, two years:

  $$(e - e^{HP}) = \beta_0 + \beta_1 X1 + \beta_2 X2 + \ldots \quad [5]$$

  For the purpose of this regression the final two years of data are discarded, because the preliminary labour efficiency-gap estimate may be contaminated by the end-point problem. The Xn variables which are found to be most useful across the G7 countries are survey measures of capacity utilisation and the share of investment in GDP, both expressed as deviations from long-run averages. In the case of Japan, the estimated equation explains the labour-efficiency gap in terms of contemporaneous and lagged manufacturing capacity utilisation and the lagged investment ratio with a high goodness-of-fit, despite the absence of lagged dependent variables (Table 2).

- *Third stage*: Derive an estimate of cyclically-adjusted labour efficiency, e^{CA}, by subtracting the estimated contribution of the Xn variables using the estimated β_n coefficients from the previous regression. Comparing the raw labour efficiency series, e, with the cyclically-adjusted series for Japan (Figure 2), it is apparent that fluctuations in the raw series have been reduced. This suggests that the adjusted series, once filtered, is likely to be less vulnerable to revision as new data points become available, than the raw labour efficiency series, as demonstrated below.

  $$e^{CA} = e - \{\beta_1 X1 + \beta_2 X2 + \ldots\} \quad [6]$$

- *Fourth stage*: Finally, take an HP filter of the cyclically-adjusted labour efficiency series, e^{CA}, to derive trend labour efficiency, e*, and the final labour efficiency gap $(e - e^*)$.

8. Where the forecast of labour efficiency is derived as the residual from forecast values of GDP, capital and employment.

Table 2**. Regressions explaining the labour efficiency gap for the G7 countries**

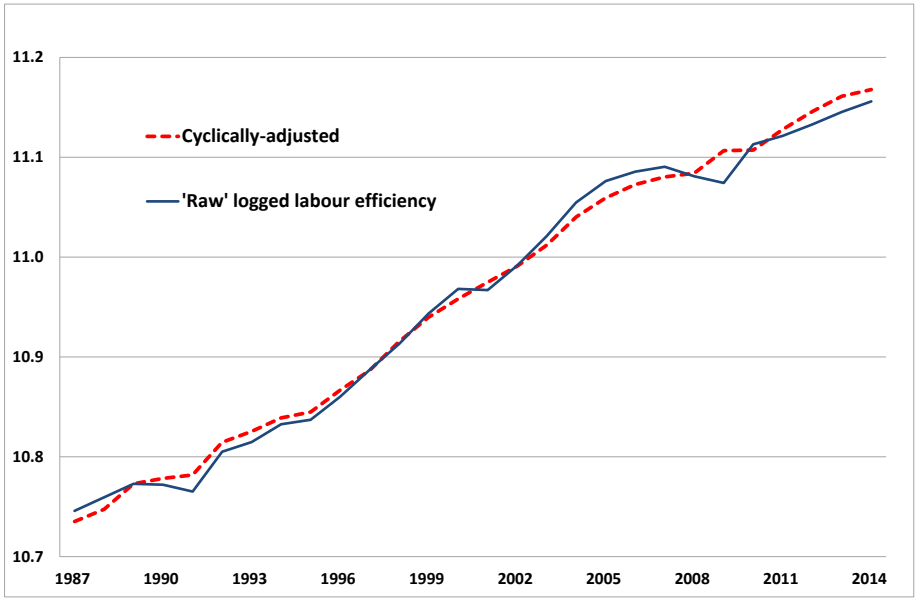
Sample period 1985 – 2012, annual data

	US		JPN		DEU		FRA		GBR		ITA		CAN	
Constant	0.081		1.457	***	0.607	**	0.133		-0.384		-0.033			
∆CAPU	0.297	***	0.258	***			0.320	***			0.469	***		
CAPU					0.516	***							0.295	***
CAPU(-1)			0.197	***			0.236	***			0.357	***		
∆ITR											0.807	*		
ITR	0.555	***					0.768	***					0.425	***
ITR(-1)			0.949	***	0.503	**								
CR(-1)	0.079	***												
CR(-2)									0.087	***				
HP									0.079	***				
∆UNR									-1.979	***				
UGAP													1.048	***
Rsqd-adj	0.73		0.83		0.75		0.74		0.72		0.70		0.87	

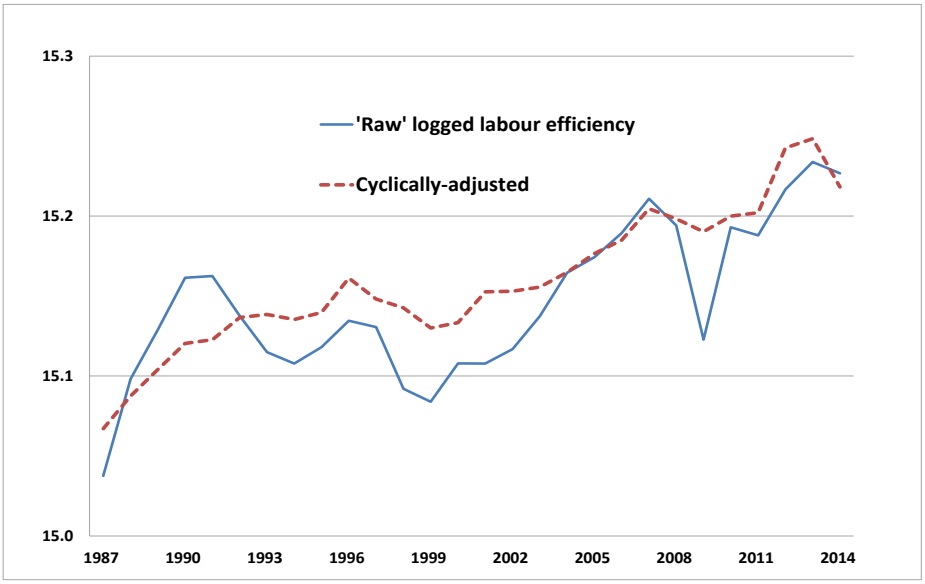
Note: The dependent variable is the preliminary estimate of the labour efficiency gap (e - e^{HP}), see text for details; CAPU is the de-meaned survey measure of manufacturing capacity utilisation; ITR is the ratio of nominal investment to nominal GDP; CR is the credit-to-GDP ratio, first expressed as the deviation from a 10-year moving average and then de-meaned; HP is the ratio of house prices to disposable income, first expressed as the deviation from a 10-year moving average and then de-meaned; UNR is the unemployment rate; UGAP is a measure of the unemployment gap described in section 5.1; ∆ is the first difference operator; **'***'**, **'**'** and **'*'** denote statistical significance of coefficients at the 1%, 5%, and 10% levels, respectively.

Figure 2. Japan: the effect of the cyclical adjustment on logged labour efficiency

A. United States



B. Japan



4.2 The choice of macroeconomic variables to cyclically adjust labour efficiency

17. The variables which are found to be most consistently highly correlated with the labour efficiency gap, and therefore most useful in providing a cyclical adjustment, are manufacturing capacity utilisation and the share of investment in GDP. Survey-based measures of manufacturing capacity utilisation are attractive because they measure a similar concept to the output gap and are available on a

timely basis.[9] On the other hand, such series only relate to the manufacturing industry which only accounts for a small and declining share of most OECD countries' GDP. Moreover, survey measures of capacity utilisation are not available for all countries. Thus, it should largely be an empirical question as to whether capacity utilisation should be incorporated into potential output estimation. Among the G7 countries, the correlation between the labour-efficiency gap and manufacturing-capacity utilisation is highest for Japan, Germany and Italy, whereas it is much lower for the United Kingdom and United States. The other variable which was found to be most consistently correlated with the labour-efficiency gap was the share of (nominal) investment in GDP, reflecting the pro-cyclical nature of investment, which is often captured in empirical estimates of an accelerator relationship between investment and output.

18. For a few countries, notably the United States and the United Kingdom, manufacturing-capacity utilisation and the investment share are less strongly correlated with the labour-efficiency gap, which limits the magnitude of any improvement in end-point revisions from using the procedure. For both the United States and the United Kingdom, an additional variable correlated with the labour-efficiency gap is (a transformation of) the credit-to-GDP ratio. For the United Kingdom, additional variables correlated with the labour-efficiency gap are the house-price-to-disposable-income ratio and the change in the unemployment rate. The derivation of the unemployment gap, which was also found to be useful in the adjustment for Canada, is described in the next section.

19. The use of the credit-to-GDP ratio (for the US and UK) and house-price-to-disposable-income ratio (UK only) is, however, problematic because these variables need to be de-trended before being used and there is no unique way of doing this. For the current purpose the series are first expressed as the difference from a 10-year moving average and then the resulting series are de-meaned. A second reason why the use of these country-specific variables might be considered unsatisfactory is that the process of determining potential output becomes less standardised across countries.

4.3. The effect on end-point revisions

20. To investigate the potential benefits of the procedure, it is applied across all G7 countries and the scale of revisions around pronounced turning points evaluated. The revisions are calculated by first applying the procedure to data ending in 2007 (the year preceding the start of the financial crisis) and then evaluating the revision to trend labour efficiency in the year 2007 when the procedure is run over the full sample period (here ending in 2014). This is then repeated for the year 2009 (in most countries the trough of the downturn following the financial crisis). To provide a control and basis for comparison, revisions are compared with those obtained when the exercise is repeated but using only an HP filter (Table 3).[10] This implies that the testing procedure is only in 'quasi' real time as actual vintage data are not used for this exercise (but rather data that are currently available up to the period in question, but which may have been revised over time).

21. The additional cyclical adjustment is not a panacea, with end-point revisions around the period of the crisis still substantial. In some cases applying the adjustment even increases the absolute magnitude of the revision relative to just using an HP filter. However, it does substantially reduce the frequency of very large end-point revisions; the occurrence of end-point revisions exceeding 2 percentage points is reduced from seven (out of the total of 14) episodes, involving six of the G7 countries, to two episodes and a single country (Figure 3). Similarly, applying the additional cyclical adjustment reduces the root mean square

9. The European Commission uses survey measures of capacity utilisation to derive estimates of labour efficiency/total factor productivity as part of their potential output methodology for EU countries (Havik et al., 2014)

10. Throughout all the exercises reported in this paper a value of lambda equal to 100 is used for the Hodrick Prescott filter.

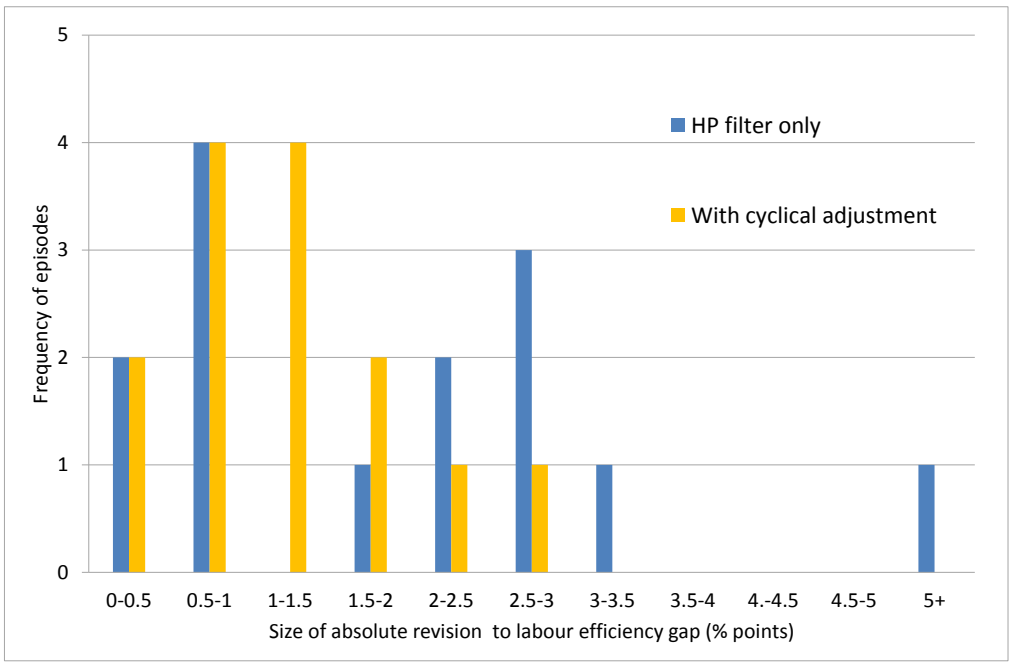
revision for every G7 country by about one-third on average, compared to the case when only an HP filter is used (Figure 4). Finally, in terms of the estimate of the 2007 labour-efficiency gap, the initial and final estimates switch signs for four countries when using only the HP filter, whereas this only occurs for one country with the additional cyclical adjustment. Among the G7 countries, the adjustment is perhaps least satisfactory for the UK, because even after the adjustment the revisions remain substantial (although reduced relative to only using an HP filter), and also because the adjustment relies on country-specific variables (house prices and credit).

Table 3. Revisions to the labour efficiency gap for 2007 and 2009

	HP filter only (λ=100)			**HP filter with cyclical adjustment**		
2007 labour-efficiency gap	Initial estimate	Most recent estimate	Revision	Initial estimate	Most recent estimate	Revision
United States	**-1.5**	**1.2**	**2.6**	0.5	1.9	1.4
Japan	2.1	3.9	1.8	2.2	2.3	0.1
Germany	**2.4**	**4.4**	**2.0**	2.5	3.5	1.0
France	**0.1**	**2.6**	**2.5**	1.2	2.8	1.6
United Kingdom	**-0.5**	**4.5**	**5.0**	**2.5**	**5.5**	**3.0**
Italy	**-0.3**	**2.4**	**2.7**	0.3	1.9	1.6
Canada	**-2.1**	**1.0**	**3.1**	-0.3	1.1	1.4
2009 labour-efficiency gap						
United States	-3.4	-2.8	0.6	-3.4	-2.6	0.9
Japan	-5.6	-6.3	-0.7	-7.7	-7.8	-0.2
Germany	-6.3	-6.4	-0.1	-8.2	-7.4	0.8
France	-4.2	-3.3	0.9	-4.5	-3.3	1.2
United Kingdom	**-6.9**	**-4.2**	**2.7**	**-6.3**	**-4.1**	**2.3**
Italy	-5.3	-4.8	0.5	-7.2	-5.8	1.4
Canada	-4.6	-4.1	0.5	-5.4	-4.5	1.0
Average absolute revision			1.8			1.3

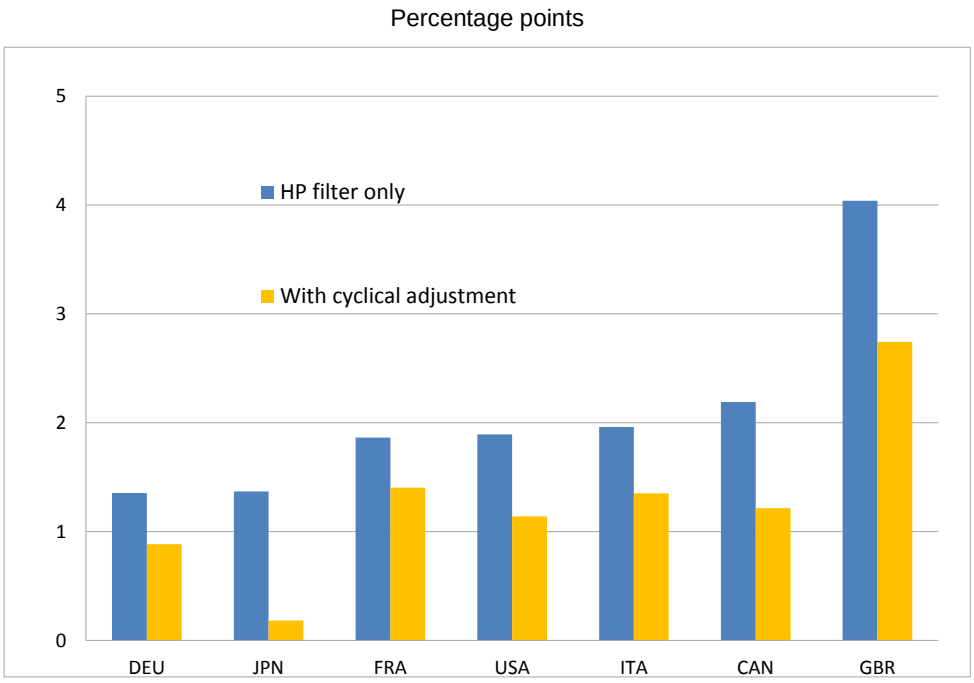
Note: Revisions for 2007 (2009) are calculated by applying the filtering procedure to data ending in 2007 (2009) to derive an initial estimate of the labour-efficiency gap and then applying the same procedure over the full sample to 2014. Revisions are calculated both for a simple HP filtering procedure, in the first three columns, and an HP filter which is modified with the additional cyclical adjustment described in the text, in the second three columns. Revisions exceeding 2 percentage points are highlighted in bold.

Figure 3. Absolute revisions to the labour efficiency gap for 2007 and 2009



Note: Revisions based on results reported in Table 3.

Figure 4. Root mean squared revisions of the labour efficiency gap for 2007 and 2009



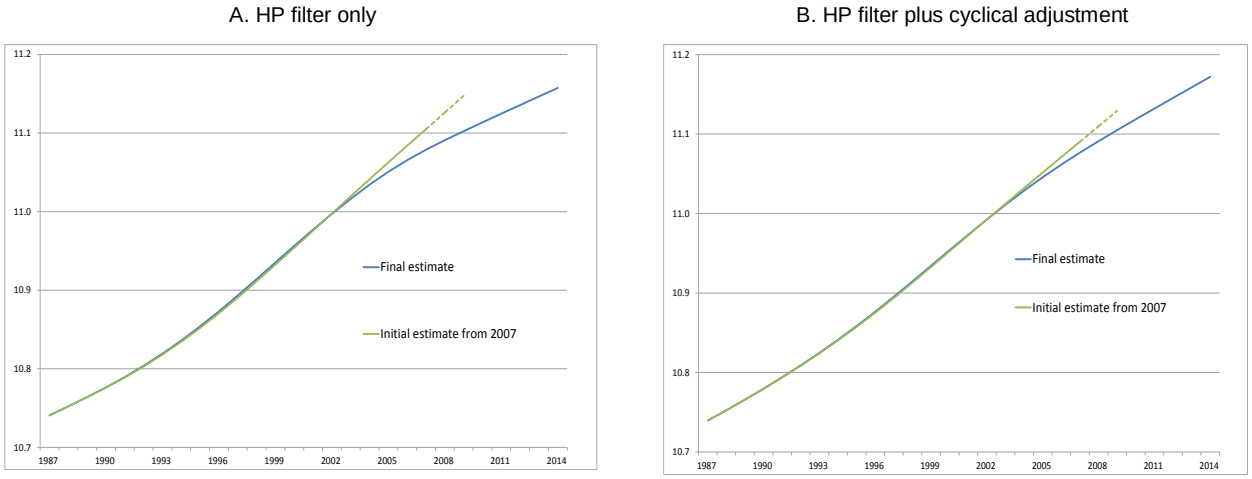
Note: Revisions based on results reported in Table 3.

4.4 The effect on the growth rate of labour efficiency

22. The additional cyclical adjustment not only has a significant effect on the *level* of trend labour efficiency at the end-point, but also on the trend *growth* rate. This could be particularly important if the end point occurs at a cyclical turning point and the final end-point growth rate is used as the basis for a projection.

23. This is illustrated for the case of the United States by running the two filtering procedures, the simple HP filter and the cyclically-adjusted HP filter, on raw labour efficiency data to 2007 and then projecting trend labour efficiency over 2008-9 by applying the average growth rate estimated for trend labour efficiency over 2005-7 (Figure 5). These projected growth rates are then compared with the growth rates obtained for 2008-9 when the filtering procedures are applied over the full sample to 2014. While both procedures over-estimate the post-crisis growth rates, the size of the over-prediction is reduced by applying the cyclical adjustment, a result which holds across all the G7 countries (Table 4).

Figure 5. United States: projecting the post-crisis growth rate of labour efficiency



Note: The initial estimate 2007 is derived by applying the filtering procedure to data ending in 2007. The period 2008-9 is then projected (dashed line) by applying the average growth rate over the period 2005-7. Revisions are calculated both for a simple HP filtering procedure, in the left hand panel, and an HP filter which is modified with the additional cyclical adjustment described in the text, in the right hand panel.

Table 4. Revisions to the average projected trend labour efficiency growth rate for 2008-9

(per cent per annum)

	HP filter only (λ=100)	HP filter with cyclical adjustment
United States	-0.9	-0.5
Japan	-0.5	0.0
Germany	-0.6	-0.4
France	-0.9	-0.7
United Kingdom	-2.0	-1.3
Italy	-1.0	-0.7
Canada	-1.0	-0.6
Average	-1.0	-0.6

Note: The revision to the growth rate is calculated as the difference between a final estimate and an initial estimate. The initial estimate is derived by applying the filtering procedure to data ending in 2007 and then assuming the growth rate for the period 2008-9 is the same as the average growth rate over the period 2005-7. The final estimate is calculated by applying the filtering procedure over the full sample to 2014. Revisions are calculated both for a simple HP filtering procedure, in the first column, and an HP filter which is modified with the additional cyclical adjustment, in the second column.

4.5 The effect on the profile of trend labour efficiency and the gap over the full sample

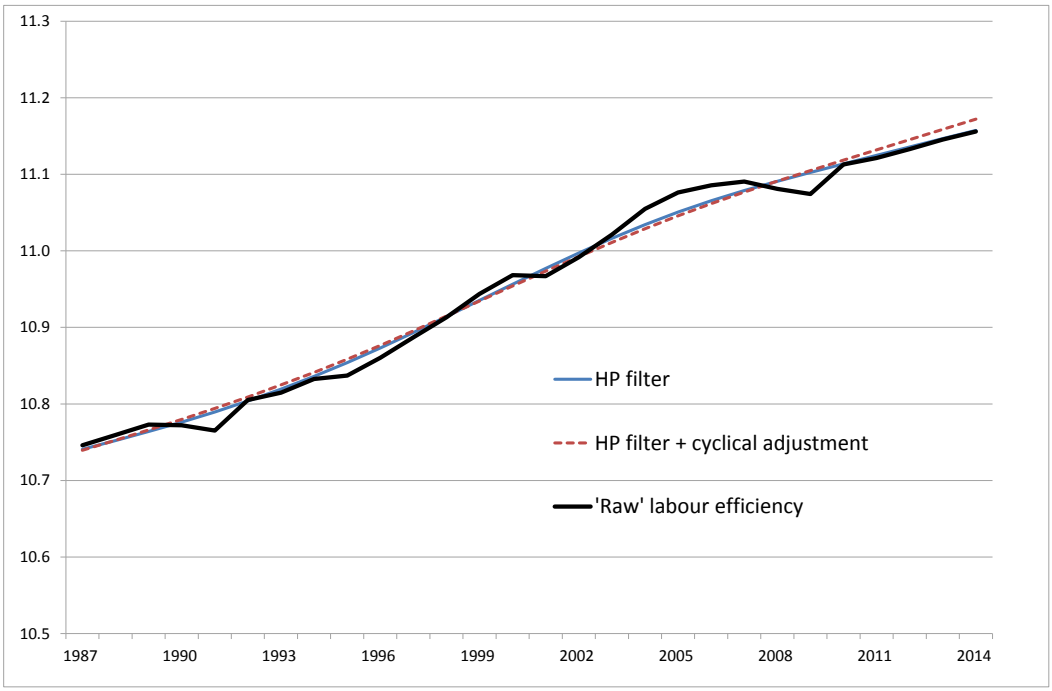
24. While the main purpose of the additional adjustment is to reduce the scale of end-point revisions, it is also important to consider what effect the adjustment has on estimates of trend labour efficiency, and hence the gap, over the full sample. For the G7 countries, with the exception of Japan, the difference would seem to be mostly minor, except at the end-point. Thus the average absolute difference for all G7 countries, excluding Japan, between estimates of trend labour efficiency derived from the two filtering procedures is less than one-half a percentage point,[11] with the biggest differences usually occurring near the end-point. The United States is typical of most countries: there is little discernible difference between the estimates of trend labour efficiency, except from about 2011 onwards where the cyclical adjustment implies a slightly higher level of trend labour efficiency and a persistent negative gap, whereas the HP filter exhibits its in-built bias to close gaps over any prolonged period (Figure 5A). For other G7 countries, the labour-efficiency gap over the period 2011-14 is similarly depressed by an average of about 1 percentage point relative to just using an HP filter.

25. The major exception is Japan where the more extreme movements in the cyclical adjustment variables (manufacturing capacity utilisation and the investment rate) produce a more persistent negative gap over the period of Japan's so-called 'lost decade'(Figure 5B).

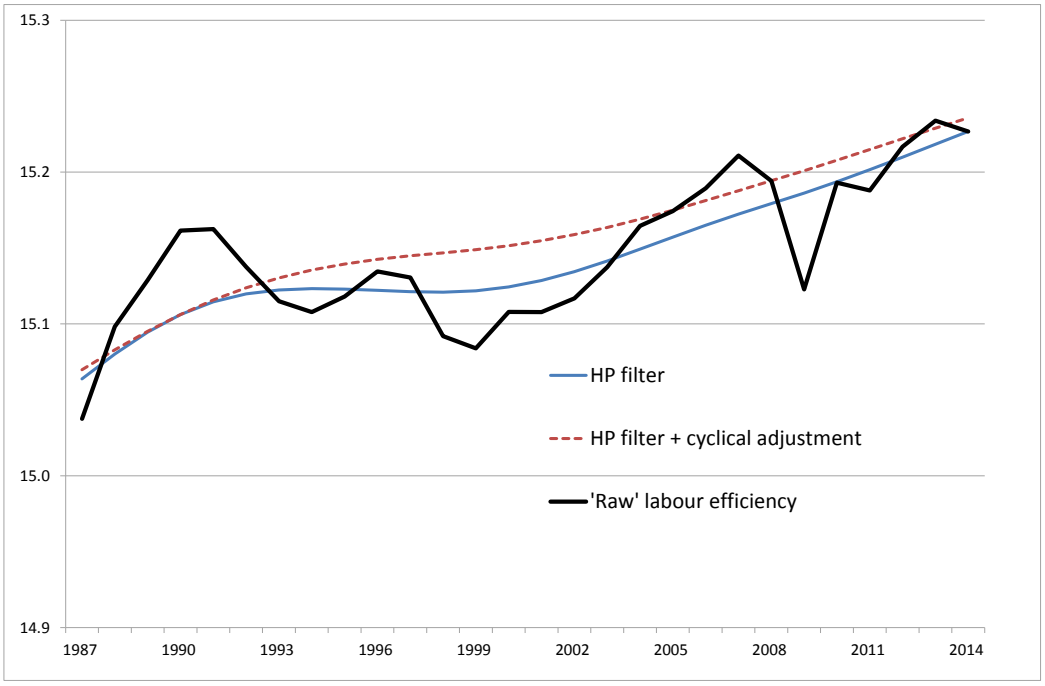
11. This would translate into a difference of less than one-third of a percentage point on potential output.

Figure 6. Sensitivity of trend-logged labour efficiency to the proposed adjustment

A. United States



B. Japan



5. Estimating the unemployment and labour force gaps

26. The OECD methods for deriving the unemployment and labour force gaps have recently changed in ways which, as described below, should help to reduce real-time revisions in future, although because the methodological changes are recent, this is not apparent when examining the track record of revisions over the crisis period (as in section 3).

5.1 Estimating the unemployment gap

27. The unemployment gap is estimated using a Kalman filter embedded within a Phillips curve equation explaining inflation, reflecting the central importance of inflation in most definitions of potential output. In the context of the current paper, a further advantage of using information on inflation is that it should better anchor estimates of the unemployment gap and make them less vulnerable to end-point revision, although this depends on the robustness of the estimated Phillips curve relationship between inflation and the unemployment gap. Moreover, because the Phillips curve equation specification has recently been revised to provide a stronger statistical relationship between inflation and the unemployment gap, the unemployment gap estimates should now be more robust to end-point revision than previously.

28. Prior to the November 2014 *OECD Economic Outlook*, the Phillips curve was a 'backward-looking' specification, so current inflation was partly explained by lags of past inflation, representing inflation expectations formed on the basis of past inflation outcomes (Richardson et al., 2000). The new approach adjusts this specification to incorporate the notion that inflation expectations are anchored around the central bank's inflation objective (Rusticelli et al., 2015). The new specification systematically outperforms the former, particularly in terms of the statistical significance of the unemployment gap, for an overwhelming majority of OECD countries over recent sample periods. The new specification also reduces real-time revisions to the unemployment gap following a similar testing procedure to that described for labour efficiency in the previous section (Rusticelli et al., 2015).[12] For example, for Italy – the G7 country which has experienced the largest increase in the unemployment rate since the financial crisis – the root mean square revisions to the unemployment gap is reduced from around 4 percentage points to 1 percentage point for the immediate pre-crisis period, and from over 7 percentage points to 1.7 percentage points for a representative post-crisis period.

5.2 Estimating the labour force gap

29. The method of estimating the labour force gap used at the time of the financial crisis involved taking an HP filter of actual labour force data extended using forecast data. This method has evolved to make use of the unemployment gap to try to ensure greater consistency between the labour force and unemployment gaps; thus if the labour market is depressed, then it might be expected both that unemployment would be in excess of the equilibrium rate and the labour force would be lower than the trend labour force because of a discouraged worker effect.

30. To introduce this consistency, a similar procedure to that used for the cyclical adjustment of labour efficiency in section 3 is used, but using an estimate of the unemployment gap as the adjustment variable (rather than manufacturing capacity utilisation or the investment rate). Thus a preliminary estimate of the labour force gap is derived by taking an HP filter of labour force data, and after discarding the final 2 years of data (because of possible end-point issues), this preliminary estimate is regressed on

12. This involves deriving an estimate of the unemployment gap on a reduced sample ending in a given pre-crisis period, the same method is then repeated over the full sample and the revision to the pre-crisis period calculated. This procedure is repeated using the old and new Phillips curve specifications; see Rusticelli et al. (2015) for details.

contemporaneous and lags of the unemployment gap. The regression coefficients are then used to derive a cyclically adjusted measure of the labour force (in the same manner as stage 3 described in section 4), to which an HP filter is applied to generate a final estimate of trend labour force.

31. Experimentation along the lines described in the previous section (although not reported in detail here), suggests that this procedure usually helps to reduce the extent of revisions relative to using an HP filter alone. Thus, when using only an HP filter (with lambda equal to 100), the average root mean square end-point absolute revision for the G7 for 2007 is 0.16 percentage points, whereas with the unemployment gap adjustment this is reduced to 0.04 percentage points. This finding does, however, depend on having a consistent measure of the unemployment gap, which itself is not subject to revision. Also the magnitude of the improvement is modest (relative to those achieved by the adjustment of labour efficiency), but this mainly reflects the fact that the labour force is much less volatile than labour efficiency. A further advantage of the procedure is that it produces greater consistency between the unemployment and labour force gaps, reducing the number of periods for which the unemployment and labour force gaps are of conflicting signs.[13]

6. On the importance of minimising revisions

32. Avoiding large revisions might be regarded as a necessary condition for output gap calculations being a useful input to macro policy and the present paper has explored methodological changes which aim to reduce such revisions. However, this is not the same as arguing that small revisions are a sufficient condition for output gap calculations to be useful, or even that smaller revisions from one method mean that it is necessarily superior to another method that produces larger revisions. Indeed, if the only criteria for judging the merit of a methodology were to minimise revisions, then it would be easy to derive a winning methodology; for example, a rule that the output gap is always zero![14] Slightly less trivially, choosing an HP filter with an extremely low lambda will produce a series of potential output which will closely 'hug' the series for actual GDP, with the consequence that real-time revisions of the output gap (rather than potential growth) would be small, but the absolute size of the output gap would always be so small as to be meaningless for policy purposes. It follows that, if the extent of end-point revisions to the output gap is one criteria to be used in discriminating between potential output methodologies, then it is important to provide a level playing field by ensuring that the smoothness of potential output estimates are similar across competing methodologies. In the current paper, this has been achieved by using the same value of lambda in the HP filter across competing approaches.

33. More generally, real-time reliability should not be the only criteria for evaluating output gaps. Other criteria should include: their ability to explain inflation, given that most definitions of potential output refer to a sustainable level of output consistent with stable inflation; whether the underlying methodology can be consistently applied across many countries, so providing a test of robustness; and finally, although difficult to formulate formally, output gap estimates should also pass a "smell test" in that they don't depart too widely from what country experts believe to be plausible.

34. Finally, and of particular relevance in judging the OECD's track record of published output gaps, it should be recognised that changes to methodology – which are usually implemented with the motive of improving estimates in some respect – are likely to worsen the consistency with the published track record of past output gap estimations. However, if the methodology succeeds, for example, in providing a closer

13. Conflicting signs here means that unemployment is above (below) the equilibrium rate whilst the labour force is above (below) the trend labour force.

14. A stopped clock is correct (only) twice a day in telling the time, but if its performance is judged not by how accurately it tells the time but by how often it is revised (i.e. not at all), then its performance would be judged to be perfect!

link between potential output and inflation – as Rusticelli et al. (2015) argue is the case in the revised estimation of the unemployment gap – then this should be judged as an improvement to the potential output methodology, which should contribute to reducing real time revisions in the future.

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APPENDIX 1. VINTAGES OF PUBLISHED OUTPUT GAPS FOR THE G7

The following tables show vintages of output gaps for each of the G7 economies which have been published in successive *OECD Economic Outlooks*. The vintages of estimates are shown in each row of the table, where the heading of the row "EOXX" denotes the number "XX" of the *Economic Outlook* which is published twice a year, in May/June and November/December and begins with the November 2005 issue (EO78) and finishes with the May 2015 issue (EO97). The output gap estimates shown are only those for which at least an initial outturn estimate for GDP would have been available at the time, for example, for the *Economic Outlook* published in May 2015 only the output gap up to 2014 is shown.

At the foot of the table is a summary of the revisions for each year. For any particular output gap estimate the revision is calculated as the difference between it and the estimate for the same year in the latest vintage (EO97). The average revision is then calculated as the average revision across all vintages shown. The largest revision is the largest revision in the absolute terms across all vintages. A final row notes where there has been a switch in the sign of the output gap across vintages.

United States

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	2.1	3.0	3.2	2.7	0.1	-4.5	-3.8	-3.9	-3.4	-3.0	-2.5
EO96	2.1	3.1	3.3	2.7	0.0	-4.7	-4.0	-4.2	-3.7	-3.4	
EO95	1.9	2.8	3.1	2.4	-0.2	-4.8	-4.2	-4.2	-3.4	-3.5	
EO94	2.0	3.0	3.3	2.8	0.3	-4.2	-3.5	-3.4	-2.6		
EO93	1.9	2.7	3.2	2.9	0.5	-4.2	-3.4	-3.4	-3.0		
EO92	2.0	2.7	3.0	2.6	0.1	-4.6	-4.0	-4.0			
EO91	2.1	2.8	3.1	2.8	0.2	-5.0	-3.7	-3.9			
EO90	1.4	2.3	2.7	2.5	0.2	-4.9	-3.7				
EO89	0.7	1.4	1.6	1.2	-0.8	-5.0	-3.8				
EO88	0.7	1.4	1.7	1.3	-0.7	-4.6					
EO87	0.7	1.2	1.3	0.9	-1.2	-5.1					
EO86	0.2	0.8	1.1	1.0	-0.9						
EO85	0.1	0.7	1.2	0.9	-0.5						
EO84	0.6	1.0	1.2	0.7							
EO83	0.0	0.5	0.7	0.4							
EO82	-0.1	0.4	0.7								
EO81	-0.4	0.1	0.7								
EO80	-0.6	-0.1									
EO79	-0.6	0.0									
EO78	-0.8										
Revision summary											
Average	**1.3**	**1.5**	**1.2**	**0.9**	**0.3**	**0.2**	**0.0**	**-0.1**	**-0.2**	**0.5**	
Largest	**2.8**	**3.1**	**2.6**	**2.3**	**1.3**	**0.6**	**0.4**	**-0.5**	**-0.8**	**0.5**	
Sign switch	**Y**	**Y**	**N**	**N**	**Y**	**N**	**N**	**N**	**N**	**N**	

Japan

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	-0.4	0.3	1.4	2.9	1.2	-4.8	-0.7	-1.6	-0.3	0.8	0.1
EO96	-0.4	0.3	1.4	2.9	1.2	-4.8	-0.8	-1.7	-0.7	0.2	
EO95	-0.4	0.3	1.4	3.0	1.3	-4.6	-0.6	-1.5	-0.7	0.2	
EO94	-0.4	0.3	1.4	3.0	1.3	-4.8	-0.9	-2.1	-0.9		
EO93	-0.4	0.3	1.4	3.0	1.3	-4.8	-0.9	-2.0	-0.8		
EO92	-0.4	0.2	1.2	2.8	1.0	-5.0	-1.3	-2.8			
EO91	0.1	0.8	1.8	3.4	1.6	-4.5	-0.8	-2.2			
EO90	-1.1	-0.1	1.2	3.0	1.1	-5.7	-3.2				
EO89	-1.1	-0.3	0.9	2.5	0.6	-6.4	-3.6				
EO88	-1.2	-0.3	0.8	2.4	0.4	-5.3					
EO87	-1.2	-0.3	0.7	2.2	0.1	-5.5					
EO86	-0.6	0.4	1.7	3.5	2.3						
EO85	-0.5	0.8	2.0	3.3	1.3						
EO84	-1.2	-0.5	0.7	1.6							
EO83	-1.4	-0.9	0.0	0.5							
EO82	-1.5	-0.9	-0.2								
EO81	-1.6	-1.2	-0.6								
EO80	-2.1	-1.0									
EO79	-1.9	-0.8									
EO78	-1.5										
Revision summary											
Average	**0.6**	**0.5**	**0.4**	**0.3**	**0.1**	**0.4**	**0.8**	**0.5**	**0.5**	**0.6**	
Largest	**1.7**	**1.5**	**1.9**	**2.4**	**1.1**	**1.6**	**2.9**	**1.2**	**0.6**	**0.6**	
Sign switch	**Y**	**Y**	**Y**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	

Germany

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	-1.6	-1.7	0.8	2.7	1.9	-4.8	-2.2	0.0	-0.6	-1.4	-0.9
EO96	-1.3	-1.4	1.1	3.0	2.2	-4.6	-2.1	0.2	-0.5	-1.3	
EO95	-2.2	-2.3	0.2	2.2	1.7	-4.5	-1.8	0.3	0.1	-0.6	
EO94	-2.2	-2.3	0.2	2.2	1.6	-4.5	-1.9	0.2	-0.1		
EO93	-1.7	-1.9	0.7	2.6	2.0	-4.2	-1.4	0.5	0.1		
EO92	-1.6	-1.9	0.5	2.4	1.6	-4.8	-2.1	-0.5			
EO91	-1.6	-1.8	0.6	2.5	1.7	-4.6	-2.3	-0.7			
EO90	-2.5	-2.6	0.2	2.2	1.6	-4.5	-2.3				
EO89	-2.2	-2.1	0.4	1.9	1.1	-4.7	-2.5				
EO88	-2.0	-2.0	0.3	1.6	0.6	-5.2					
EO87	-1.8	-1.7	0.4	1.5	0.9	-5.2					
EO86	-1.6	-1.3	1.1	2.6	2.4						
EO85	-1.6	-1.3	1.0	2.6	1.9						
EO84	-1.6	-1.8	0.1	1.2							
EO83	-2.0	-2.3	-0.6	0.5							
EO82	-2.1	-2.6	-1.0								
EO81	-2.0	-2.4	-0.9								
EO80	-1.8	-2.2									
EO79	-1.5	-1.9									
EO78	-1.6										
Revision summary											
Average	0.2	0.3	0.6	0.6	0.3	-0.1	-0.2	0.0	-0.5	-0.5	
Largest	0.9	0.9	1.9	2.2	1.3	-0.6	-0.9	0.7	-0.7	-0.8	
Sign switch	N	N	Y	N	N	N	N	Y	Y	N	

France

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	1.0	1.1	2.2	3.0	1.7	-2.2	-1.3	-0.2	-1.0	-1.3	-2.3
EO96	1.1	1.1	2.2	3.0	1.7	-2.2	-1.3	-0.2	-0.8	-1.4	
EO95	1.3	1.7	2.9	3.6	1.8	-2.2	-1.6	-0.8	-2.0	-2.9	
EO94	1.0	1.4	2.6	3.3	1.5	-2.5	-1.9	-1.2	-2.3		
EO93	1.2	1.6	2.8	3.5	1.8	-2.3	-1.8	-1.3	-2.4		
EO92	1.3	1.6	2.6	3.2	1.4	-2.7	-2.3	-2.0			
EO91	1.2	1.5	2.5	3.0	1.1	-3.0	-2.7	-2.5			
EO90	-0.2	-0.1	0.9	1.4	-0.4	-3.9	-3.6				
EO89	-0.4	-0.2	0.4	0.8	-0.6	-4.3	-4.1				
EO88	-0.4	-0.2	0.4	1.0	-0.4	-3.8					
EO87	-0.4	-0.3	0.3	0.7	-0.6	-4.5					
EO86	0.0	0.3	1.1	1.8	0.4						
EO85	-0.1	0.2	1.1	1.8	0.2						
EO84	-0.3	-0.1	0.7	0.9							
EO83	-0.4	-0.4	0.1	0.3							
EO82	-0.3	-0.6	-0.3								
EO81	-1.4	-1.9	-1.6								
EO80	-1.4	-2.0									
EO79	-1.3	-1.8									
EO78	-1.2										
Revision summary											
Average	1.1	1.0	1.0	1.0	1.0	0.9	1.1	1.1	0.9	0.8	
Largest	2.4	3.2	3.8	2.7	2.3	2.3	2.8	2.3	1.4	1.6	
Sign switch	Y	Y	Y	N	Y	N	N	N	N	N	

Italy

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	1.2	1.4	2.6	3.3	1.8	-3.9	-2.4	-1.7	-4.4	-5.8	-6.1
EO96	1.3	1.3	2.4	3.2	1.6	-4.1	-2.4	-1.9	-3.9	-5.6	
EO95	0.8	0.9	2.4	3.2	1.5	-4.3	-2.8	-2.3	-4.3	-5.6	
EO94	0.9	1.1	2.5	3.3	1.5	-4.3	-2.8	-2.4	-4.6		
EO93	1.0	1.1	2.5	3.3	1.6	-4.2	-2.8	-2.4	-4.5		
EO92	1.2	1.3	2.6	3.3	1.5	-4.4	-2.9	-2.8			
EO91	0.9	0.9	2.3	3.0	1.2	-4.6	-3.1	-2.8			
EO90	0.3	0.7	2.3	3.3	1.5	-3.7	-2.2				
EO89	-0.1	0.2	1.6	2.2	0.4	-4.9	-3.6				
EO88	-0.5	-0.3	1.0	1.5	-0.4	-5.5					
EO87	-0.6	-0.4	1.0	1.6	-0.3	-5.5					
EO86	-0.7	-0.5	0.9	1.5	-0.6						
EO85	-0.8	-0.7	0.7	1.2	-0.9						
EO84	-0.5	-0.8	-0.2	0.2							
EO83	-0.9	-1.5	-1.1	-1.2							
EO82	-1.5	-2.4	-1.7								
EO81	-1.2	-2.4	-1.8								
EO80	-0.3	-1.5									
EO79	-0.3	-1.4									
EO78	-0.3										
Revision summary											
Average	1.2	1.6	1.5	1.2	1.0	0.6	0.5	0.7	-0.1	-0.2	
Largest	2.6	3.8	4.4	4.5	2.7	1.5	1.3	1.1	-0.5	-0.3	
Sign switch	Y	Y	Y	Y	Y	N	N	N	N	N	

United Kingdom

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	1.1	1.7	2.8	3.5	1.7	-3.5	-2.4	-1.7	-2.2	-1.8	-0.8
EO96	1.3	1.8	2.8	3.5	1.5	-3.7	-2.7	-2.0	-2.4	-1.9	
EO95	0.9	2.0	3.0	4.9	2.6	-3.4	-2.5	-2.1	-2.8	-2.4	
EO94	0.9	2.0	3.0	4.9	2.6	-3.3	-2.3	-1.9	-2.7		
EO93	1.1	1.7	2.4	4.4	1.9	-2.9	-1.8	-1.5	-2.1		
EO92	1.2	1.7	2.5	4.4	2.0	-2.8	-1.7	-1.4			
EO91	1.6	1.6	2.5	4.4	1.8	-3.5	-2.4	-2.6			
EO90	1.6	1.4	1.8	3.2	0.7	-4.4	-3.5				
EO89	1.2	1.3	2.0	2.7	1.1	-4.6	-3.6				
EO88	1.0	1.0	1.8	2.6	1.0	-5.0					
EO87	1.0	0.9	1.5	1.8	0.1	-6.4					
EO86	1.0	0.9	1.5	1.8	0.0						
EO85	0.7	0.5	1.1	1.9	0.4						
EO84	0.5	0.0	0.4	1.3							
EO83	0.9	-0.3	-0.2	0.2							
EO82	0.7	-0.1	0.0								
EO81	0.6	-0.1	-0.2								
EO80	0.6	-0.3									
EO79	0.6	-0.5									
EO78	0.5										
Revision summary											
Average	**0.2**	**0.8**	**1.1**	**0.5**	**0.4**	**0.5**	**0.1**	**0.2**	**0.3**	**0.4**	
Largest	**0.7**	**2.2**	**2.9**	**3.3**	**1.7**	**2.8**	**1.1**	**0.9**	**0.7**	**0.6**	
Sign switch	**N**	**Y**	**Y**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	

Canada

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EO97	0.7	1.4	1.6	1.4	0.5	-3.7	-2.1	-1.1	-1.2	-1.1	-0.5
EO96	1.0	1.7	2.0	1.8	1.0	-3.1	-1.5	-0.4	-0.4	-0.2	
EO95	1.2	1.9	2.2	2.0	1.2	-3.0	-1.4	-0.7	-0.9	-0.8	
EO94	1.2	1.9	2.2	2.0	1.3	-2.9	-1.2	-0.4	-0.5		
EO93	1.3	1.9	2.2	2.2	1.4	-2.8	-1.2	-0.4	-0.4		
EO92	1.3	1.9	2.2	2.1	1.2	-2.9	-1.4	-0.7			
EO91	1.4	1.9	2.4	2.4	1.1	-3.1	-1.5	-1.1			
EO90	0.9	1.3	1.5	1.3	-0.1	-4.4	-2.8				
EO89	0.6	0.9	1.0	0.7	-1.1	-5.2	-3.9				
EO88	0.7	0.9	0.9	0.7	-0.9	-5.1					
EO87	0.7	0.9	0.9	1.0	-1.0	-5.3					
EO86	0.8	1.2	1.3	1.6	-0.2						
EO85	0.4	0.9	1.2	1.5	-0.4						
EO84	0.6	0.8	1.3	1.6							
EO83	0.4	0.5	0.4	0.2							
EO82	0.5	0.6	0.6								
EO81	0.5	0.4	0.0								
EO80	0.5	0.4									
EO79	0.2										
EO78	0.1										
Revision summary											
Average	**0.0**	**0.3**	**0.2**	**-0.1**	**0.2**	**0.1**	**-0.3**	**-0.5**	**-0.6**	**-0.6**	
Largest	**0.6**	**1.4**	**1.6**	**1.2**	**1.6**	**1.7**	**1.8**	**-0.8**	**-0.8**	**-0.9**	
Sign switch	**N**	**Y**	**N**	**N**	**Y**	**N**	**N**	**N**	**N**	**N**	

APPENDIX 2. DECOMPOSING OUTPUT GAP REVISIONS BETWEEN ACTUAL GDP AND POTENTIAL OUTPUT*

The output gap is defined as the difference between actual GDP and potential output, so that following the notation used in Section 2:

$$GAP = y - y^* \qquad [A2\text{ -}1]$$

Hence, any revision (denoted "Rev") to the output gap must be accounted for by a revision to actual GDP or potential output:

$$Rev(GAP) = Rev(y)-Rev(y^*) \qquad [A2\text{-}2]$$

To analyse output gap revisions for the G7 economies since 2004, revisions are defined as the difference between an 'initial' and 'final' estimate of the output gap. The initial output gap estimate for a particular year is defined as the first estimate that was published once GDP first was available for that year. The final estimate is taken to be the estimate published in the May 2015 *Economic Outlook*.

In practice, the decomposition analysis is not as straightforward as suggested by equation (A2-2) because of re-basing of national accounts data. To overcome this problem, the data is indexed by defining GDP in the first year (2004) in the first vintage of data as 100.0. Subsequent vintages of GDP and potential output, which remain on the same base year, are divided by 2004 GDP (and multiplied by 100) in the first vintage of data. However, when a new vintage of data has a different base year, then it is assumed that the GDP index for 2004 is the same as in the previous vintage of data (which is not necessarily 100.0) and GDP and potential output in all subsequent years are divided by this new level of 2004 GDP. This re-scaling of the data ensures that the output gaps in the original data are always preserved.

On this basis, revisions to the output gap over the period 2004-13 can be decomposed into revisions to actual GDP and to potential output (Table A2.1). The magnitude of the correlation coefficient between revisions to the output gap and revisions to potential output is 0.82, whereas between revisions to the output gap and revisions to GDP it is only 0.12. Focusing on the largest revisions to the output gap, where there has been a revision to the output gap of more than two (one) percentage points, in 90% (85%) of cases the main contribution has been a revision to potential output rather than GDP.

* Particular thanks are due to Sylvie Toly for undertaking this analysis.

Table A2.1. The contribution to output gap revisions from GDP and potential output

(percentage points)

		(1)	(2)	(3)
			Due to revision in	
		Output gap revision	GDP	Potential GDP
United States	2004	**2.8**	0.0	**2.8**
	2005	**3.0**	-0.2	**3.0**
	2006	**2.6**	0.0	**2.5**
	2007	**2.3**	0.4	**1.8**
	2008	0.6	-0.6	1.2
	2009	0.1	-0.3	0.4
	2010	0.1	-0.6	0.7
	2011	0.0	0.4	-0.5
	2012	-0.4	0.7	-1.1
	2013	0.5	-0.3	0.8
Japan	2004	**1.1**	0.0	**1.2**
	2005	**1.1**	0.0	**1.1**
	2006	**1.9**	-0.1	**2.0**
	2007	**2.4**	-0.2	**2.6**
	2008	-0.1	-0.4	0.3
	2009	0.5	-0.2	0.8
	2010	**2.9**	**1.5**	**1.4**
	2011	0.6	1.7	-1.0
	2012	0.5	-0.1	0.5
	2013	0.6	0.4	0.2
Germany	2004	0.0	0.0	0.0
	2005	0.2	-0.2	0.4
	2006	**1.7**	**1.1**	0.7
	2007	**2.2**	**2.1**	0.1
	2008	0.1	1.7	-1.6
	2009	0.4	0.4	0.0
	2010	0.2	0.8	-0.6
	2011	0.7	0.4	0.3
	2012	-0.7	-0.3	-0.3
	2013	-0.8	-0.8	0.0
France	2004	**2.2**	0.0	**2.2**
	2005	**2.9**	0.2	**2.7**
	2006	**3.8**	**1.2**	**2.6**
	2007	**2.7**	0.2	**2.4**
	2008	**1.5**	-0.2	**1.7**
	2009	**1.6**	-0.4	**2.1**
	2010	**2.8**	0.2	**2.6**
	2011	**2.3**	0.9	**1.4**
	2012	**1.4**	**1.2**	0.3
	2013	**1.6**	**1.2**	0.4

Table A2.1. The contribution to output gap revisions from GDP and potential output (*cont'd)*

(percentage points)

		(1)	(2)	(3)
		Output gap revision	Due to revision in	
			GDP	Potential GDP
United Kingdom	2004	0.7	0.0	0.6
	2005	**2.2**	**1.0**	**1.2**
	2006	**2.9**	**1.1**	**1.8**
	2007	**3.3**	-0.1	**3.3**
	2008	**1.3**	-2.7	**3.9**
	2009	**1.5**	**1.2**	0.4
	2010	**1.1**	**1.7**	-0.5
	2011	0.9	1.9	-1.0
	2012	-0.1	0.8	-0.9
	2013	0.6	1.5	-0.9
Italy	2004	**1.5**	-0.1	**1.6**
	2005	**2.8**	0.9	**1.9**
	2006	**4.4**	0.8	**3.6**
	2007	**4.5**	0.0	**4.3**
	2008	**2.7**	-0.5	**3.1**
	2009	**1.5**	-0.6	**2.2**
	2010	**1.3**	0.0	**1.3**
	2011	**1.1**	-0.2	**1.3**
	2012	0.1	-0.5	0.6
	2013	-0.2	-0.4	0.2
Canada	2004	0.6	0.0	0.6
	2005	**1.4**	0.3	**1.1**
	2006	**1.6**	0.1	**1.4**
	2007	**1.2**	-0.6	**1.8**
	2008	0.9	0.2	0.8
	2009	**1.4**	0.2	**1.3**
	2010	**1.8**	0.4	**1.4**
	2011	0.0	0.9	-1.0
	2012	-0.8	0.8	-1.6
	2013	-0.3	0.6	-0.9

Note: The output gap revision shown in column (1) is the difference between the 'initial estimate' taken from the *Economic Outlook* when the GDP outturn for that year was first known and a final estimate, here taken to be the estimate in the May 2015 *Economic Outlook*. This output gap revision is decomposed into a revision from GDP and a revision from potential output, where downward revisions to potential output are shown as positive number, so that column (1) = column (2) + column (3). Revisions to the output gap of more than 1 percentage point are highlighted with bolding.

APPENDIX 3. THE OECD FRAMEWORK FOR ESTIMATING POTENTIAL OUTPUT

Estimates of potential output are based on an aggregate production function approach using trend input components. For all countries a whole economy approach is employed using a commonly specified production function, namely a constant-returns-to-scale Cobb-Douglas production function with Harrod-neutral labour-augmenting technical progress, which can be represented as the following, using mnemonics as they appear in ADB and EO databases:

$$GDPV = \left(EFFLAB * ET\right)^{\alpha} \left(KPTV\right)^{1-\alpha} \quad \text{[A3-1]}$$

where: *ET* denotes total employment (the national account measure where available, otherwise a labour force survey based measure); *KPTV* represents the whole economy measure of productive capital (where the source of capital stock data differs between countries as shown in Table A3.1); *EFFLAB* represents labour efficiency, which is not directly observable and is therefore calculated as a residual; and α is assumed to be 0.67 for all countries.

Total employment can be decomposed into the product of: the rate of participation for those aged 15-74 (*LFPR1574*); the population aged 15-74 (*POP1574*); (one minus) the rate of unemployment (*UNR*); and an adjustment (*CLF*) to ensure consistency between the labour force definition of employment and the population measure.

$$ET = POP1574 * LFPR1574 * CLF * (1 - UNR) \quad \text{[A3-2]}$$

Combining [A1-1] and [A1-2], the representation of output becomes:

$$GDPV = \left(EFFLAB * POP1574 * LFPR1574 * CLF * (1 - UNR)\right)^{\alpha} \left(KPTV\right)^{1-\alpha} \quad \text{[A3-3]}$$

Thus, the level of potential output (*GDPVTR*) is calculated by substituting trend variables in [A1-3], with the exception of capital (which remains at its actual value). The trend level of unemployment (*NAIRU*) is estimated using a Kalman filter within the context of a Phillips curve equation with anchored inflation expectations (see Rusticelli et al., 2015). The trend rate of participation (*LFPRS1574*) is determined by an HP filter of the actual participation rate extended by projections which distinguish age and gender cohorts and the unemployment gap, which are then filtered.

Trend labour efficiency is computed with an HP filter, with historical data extended with projections to try to limit end-point bias. Potential output is then calculated as:

$$GDPVTR = \left(EFFLABS * POPS1574 * LFPRS1574 * CLFS * (1 - NAIRU)\right)^{\alpha} \left(KPTV\right)^{1-\alpha} \quad \text{[A3-4]}$$

where *EFFLABS*, *LFPRS1574*, *POPS1574*, and *CLFS* are the trended counterparts of *EFFLAB*, *LFPR1500*, *POP1500* and CLF, respectively. Thus equation [A1-4] relates the evolution of potential output to trends in labour efficiency, potential employment and actual capital input.

Table A3.1. Sources of capital stock data

Data from OECD Statistics Directorate	AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ITA, JPN, KOR, NLD, NZL, PRT, SWE, USA
Constructed using a Perpetual Inventory Method	GRC, CHL, COL, CZE, HUN, ISL, ISR, LVA, LUX, MEX, NOR, POL, SWE, SVK, SVN, TUR, RUS, ARG, BRA, IDN, IND, SAU
Obtained from national sources	CHN, ZAF