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Output trends and Okun's law

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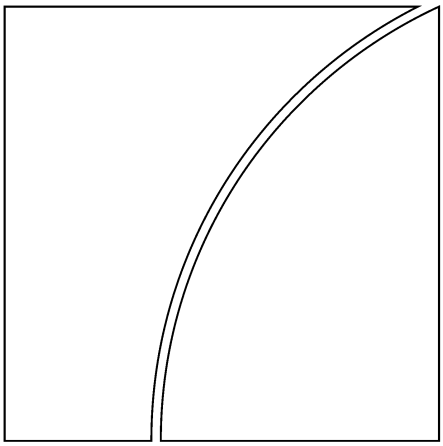

Abstract

This paper estimates trend growth rates for a sample of industrial countries by applying Okun's law in first differences. Despite the simplicity of the approach and the restrictive assumptions, the method typically yields reasonable results when trend shifts in the Okun coefficients and changes in structural unemployment are allowed for. Particular caution is required in using the method for estimating output gaps.

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1. Introduction[1]

The primary purpose of this paper is to examine whether a first-difference version of Okun's law can be used to derive estimates of trend output growth. Second, the paper analyses whether it is possible to use trend growth rates thus derived in constructing measures of the output gap.

The empirical results suggest that, once periodic changes are allowed for, the parameters obtained by regressing changes in unemployment on output growth provide plausible measures of trend output growth. However, using these measures to construct output gaps is problematic, inter alia because of structural changes in the rate of unemployment. Consequently, we derive a second set of estimates where trend changes in unemployment are also allowed for. This departure from the original Okun law produces different estimates of trend output growth and more plausible measures of output gaps. This result implies that developments in output and labour markets have significantly diverged over the sample period. Consequently, estimates of trend output growth derived from Okun equations must be interpreted and used with caution. Nonetheless, our results compare reasonably well with other recent estimates of the "Okun coefficient" as well as with estimates of potential growth rates (HP filter, OECD estimates). In fact, our coefficients are in most cases similar in both size and variations over time and across countries (see Table 1).

Section 1.1 below provides a brief discussion of Okun's law and the underlying assumptions. In Section 2 our estimation procedures are described. Section 3 discusses the most plausible results for the sample countries, including regressions where trend changes in unemployment are allowed for; the results are compared with trend rates of growth obtained from alternative sources and methods of estimation. Section 4 concludes.

1.1 Okun's law

Talking of Okun's law requires a conscientious distinction between a relationship expressed in levels and one expressed in changes. As already indicated in the title of his famous article "Potential GNP: its measurement and significance" (Okun (1962)), Okun was primarily interested in deriving a measure of potential GNP, ie a relationship in *levels*, assuming a "natural" rate of unemployment of 4%. He tested various regressions of the rate of unemployment on the output gap and selected those that met statistical criteria and were compatible with the assumed natural rate.[2] The estimated coefficients on the gap ranged between –0.28 and –0.38, depending on the trend growth and the sample period chosen. In other words, according to Okun's estimates each percentage point change in the rate of unemployment is associated with an output change of about 3%. However, Okun also presented estimates based on *changes* in GDP and unemployment (which do not need any assumptions with respect to the natural rate of unemployment or the trend rate of growth) and the output coefficients were very close to those obtained from the level regressions.

1.2 Underlying assumptions of the estimates

Since Okun's results were first published, many others have replicated his equation for the United States and the estimated coefficients have remained remarkably stable. Indeed, Okun's equation is frequently regarded as an "empirical law" and widely applied when converting unemployment data into data on the output gap (and vice versa). Estimates have also been extended to include other countries but, in most cases, the coefficients have been much less stable than for the United States and the results generally less satisfactory.

[1] My special thanks go to Palle Andersen. This paper would not have been written without his continuous, patient advice. I am also grateful to Jeffery Amato, Claudio Borio, Stefan Gerlach and Willi Fritz for their comments.

[2] He tested various versions of trend growth rates and benchmark levels so that the output gap was zero when the unemployment rate was 4%.

Table 1

Comparison of estimates of Okun coefficients[1]

Country	Own estimates[2]	Lee[3]	Moosa[4]	Others[5]
United States	(1954-2000) –0.42 (1990-2000) –0.44	(1955-96) –0.54	(1960-95) –0.46	(1948-88) –0.31 (Weber) (1960-96) 0.46 (Altig et al) (1990-95) –0.51 (Kahn) (1975-97) –0.44 (Buscher et al)
Japan	(1962-2000) –0.04 (1993-2000) –0.21	(1955-96) –0.23	(1960-95) –0.09	(1975-99) –0.21 (Haltmaier)
Germany	(1964-2000) –0.27 (1992-2000) –0.52	(1960-96) –0.40	(1960-95) –0.41	(1975-97) –0.27 (Buscher et al)
France	(1966-2000) –0.17 (1992-2000) –0.60	(1955-96) –0.34	(1960-95) –0.36	
Italy	(1962-2000) –0.14 (1992-2000) –0.78	(1955-96) –0.92	(1960-95) –0.18	
United Kingdom	(1963-2000) –0.50 (1991-2000) –0.75	(1955-96) –0.72	(1960-95) –0.37	(1975-90) –0.41 (Buscher et al) (1991-96) –0.50 (Buscher et al)
Canada	(1962-2000) –0.33 (1990-2000) –0.48	(1955-96) –0.60	(1960-95) –0.49	
Euro area	(1966-2000) –0.23 (1992-2000) –0.67			
Australia	(1961-2000) –0.36 (1991-2000) –0.50	(1955-96) –0.65		
Netherlands	(1971-2000) –0.65 (1992-2000) –0.58	(1955-96) –0.90		(1975-97) –0.37 (Buscher et al)
Spain	(1965-2000) –0.48 (1992-2000) –0.95			
Sweden	(1961-2000) –0.25 (1991-2000) –0.38	(1955-96) –0.53		

[1] Estimated slope coefficient(s). [2] Change in the unemployment rate regressed on current and lagged changes in log GDP using annual data; OLS. [3] Growth regressed on the change in unemployment (coefficients inverted). [4] Cyclical unemployment regressed on its lagged values and the cyclical component of log GDP. [5] Buscher et al: change in the rate of unemployment regressed on its lagged values and the lagged output gap; Kahn, Haltmaier: coefficients are derived from growth decomposition and refer to the impact of growth on the employment rate; Weber: static OLS, unemployment gap regressed on the output gap (structural break in 1973).

As we do not have any reliable estimates of the natural rate of unemployment, this note applies the Okun equation in its first-difference version and mainly with a view to finding rates of potential growth.[3] To see the rationale behind this approach, consider the equation:[4]

$$\Delta u = \mu + \phi \Delta y + \varepsilon \qquad \text{(i)}$$

where *u* is the rate of unemployment (possibly in natural logs[5]), *y* is log real GDP and ε is a random error. When the rate of unemployment is constant, it can be assumed that *y* is growing at its potential rate (Δy^*), which can be derived from the estimated values of μ and ϕ as $-\mu/\phi$.

However, before looking at the empirical results and their interpretation, it is useful to discuss the stringent assumptions underlying the Okun equation. In doing so, we follow Prachowny (1993), who starts from a Cobb–Douglas production function (in natural logs) with constant returns to scale:[6]

$$y = \alpha(k + c) + (1 - \alpha)(\gamma n + \delta h) + \tau \qquad \text{(ii)}$$

where *y* is output, *k* capital input, *c* the capital utilisation rate, *n* the number of workers employed, *h* the average number of hours worked and *t* disembodied technological change. Similarly, potential output (y^*) can be written as a function of inputs at their long-run equilibrium levels:

$$y^* = \alpha(k^* + c^*) + (1 - \alpha)(\gamma n^* + \delta h^*) + \tau^* \qquad \text{(iii)}$$

so that the output gap and its composition can be written as:

$$(y - y^*) = \alpha(k - k^*) + \alpha(c - c^*) + (1 - \alpha)\gamma(n - n^*) + (1 - \alpha)\delta(h - h^*) + (\tau - \tau^*) \qquad \text{(iv)}$$

If labour supply is denoted by *s*, the rate of unemployment can be approximated by $u = s - n$[7] and the equilibrium or natural rate as $u^* = s^* - n^*$. Substituting into (iii) then gives:

$$(y - y^*) = \alpha(k - k^*) + \alpha(c - c^*) + (1 - \alpha)\gamma(s - s^*) - (1 - \alpha)\gamma(u - u^*) + (1 - \alpha)\delta(h - h^*) + (\tau - \tau^*) \qquad \text{(v)}$$

Estimates of Cobb-Douglas production functions usually produce employment coefficients of about 0.75, ie only a quarter of the size of the coefficient obtained by Okun when estimating the relationship between output and unemployment directly. Consequently, in order to obtain a rise in actual output relative to potential of 3% when the rate of unemployment declines by 1 percentage point, other inputs would have to change as well. For instance, if we let both γ and δ = 1, implying that a 1% change in labour supply and hours worked would have the same impact on the output gap, a 1 point fall in unemployment, accompanied by a 3% rise in average hours worked or in labour supply, would raise output by 3% relative to potential. A similar rise in output would be observed if the 1 point fall in unemployment were accompanied by a 9% rise in the capital stock or in the capacity utilisation rate.

These are quite stringent assumptions and they also need to be kept in mind when estimating the Okun equation in first differences: as a starting point, consider (v), written in log changes:

$$\Delta(y - y^*) = \alpha\Delta(k - k^*) + \alpha\Delta(c - c^*) + (1 - \alpha)\gamma\Delta(s - s^*) - (1 - \alpha)\gamma\Delta(u - u^*) + (1 - \alpha)\delta\Delta(h - h^*) + \Delta(\tau - \tau^*) \qquad \text{(vi)}$$

Putting the rate of unemployment on the left-hand side, letting $\gamma = \delta = 1$ and normalising yields:

$$\Delta u = -\lambda\Delta(y - y^*) + \lambda\alpha\Delta(k - k^*) + \lambda\alpha\Delta(c - c^*) + \Delta(h - h^*) + \Delta(s - s^*) + \Delta u^* + \lambda\Delta(\tau - \tau^*) \qquad \text{(vii)}$$

where $\lambda = 1/(1-\alpha)$

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[3] Lee (2000) performs a comprehensive re-estimation of Okun coefficients for most of the OECD countries. He presents three types of estimates in levels and one in changes, which is similar to the one used in this note. Table 1 gives a comparison of the Okun coefficients obtained by Lee and those found in this note.

[4] Okun estimated $\Delta u = .30 - .30\Delta y$ for the US economy for 1947-60, see Okun (1962).

[5] Estimates based on changes in log levels would have been the correct procedure to apply. However, for small changes in unemployment, it should not make much of a difference, so we followed the usual practice and regressed changes in the rate of unemployment on log changes in GDP.

[6] Prachowny presents his arguments in terms of a production function in levels. However, as can be seen below, they also hold for an equation in changes.

[7] Expressed in levels, the unemployment rate is $U = (S - N)/S = 1 - N/S$ and in logs approximately = $s - n$.

From this it is easily seen that Δu is not only determined by developments in output. Even when $\Delta y = \Delta y^*$, unemployment will tend to fall if, ceteris paribus, the average number of working hours or the labour force decline relative to their long-run values. Similarly, a decline in the capital stock or in its utilisation will, ceteris paribus, put downward pressure on unemployment. Conversely, a pickup in the rate of disembodied technical progress or in the natural rate of unemployment will raise unemployment, given output growth. While it is possible to simplify (vii) through various not very restrictive assumptions,[8] the fact remains that when applying (i) in estimating (vii), we are likely to encounter various biases and problems of interpretation. First, when using only output growth as the explanatory variable, the estimates of λ will be subject to a missing-variable bias. Since the direction or sign of the bias depends on the strength and signs of the covariances being suppressed, it is generally not possible to predict the deviation of the estimated λ from its true value.[9] Second, and more importantly, when combining all variables other than Δy into the intercept term, there are numerous potential sources of changes in the intercept, only some of which affect potential output growth. Consequently, the growth rate derived by setting $\Delta u = 0$ can best be interpreted as the rate of output growth which is compatible with a constant rate of unemployment and not necessarily as potential output growth. Third, generally it is not possible to say whether changes in a variable not included in our estimates would affect the slope coefficient or the intercept or both. Similarly, sectoral shifts (for instance from industry to services) may affect the intercept term or the slope, or both.[10]

In addition to these implicit assumptions regarding the development of variables other than GDP growth which determine the change in unemployment, there are methodological caveats such as possible cointegration between output and unemployment, both of which are I(1) variables for many countries.[11] Another point to bear in mind is a possible asymmetry between phases of increasing and decreasing output. We have not pursued this systematically.[12]

2. Estimation procedures

The problems mentioned above may not be too serious as long as the sample period is relatively short and purged of cyclical biases. However, for longer periods (several decades) an assumption of stable parameters is rather restrictive and, most likely, unrealistic. Consequently, we have estimated (i) over a long period as well as over subperiods.[13] The subperiods were chosen to cover full cycles with cyclical peaks as start and endpoints. In line with the common definition, a quarterly peak in GDP is characterised by two subsequent quarters of decreases in GDP. To get a "feel" for the plausibility of this approach and for the potential parameter changes, we started with annual data and then repeated

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[8] For instance, s and h as well as c and k might be combined into single variables and, given the constant returns to scale assumption, we might simplify further by measuring $(k+c)$ per working hour.

[9] Consider the case where labour supply changes procyclically and the covariance of $\Delta(y-y^*)$ and $\Delta(s-s^*)$ is positive. If this is the only missing variable, λ will tend to be understated compared with its true value and the equation will (falsely) give the impression that the production process is not very labour-intensive, as the expected reduction in the rate of unemployment is not observed due to a cyclical rise in the labour supply. Similarly, if there is a (policy-induced or autonomous) change in the behaviour of labour supply so that it becomes less procyclical than it used to be, ignoring such a change will lead to an upward bias on λ and an impression that the production process has become more labour-intensive. Mostly, however, there will be more than one missing variable, rendering such interpretations difficult.

[10] This ambiguity is clearly evident in our empirical estimates that allow both the intercept and the slope coefficient to change between periods. In general, we tried to overcome the problem by allowing only one parameter change and selected it on grounds of plausibility. However, alternative tests and calculations showed that estimates of trend growth are more or less the same regardless of whether dummies are used for the constant or for the slope coefficient.

[11] Lee (2000) has done extensive work on this, finding that: "... estimates of the short-run relationship between output and unemployment are not particularly sensitive to the presence of their long-run co-movements" (p 343); on the issue of cointegration, see also Attfield and Silverstone (1997) and (1998).

[12] Looking at the subperiods, there would be too few observations with decreasing GDP. Lee's findings suggest that for periods with decreasing unemployment rates, the Okun coefficients for the United States and Japan are significantly lower than for periods with increasing unemployment rates, indicating that employment effects are larger when growth is low or negative; the reverse appears to hold for Canada, France and the Netherlands (see also Viren (2001)).

[13] Thus differing from Lee (2000), who estimated over a single long period only.

the exercise on quarterly data for the most recent cycle. More specifically, potential parameter shifts were estimated, using the specification:

$$\Delta u = \mu_o + d_i\mu_i + \phi_o \Delta y + d_i\phi_i \Delta y_i + \varepsilon \qquad \text{(viii)}$$

where the parameters with the subscript *o* refer to the basic equation, estimated over the whole period without parameter shifts, *i* refers to the subperiods between cyclical peaks and d_i are dummy variables which take the value 1 for the selected subperiod and otherwise are set to 0. As an illustration, assume that $d_i\mu_i$ for *i* = 1990-2000 is found to be significantly positive whereas $d_i\phi_i$ is insignificant. In that case, trend or potential growth would have increased from $-\mu_o/\phi_o$ to $-(\mu_o + d_i\mu_i)/\phi_o$ for the period 1990-2000. Similarly, if both $d_i\mu_i$ and $d_i\phi_i$ are significantly positive for 1990–2000, potential growth would be calculated as $\Delta y^* = -(\mu_o + d_i\mu_i)/(\phi_o + d_i\phi_i)$ which may be either higher or lower than $-\mu_o/\phi_o$, depending on the relative size of the parameter changes.[14]

Estimates were done separately for each of the G7 countries, the euro area as a whole, and for a few other countries (Australia, the Netherlands, Sweden and Spain). The trends obtained from estimates of the Okun relation are very close to the actual average growth rates for the full sample period as well as for subperiods (eg Canada, the United Kingdom). However, for others the estimated trend growth rates deviate from the actually observed peak-to-peak trends in all subperiods (eg Italy, Japan). For nearly all countries the quarterly estimates (Annex Tables 2a and 2b) for the most recent cycle lead to trend growth rates similar to the annual estimates, ie not deviating by more than 0.2 percentage points.

In a second step, we used in our annual estimates demeaned changes in the unemployment rate as the dependent variable. This adjustment explicitly takes into account that not all changes in the output/unemployment relationship are cyclical but may also reflect long-term developments.[15] Consequently, trend growth of GDP has to be reinterpreted as the growth rate, which is necessary to keep the change in unemployment in line with its mean change. The adjustment of the trend growth rate with respect to its non-demeaned version depends on the trend change in unemployment $\Delta\underline{u}$ and the size of the originally estimated coefficients.[16] A positive $\Delta\underline{u}$ would imply that less growth would be required to keep unemployment stable, hence leading to a downward adjustment of our trend estimation.

Next, the implied output gaps were compared with other estimates. For the recent cycle, Graphs 2a and 2b present gaps derived from the annual estimates using both equation (i) and its demeaned version, whereas the gaps in Graphs 3a and 3b are based on quarterly estimates of equation (i).[17] For both sets of graphs, the gaps were calculated by applying the estimated trend growth rates to actual GDP in a period (the base period) when, according to the OECD figures, the output gap was closed or very small and thus actual output equal to potential output. This is somewhat arbitrary and there is no specific reason to assume that the trend growth rate equals the actual growth rate when the output gap is closed. However, since the output gaps are based on levels rather than rates of change, it was necessary to select a base period for the gap calculations.

Finally, allowing for continuous rather than discrete changes in the unemployment/output relationship, we also compared our estimates with results derived from rolling regressions. Trend growth rates derived from rolling regressions with the change in unemployment defined as the deviation from its mean change in the period typically do not deviate from actual growth rates during the period. However, there is a problem concerning the choice of the regression window given changes in the length and intensity of cycles.

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[14] As noted above, the parameter changes are highly interdependent and in the final estimates discussed below, only one parameter shift is included.

[15] The distinction between long-term and short-term Okun coefficients is common (see eg Moosa (1997), Buscher et al (2000)).

[16] The growth rate is to be adjusted by $\Delta\underline{u}/\Sigma\phi_i$% with respect to its non-demeaned version. $\Delta\underline{u}$ refers to the mean change in each subperiod.

[17] Quarterly data for the usually semiannual OECD gap estimates were generated using the Ginsburgh method.

To facilitate reading of the paper, the various trend estimates are summarised in one table and one graph per country, while details of the estimates are given in Annex Tables 1a-1l and 2a-2b. Graphs of annual and quarterly GDP gaps are presented at the end of the text.

3. Country results

The annual regressions for the *United States* generate coefficients that are significant for all subperiods (Annex Table 1a). There is nearly no autocorrelation in the residuals, indicating that the Okun relation is not misspecified. Nonetheless, the parameters have not been entirely stable and the diagnostic statistics improve when separate subperiods are allowed for. Against the background of recent discussions in the literature as well as among policymakers, the trend estimates for the recent cycle were split into two subperiods: 1990-94 and 1995-2000. This was done to get a more precise idea of whether the impact of investment in new technology can be identified in a discernibly different intercept (μ) or slope coefficient (ϕ) for the subperiod 1995-2000.[18] As shown in Table 2a, the estimated trend growth decreased from the 1960s, as in most other countries, but seems to have picked up since the mid-1990s.[19] According to our estimates (see the last two lines of Table 2a), the GDP growth rate required to keep unemployment constant rose from 2.6% to 3.2%.

Table 2a

GDP growth in the United States, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS[4]	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[5]
1953-2000	3.3	.	3.3	3.3	3.3
1953-60	2.4	.	2.7	3.2	2.7
1960-73	4.3	.	4.1	4.0	4.1
1974-80	2.5	3.2	2.8	3.2	2.6
1981-89	3.3	2.9	3.2	2.8	3.3
1990-2000	3.2	3.2	3.3	2.9	3.1
of which:					
1990-94	2.4	2.6	2.7	2.6	2.4
1995-2000	4.1	3.7	3.8	3.2	3.8

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; $\lambda = 1600$. [4] Estimated with split subperiods for the 1990s. [5] Δu_{mean} refers to the mean change in unemployment in the subperiod.

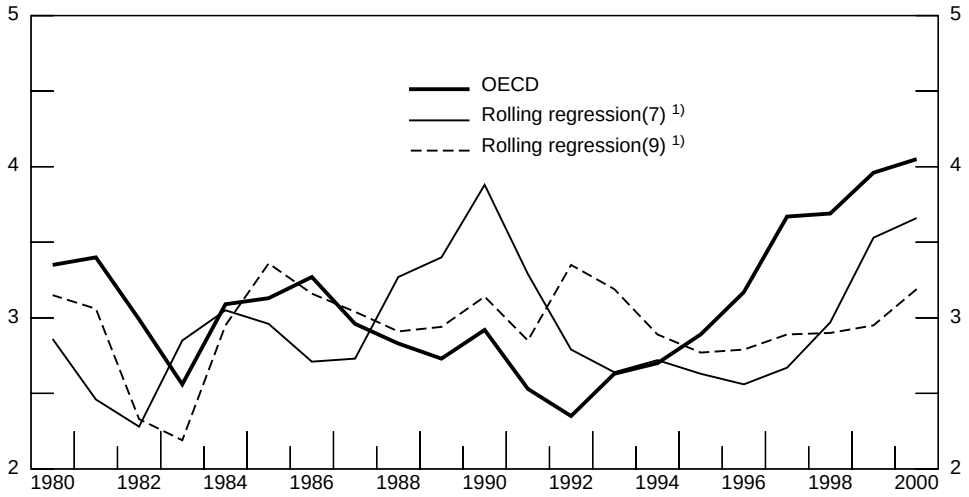
Estimates using $\Delta u - \Delta \underline{u}$ as the dependent variable yield very similar results for nearly all subperiods. However, for the period 1995 Q1-2001 Q2 a trend growth rate of nearly 4% is obtained. This is broadly in line with most of the "new economy" estimates, which assume a structural reduction in average unemployment in the second half of the 1990s.

[18] The 1996 chain-based GDP data were used.

[19] Recalling that the early phase of the latest recovery has often been referred to as a "jobless recovery", it is somewhat puzzling that the estimates with a trend shift in the mid-1990s actually imply a decline in trend growth between the 1980s and the first half of the 1990s. In fact, this is the main reason why the Okun relation produces a higher output gap than the one estimated by the OECD (see Graph 2a).

According to the quarterly estimates (Annex Table 2a), US trend growth has increased from 2.3% to 3.3% between the first and the second half of the 1990s. This shift is broadly consistent with the current consensus. It implies a gradually widening excess demand gap during the second half of the 1990s up to 2000. Taking the second quarter of 1990 (the peak of the previous cycle) as a starting point and applying the higher trend rate from early 1995, actual output exceeded potential by about 1½% by mid-2001.

Graph 1a **Trend growth for the United States**



1) Own estimate. Rolling regression window in years indicated in brackets.

The estimates for *Japan* (Annex Table 1b) show a comparatively low (but significant) output coefficient. This is compatible with estimates by most other authors[20] and largely reflects the very low variability of unemployment relative to output. In other words, due to institutional factors in the Japanese labour market (lifetime employment contracts for workers in large manufacturing firms, high layoff costs and a tradition of keeping workers on the payroll even in periods of low demand growth), variations in output growth have only a small influence on measured unemployment. A second feature of the estimates is that we obtained the most plausible results when allowing for changes in the slope coefficients rather than the intercept term. Finally, and perhaps most importantly, it should be stressed that the estimates for the period 1992-2000 are particularly uncertain. First, as for some other countries, we have an endpoint problem as the period does not cover a full cycle. Second, given the depth and length of the recession and the preceding investment boom, it is quite likely that a substantial part of the capital stock is non-profitable and should be (or has been) scrapped.[21] Thus, going back to equation (vii), both k and c have probably declined, pushing up the rate of unemployment. If this change is regarded as cyclical, the rate of GDP growth required to keep unemployment constant increases to more than 2½% and the implied output gap is implausibly large. Alternatively, when the rise in unemployment is regarded as partly structural and (Δu-$\Delta \underline{u}$) is used as the dependent variable, the estimated trend growth rate for the current cycle is in line with the actual average growth of 1.2% and the output gap is only around 1.5% (Annex Graph 2a).[22] The estimates point to two major changes in the 1990s, both of which lowered the estimated trend rate of growth. First, the structural rise in unemployment ($\Delta \underline{u}$) increased considerably in the 1990s compared to previous cycles. Second, the discernibly larger slope coefficient suggests that structural reforms or changes in company behaviour have made unemployment more sensitive to fluctuations in output.

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[20] See, eg Lee (2000), Moosa(1997) and also Hamada and Kurosaka (1984), p 77.

[21] A similar point can be made regarding labour supply and disembodied technical progress; it takes a long time for unemployed workers "… to find jobs because there are lost labour skills and the labour force age composition changes". (Hayakawa and Ugai (2001), p 144).

[22] Trend growth estimates currently typically cluster around 2% (see eg Hayakawa and Ugai (2001) and Bayoumi (2000)), with recent estimates tending to be more conservative.

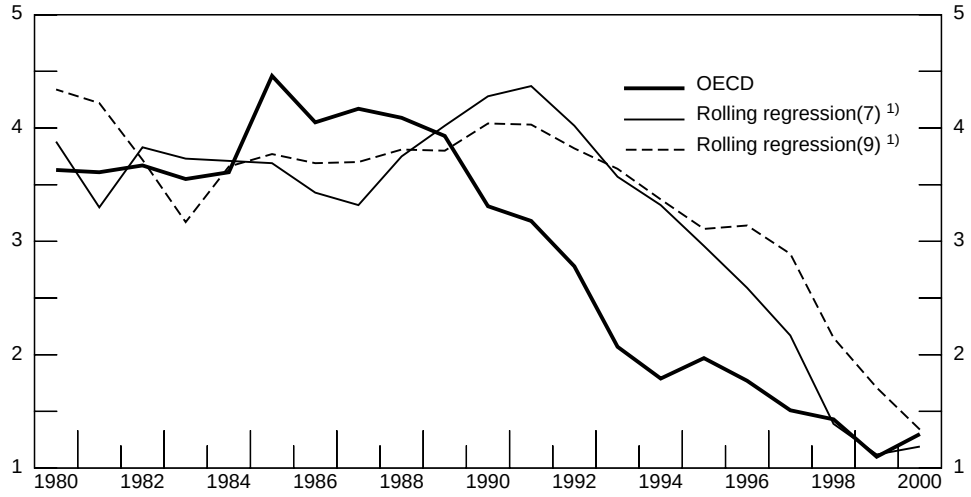
Table 2b

GDP growth in Japan, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1962-2000	4.8	.	4.8	5.2	4.8
1962-74	8.4	.	8.6	8.5	8.5
1975-92	3.7	3.6	3.7	4.0	3.6
1993-2000	1.2	1.7	1.2	2.6	1.2

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1b **Trend growth for Japan**



1) Own estimate. Rolling regression window in years indicated in brackets.

For *Germany*, the "Okun estimates" yielded trend growth rates which have exceeded the actual growth trend since the 1970s (Table 2c). It appears that the estimating equation is misspecified and this is also revealed in the quarterly estimates. Even allowing for several intercept shifts, the DW statistics remained very low (Annex Table 2a). Allowing for a long-run increase in unemployment (ie assuming a rise in the NAIRU) produces more plausible results. The estimates for the trend growth rates come close to the actual growth rates and the gap estimates move along the lines of the OECD findings (Table 2c, Annex Graph 1a). It should, however, be noted that the growth rate of 1.5% required to keep actual unemployment in line with a gradually rising structural rate of unemployment is somewhat below national estimates of potential rates of growth, which are still around 2-2.5%. This was not the case for Japan, where official estimates of potential growth have been reduced to 1-1.5%.[23]

[23] See Bank of Japan website: Monetary Policy meeting of 29 October 2001, "Outlook and risk assessment of the economy and prices" (October 2001), "... a decline in the short-term growth rate of supply capacity of Japan's economy to some 1%-plus on a year-on-year basis".

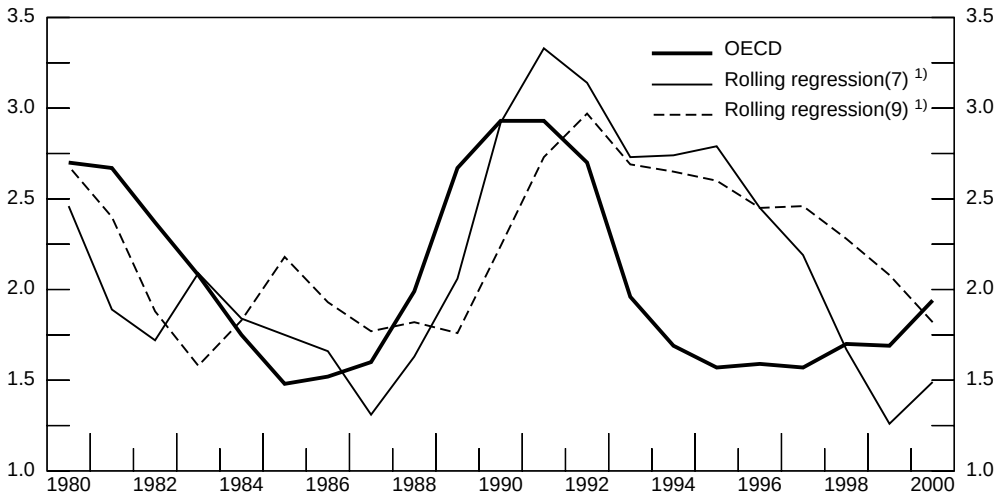
Table 2c

GDP growth in Germany, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1964-2000	2.6	.	2.6	3.1	2.6
1964-73	4.2	.	4.0	4.4	4.3
1974-79	2.4	2.4	2.4	3.3	2.3
1980-91	2.4	.	2.3	2.9	2.4
1992-2000	1.5	1.8	1.7	2.1	1.5

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1c **Trend growth for Germany**



1) Own estimate. Rolling regression window in years indicated in brackets.

Except for the 1990s, the "Okun estimates" for *France* also tend to lie above actual trend rates. The estimated decline in the trend growth implied by the Okun equation might reflect a rather "sticky" labour market in previous subperiods,[24] whereas for the more recent years, the labour market has become more flexible as the cumulative result of the numerous labour market measures introduced in the 1990s. A notable feature of these measures is that they not only stimulated employment growth but also led to higher participation rates and faster growth of the labour force, particularly during the most recent years.[25] As can be seen from Table 2d, the net effect of these influences is a decline in the trend rate implied by the Okun regressions. Using demeaned changes in unemployment yields two interesting results. First, the estimated trend rates of growth are much closer to actual rates for the period 1974-91. In other words, the rise in structural unemployment seems to have occurred in this period. Second, this trend increase in unemployment came to an end during the 1990s, as the

[24] This would be supported by Lee's findings regarding asymmetry (see footnote 12).

[25] The French labour force has expanded at an annual rate of roughly 1% since 1997.

estimated trend rates of growth are virtually independent of whether demeaned or non-demeaned changes in unemployment are used as the dependent variable. The trend implied by the quarterly estimates is similar to that obtained from the annual regressions, and the rolling regressions also yield trend growth rates for the 1990s of around 1.8%.

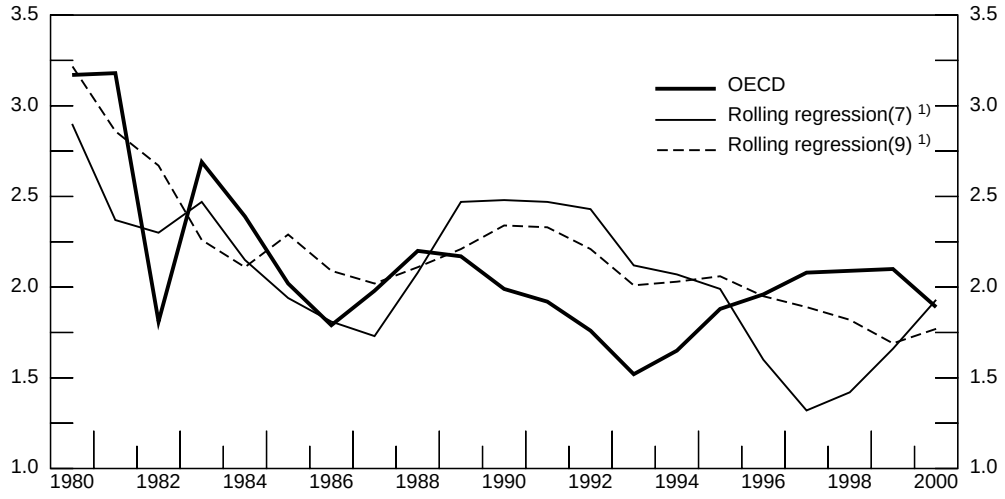
Table 2d

GDP growth in France, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	Δu-$\Delta u_{mean} = 0$[4]
1966-2000	2.8	.	2.8	3.2	2.8
1966-73	5.2	.	5.0	5.3	5.0
1974-79	2.8	3.1	2.9	3.9	2.9
1980-91	2.2	2.3	2.2	2.7	2.2
1992-2000	1.9	1.9	1.9	1.8	1.7

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1d **Trend growth for France**



1) Own estimate. Rolling regression window in years indicated in brackets.

The annual estimates for *Italy* do not reveal any obvious signs of serious specification errors, although the DW statistic is not very good and does not improve when allowing for subperiods. The comparatively small ϕ coefficients (like Japan) are not implausible. The quarterly results, however, are problematic. While the trend shift in the 1990s significantly improves the DW statistic, it remains to be explained why the trend rate of growth should have dropped from 3.2% to only 0.7% (Annex Table 2a).[26] The resulting output gap series (Graph 3a) does not look sensible. The

[26] Growth in the labour force rose in the second part whereas productivity growth seems to have fallen. Because of these offsetting changes, it is surprising that the trend estimates are significantly different for the two subperiods.

explanatory power, measured by the R^2, is also limited in both the annual and the quarterly estimates and an additional puzzle is that, unlike the other countries included in our sample, Italy saw its labour force expanding faster in the 1990s than in the earlier periods even though GDP growth declined.[27] What appears to be missing is a quantification of the various labour market rigidities, including subsidies paid to enterprises for hoarding labour, difficult and costly layoff procedures and perhaps also the dichotomy between labour markets in the south and the north. Despite their simplicity, the detrended annual results partly get around these problems; the estimated trend growth rates are much lower and, as for France, imply that structural unemployment started to increase in the mid-1970s.

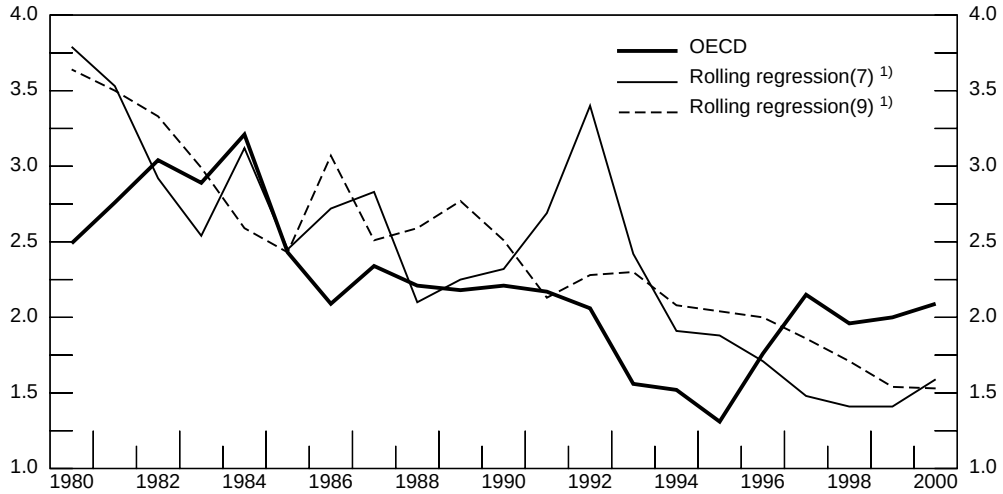
Table 2e

GDP growth in Italy, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1962-2000	3.2	.	3.2	3.6	3.3
1962-74	5.1	.	4.9	5.2	5.5
1975-81	2.9	2.9	3.1	3.7	3.1
1982-91	2.3	2.5	2.3	3.0	2.3
1992-2000	1.6	1.8	1.7	2.1	1.5

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1e **Trend growth for Italy**



1) Own estimate. Rolling regression window in years indicated in brackets.

[27] In terms of employment growth, Italy traditionally underperforms compared to other EU countries (see European Commission (1999)).

For the *United Kingdom*, the statistical significance of the Okun estimates is good for both the whole period 1963-2000 and the subperiods.[28] For the recent cycle, the estimated trend growth for both the annual and the quarterly sample is below the actual trend rate. A trend of only 1.5% (as obtained from the quarterly estimates) is also below other estimates[29] and results in a positive output gap. Assuming that all unemployment changes are cyclical is obviously too simplistic to appropriately capture the various trend shifts in the labour market, For instance, the 1990s were characterised by a significant improvement in labour market flexibility,[30] which would normally be expected to increase potential output growth. On the other hand, the various measures introduced to improve labour market flexibility also led to slower growth of the labour force, which meant that less output growth was required to keep unemployment stable. In addition, there were major changes in the sectoral composition of output and employment,[31] as service sector employment rose sharply while manufacturing declined. Yet another factor reducing the output growth required to keep unemployment stable was the fact that a substantial portion of the inflow into services was in the form of part-time workers.[32] As for France and Italy, the detrended estimates seem to better capture the various structural changes in the labour market, yielding a more reasonable trend growth rate of 2%, with an average annual decrease of unemployment of 0.2 percentage points. Consistent with the implied fall in the NAIRU, the rolling regressions on the basis of a seven-year window generate a considerable pickup in the trend growth rate for the 1990s.

Table 2f

GDP growth in the United Kingdom, actual and trend estimates[1]

	Actual GDP	**Trend GDP**			
		OECD[2]	**Own estimates**		
			HP[3]	**OLS**	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1963-2000	2.4	.	2.4	2.4	2.4
1963-73	3.4	.	2.9	3.0	3.0
1974-79	1.5	2.1	1.6	2.5	2.1
1980-90	2.2	2.1	2.4	2.6	2.5
1991-2000	2.3	2.4	2.4	1.7	2.0

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

[28] For the United Kingdom, even the GDP lagged by two years has a significant impact on the current change in unemployment and the aggregate output coefficient is comparatively high, pointing to a rather high labour intensity of output (or a relatively low level of labour productivity).

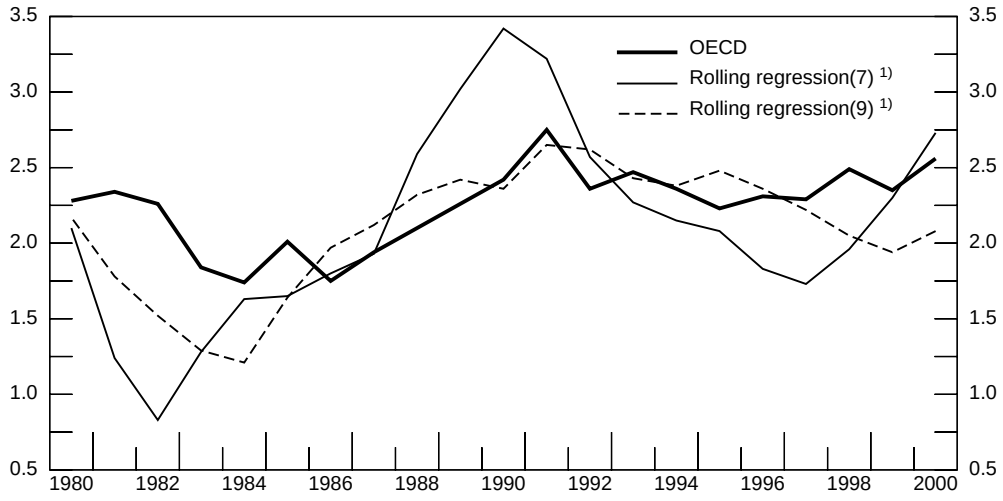
[29] See, for example, Bank of England, *Inflation Report*, August 1999 and November 1999; the assumed trend growth seems to be somewhere between 2% and 2.5%.

[30] The IMF ranks the United Kingdom as the best of all EU countries in terms of the absence of labour market regulations. The improvement in labour market flexibility can also be seen from the sharp rise in the variability of unemployment relative to that of GDP. It is also worth noting that higher variability of unemployment was already visible in the previous ("Thatcher") subperiod; it was, however, then combined with an annual growth in the labour force of nearly 1%, thus contributing to an "Okun estimate" for the 1980s which was above the actual growth path.

[31] This may explain to a large extent the decrease in productivity growth during the second part of the 1990s.

[32] The increase in the share of part-time employment between 1990 and 1998 from 20.1% to 23.0% was far above the OECD average (from 13.4% to 14.3%).

Graph 1f **Trend growth for United Kingdom**



1) Own estimate. Rolling regression window in years indicated in brackets.

The estimates for *Canada* seem to fit the actual growth trend quite well, both over the whole period and for the various subperiods (Table 2g).[33] However, the low DW statistic obtained when no break points are allowed for clearly indicates that the trend rate has not been constant. In fact, once intercept shifts are introduced, it appears that trend growth has declined from some 5% during 1963-80 to only half that rate for the 1990s. The detrended estimates yield a slightly higher growth rate of 2.5%, and the quarterly estimates with no parameter shifts generate a similar result with plausible diagnostic statistics. However, because the actual growth of GDP picked up strongly after 1995,[34] the assumption of a constant trend rate leads to a rather high degree of excess demand by the end of the decade.

Table 2g

GDP growth in Canada, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1962-2000	3.7	.	3.6	3.6	3.7
1962-80	4.7	.	4.6	4.8	4.8
1981-89	3.0	2.9	2.8	3.0	3.0
1990-2000	2.5	2.7	2.7	2.3	2.5

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

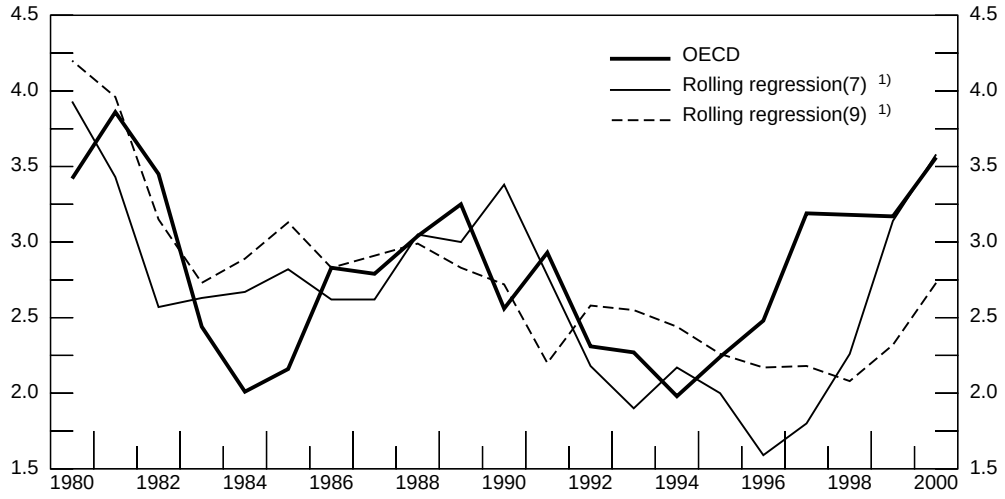
Despite the compelling evidence in the actual data, it proved difficult to identify the exact size and date of the likely parameter shift. Thus far, our best estimate points to a slight change in the slope parameter during 1996. While the shift is not quite significant, it is consistent with the view that labour

[33] Using the usual peak-to-peak identification of cycles, we could only identify three subperiods, as Canada did not experience the typical oilprice-driven downturn in the 1970s.

[34] Between 1990 Q1 and 1996 Q1, GDP growth averaged only 1.4%, compared with over 4% over the next four years.

productivity growth in Canada has picked up, though somewhat later[35] and less strongly than in the United States. Rolling regressions over seven years point to a rise in the estimated trend growth to more than 3.5% (Graph 1g).

Graph 1g **Trend growth for Canada**



1) Own estimate. Rolling regression window in years indicated in brackets.

Given the estimates for Germany and Italy, it is not surprising that also for the *euro area* a downward shift of the intercept significantly improves the result for the 1990s. The output gap based on the annual estimates also looks plausible and deviates only slightly from that shown by the OECD. In contrast, the quarterly estimates are problematic and further work is required. In Annex Table 2a, we show the two best results obtained thus far. The first equation excludes parameter shifts and generates a trend rate of about 2% with a relatively small output gap by the end of the 1990s.

Table 2h

GDP growth in the euro area, actual and trend estimates[1]

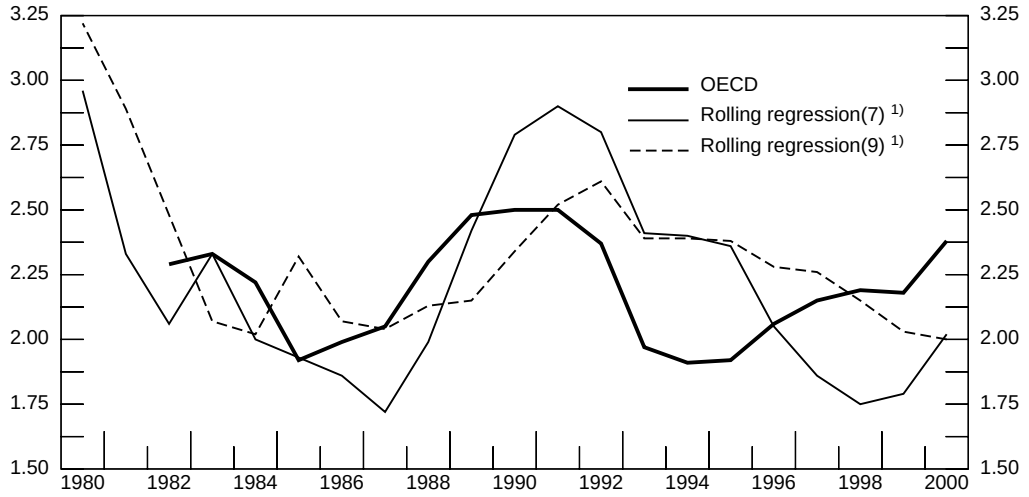
	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	Δu-$\Delta u_{mean} = 0$[4]
1966-2000	2.9	.	2.9	3.5	2.9
1966-74	4.8	.	4.7	5.2	4.9
1975-79	2.7	.	2.7	4.9	2.7
1980-91	2.3	.	2.3	2.8	2.3
1992-2000	2.0	2.1	2.1	2.1	1.9

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

[35] See Macklem and Yetman (2001) who cautiously date the pickup of productivity growth only at the beginning of 2000; see also Gust and Marquez (2000), where average labour productivity growth for 1996-99 is estimated to be smaller than for 1990-95.

However, the low DW statistic clearly indicates that the equation is misspecified. Misspecification is also evident for the second equation, which allows for an intercept shift in the mid-1990s. Moreover, because of the marked drop in the trend rate, this specification leads to an implausibly large and positive GDP gap by the end of the 1990s. Detrending unemployment reduces the trend growth rate by only 0.2 percentage points, while rolling regressions with a short window indicate that the trend rate of growth has returned to around 2% in recent years.

Graph 1h **Trend growth for the euro area**



1) Own estimate. Rolling regression window in years indicated in brackets.

In the case of *Australia*, the "Okun method" using annual data yielded a relatively good fit, compared both with actual growth and with the OECD trend estimates; this is especially true for the last two decades, during which the economy has grown at a more or less unchanged trend rate of nearly 3.5%. As for other countries, the estimates using demeaned changes in the rate of unemployment indicate a marked rise in structural unemployment during 1974-90, followed by a small decline in the 1990s. Similarities with the US pattern become more visible when looking at the recent cycle on a quarterly basis. Again, there is a significant and positive intercept shift, as both the actual and the estimated trend growth rate increased after 1996. As for the United States, the precise sources of this shift are difficult to identify. Business fixed investment has been high, with a marked shift in composition in favour of IT-related capital goods and away from capital spending in the resource sector.[36] In addition, Australia has introduced a range of deregulatory measures, including a virtual removal of trade protection measures, which have made product and labour markets far more competitive and flexible. All in all, this is likely to have pushed up labour productivity growth and potential GDP growth as well.[37] Nonetheless, as actual growth has outpaced trend growth in recent years, Australia's output gap became positive in 1998, as also suggested by OECD estimates.

[36] IT-related capital deepening accounted for about two thirds of the growth contribution of capital deepening in the 1990s (IMF (2001)).

[37] See ABS, *Australian Economic Indicators*, August 1999; apparently the growth in capital input has also increased.

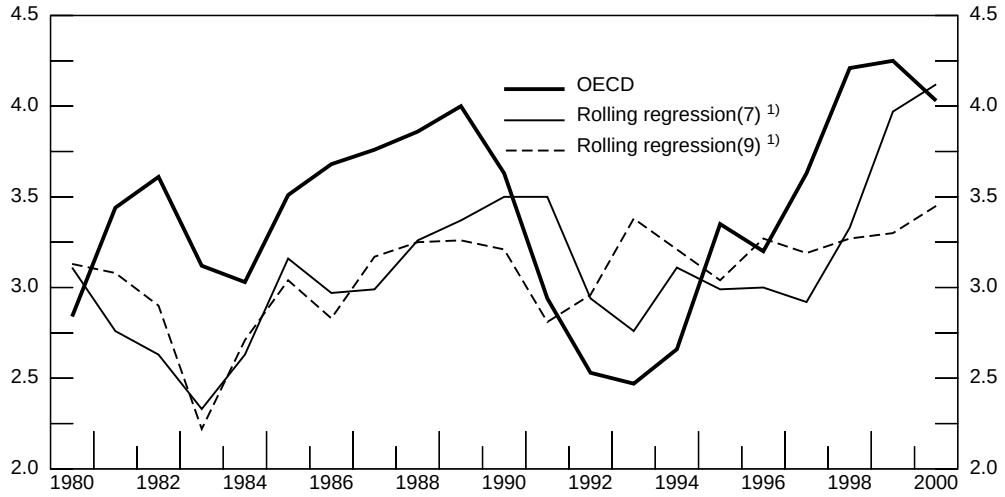
Table 2i

GDP growth in Australia, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1961-2000	3.9	.	3.8	4.0	3.7
1961-73	5.4	.	5.1	5.3	4.9
1974-81	2.8	.	2.8	3.8	2.9
1982-90	3.4	3.6	3.3	3.4	3.2
1991-00	3.3	3.4	3.5	3.2	3.4

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1i **Trend growth for Australia**



1) Own estimate. Rolling regression window in years indicated in brackets.

"Okun estimates" for *the Netherlands* also work rather well, with annual results clearly improving when intercept shifts are taken into account. In the current cycle, growth has been somewhat higher than our trend estimates (see Table 2j). This probably reflects Dutch employment policy of recent years, whereby unemployment has been reduced by fostering part-time work while the growth rate of the labour force has remained comparatively stable. The quarterly estimates very clearly show that since 1995 significantly less output growth has been required to keep unemployment stable. However, the Okun equation with just one intercept shift probably overstates the decline in trend growth and leads to a comparatively large positive output gap for end-2000 (see Graph 3b). Against this background, it is not surprising that the detrended estimates yield a somewhat higher - and comparatively stable - trend growth rate of 2.8% for the current cycle (see Table 2j and Graph 1j) as well as a decline in structural unemployment. The impression of a higher trend rate of growth in recent years is further confirmed by rolling regressions over seven years.

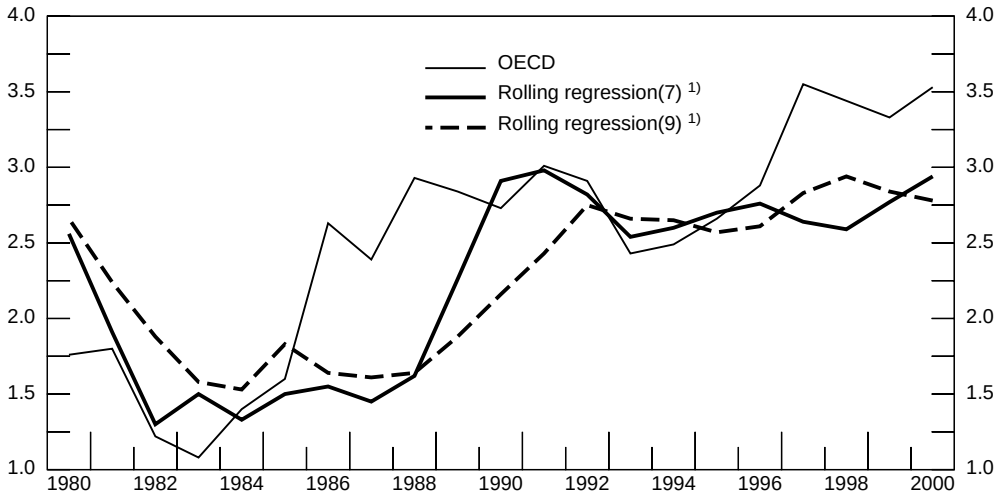
Table 2j

GDP growth in the Netherlands, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1970-2000	2.6	.	.	2.6	2.6
1970-74	3.7	.	.	4.4	4.0
1975-80	2.2	2.4	.	2.5	2.3
1981-91	2.1	2.1	2.1	2.2	2.1
1992-2000	2.9	3.0	2.9	2.5	2.8

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1j **Trend growth for the Netherlands**



1) Own estimate. Rolling regression window in years indicated in brackets.

Spain is also a country which, in recent years, has pursued an active labour market policy. This has led to changes in the relationship between output growth and unemployment, which are similar to those of the Netherlands even though the measures undertaken were quite different. Thus, Spain has focused on facilitating the employment of temporary rather than part-time workers.[38] As Table 2k shows, the growth rate required to keep unemployment stable has gradually fallen to just below 2½% for the 1990s and, according to the quarterly estimates, fell further between the first and second half of the 1990s (Annex Table 2b). However, the estimated trend rate for the second half of just above 1% clearly understates potential growth,[39] suggesting that part of the impressive decline in unemployment during this period was structural. Allowing for trend changes in unemployment in the annual estimates

[38] If temporary workers were only a substitute for permanent workers, there would be no effect on unemployment. However, by significantly reducing redundancy payments and diminishing firing restrictions, the regulatory changes allowing more temporary workers created jobs which would not have been filled by permanent workers (Wyplosz (2000)).

[39] Fernandez and Mauro (2000) estimate a potential growth rate of more than 3.5% for the coming years, which is consistent with a pickup in estimated trend growth.

generates a trend growth rate of 2.5%.[40] Although more in line with actual growth, this is probably still too low as it is difficult to locate the point at which the structural elements started to dominate changes in the rate of unemployment.

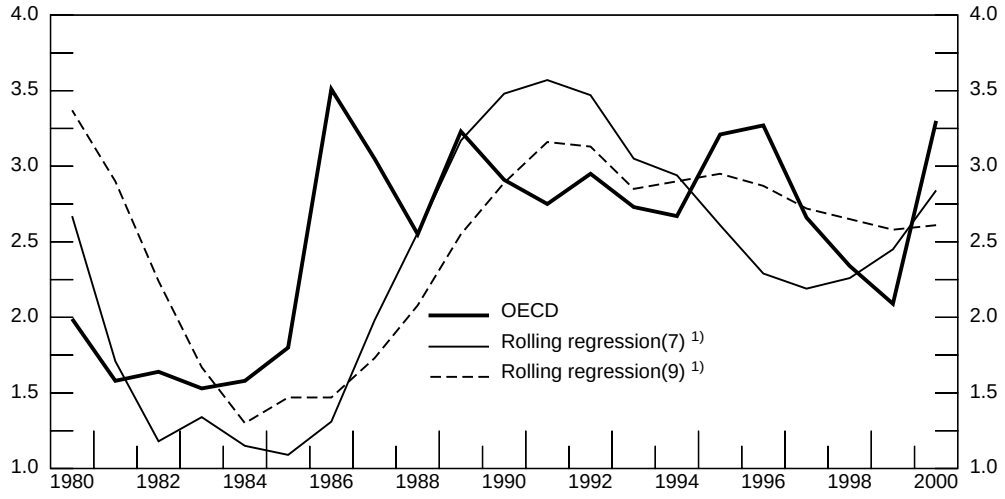
Table 2k

GDP growth in Spain, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	Δu-$\Delta u_{mean} = 0$[4]
1965-2000	3.5	.	.	3.8	3.4
1965-74	6.4	.	.	6.2	6.2
1975-79	1.6	.	2.0	3.2	1.7
1980-91	2.7	2.3	2.5	3.3	2.7
1992-2000	2.7	2.8	2.8	2.3	2.5

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1k **Trend growth for Spain**



1) Own estimate. Rolling regression window in years indicated in brackets.

A similar problem was encountered in the estimates for *Sweden*: unemployment rose sharply during the recession of the early 1990s, remained at a high level for a couple of years and then fell sharply during 1997-2000. When using non-demeaned changes in the rate of unemployment as the dependent variable, trend growth for the 1990s exceeds actual growth both in the annual and the quarterly estimates, but our gap estimates (see Graphs 2b and 3b) are more or less in line with other measures, including those published by Sveriges Riksbank.[41] Estimates based on demeaned changes

[40] The upward adjustment is comparatively small given the very flexible labour markets (large slope coefficients).

[41] Sveriges Riksbank, *Inflation Report*, 1/2000, March 2000.

in unemployment produce a trend rate of only 1.6%. While this is in line with actual average growth, it is likely to underestimate the current trend growth (see Graph 1l).

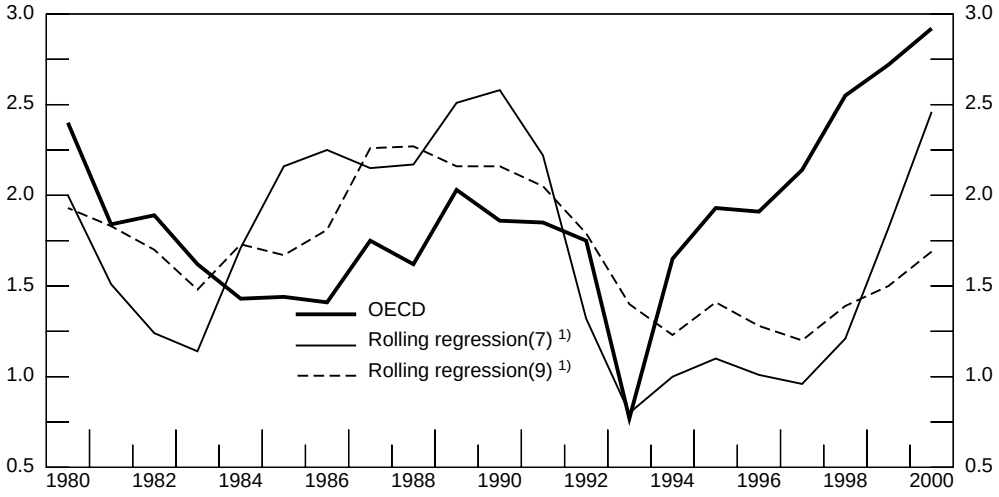
Table 2l

GDP growth in Sweden, actual and trend estimates[1]

	Actual GDP	Trend GDP			
		OECD[2]	Own estimates		
			HP[3]	OLS	
				$\Delta u = 0$	$\Delta u - \Delta u_{mean} = 0$[4]
1961-2000	2.5	.	.	2.8	2.5
1961-76	3.7	.	.	3.7	3.7
1977-79	1.3	1.9	1.3	1.4	1.0
1980-90	2.1	1.8	2.0	2.1	2.2
1991-2000	1.7	2.0	1.9	2.5	1.6

[1] Average over the period, in percentages. [2] Typically estimated using production functions. [3] Hodrick-Prescott filter applied; λ = 1,600. [4] Δu_{mean} refers to the mean change in unemployment in the subperiod.

Graph 1l **Trend growth for Sweden**



1) Own estimate. Rolling regression window in years indicated in brackets.

4. Conclusion

What can be concluded from our estimates? In spite of the very strict assumptions and the simplicity of the specification, the results are not totally unpromising and, in many cases, not very far from other estimates. For instance, as can be seen from Table 1, the coefficients with respect to changes in output are relatively close to those obtained by Lee and other authors. Moreover, the estimated trends are fairly similar to those reported by the OECD, using entirely different estimation procedures. As we had expected, the assumption of constant parameters does not hold for longer periods. For nearly all countries, the equations with no intercept or slope shifts yield very low DW statistics, implying that the equations are misspecified.

The introduction of trend shifts succeeds in relaxing some of the restrictive assumptions underlying the Okun equations and in producing better DW statistics. Yet, several shortcomings remain:

(i) our method of identifying the dates of the parameter shifts is rather ad hoc and a more precise dating could be obtained by relying on more sophisticated econometric methods;

(ii) because we only allow for intercept shifts (or in a few cases for slope shifts), we are unable to identify the precise causes of the shifts. For some countries, trend shifts seem to coincide with changes in labour force growth. However, other factors (growth of the capital stock, changes in factor productivity and labour market measures) could also have played a role;[42]

(iii) for some countries, our trend estimates can be interpreted as potential rates of growth. But in most cases, the estimated trend rates should merely be interpreted as the rates of output growth required to keep unemployment stable.[43] In particular, the rather low trend rates of growth we obtain for the more recent period probably reflect measures to reduce unemployment rather than low potential rates of growth;

(iv) using demeaned changes in unemployment as the dependent variable produces trend growth rates that do not deviate too far from actual rates and, as a result, more plausible output gaps. Comparisons with non-demeaned changes also help us to identify periods with apparent changes in structural unemployment. On the other hand, introducing non-cyclical changes in the rate of unemployment takes us quite far away from the original Okun equation and, for some countries, the exact turning points are difficult to identify.

(v) since the Okun equations merely represent a relationship between unemployment and output, the trend rates presented in this paper should not be interpreted as the rates of output growth compatible with stable inflation. Indeed, inflation does not appear in our estimates and it would require an entirely different specification to obtain growth rates which are neutral with respect to inflation.[44]

Can the estimated trend rates of growth be used in constructing output gaps? When there have been structural changes in unemployment and non-demeaned changes in unemployment are used as the dependent variable, this is not recommendable. The trend rates will be biased (upwards in the case of increases in structural unemployment) and, accordingly, so will the associated output gaps. Trend rates derived from demeaned changes in unemployment can be used, though the ad hoc nature of the estimates should be kept in mind. In addition, constructing a measure in levels from estimates in rates of change introduces some arbitrariness as a base year or a base level has to be chosen.

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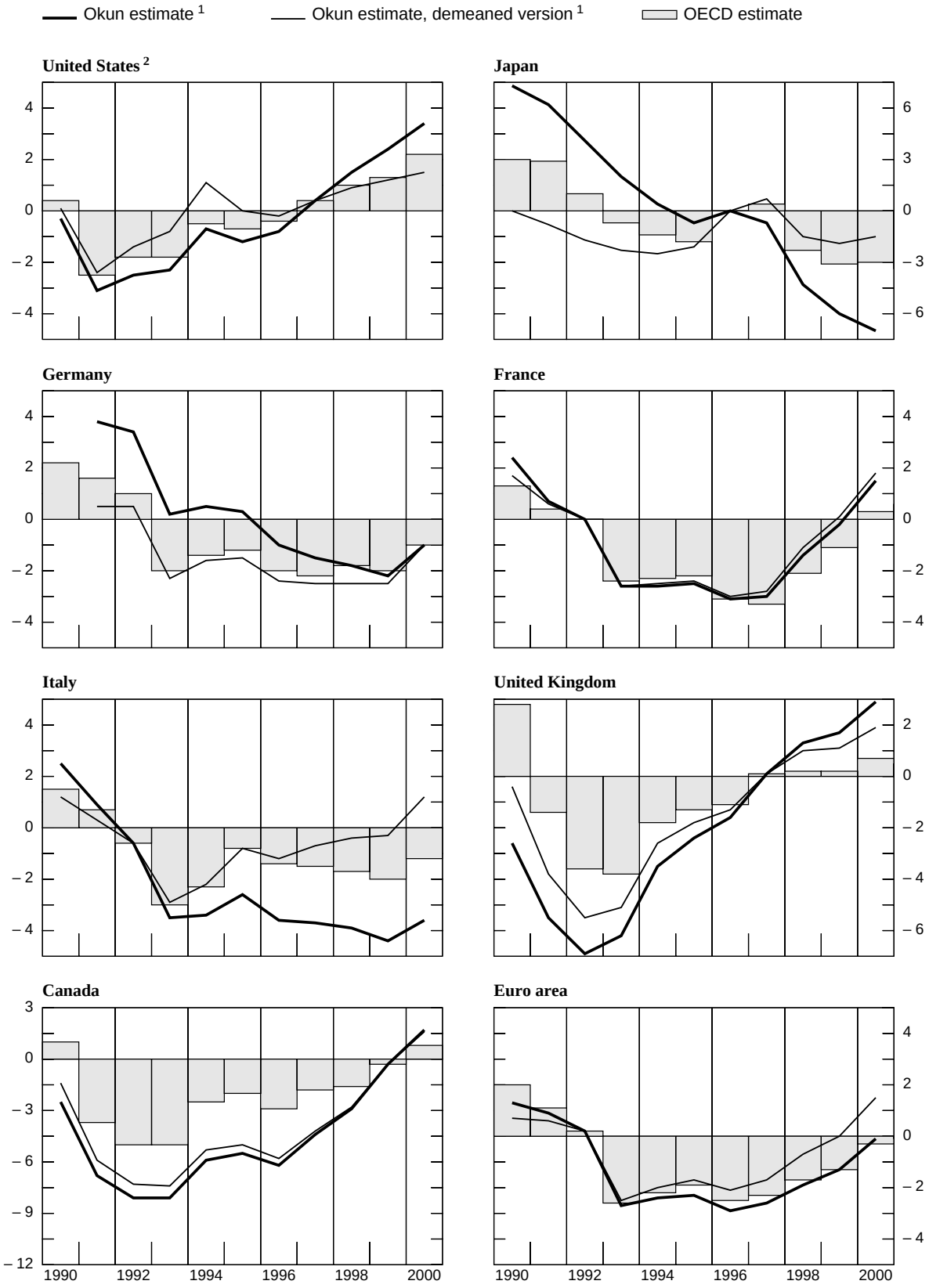
[42] In theory, we could have coped with the problems of measuring the capital stock, changes in capacity utilisation and changes in hours worked by introducing additional trend shifts. However, we had neither the information nor the degrees of freedom required for such an exercise. There is, for example, the problem of distinguishing between structural and cyclical changes. Similarly, while we know that labour market policies have changed the relationship between output and unemployment, we know of no way to quantify these changes.

[43] See JP Morgan (2000).

[44] Equation (i), with changes in inflation as the dependent variable and various supply shocks added on the right-hand side, might serve as a starting point for such an exercise.

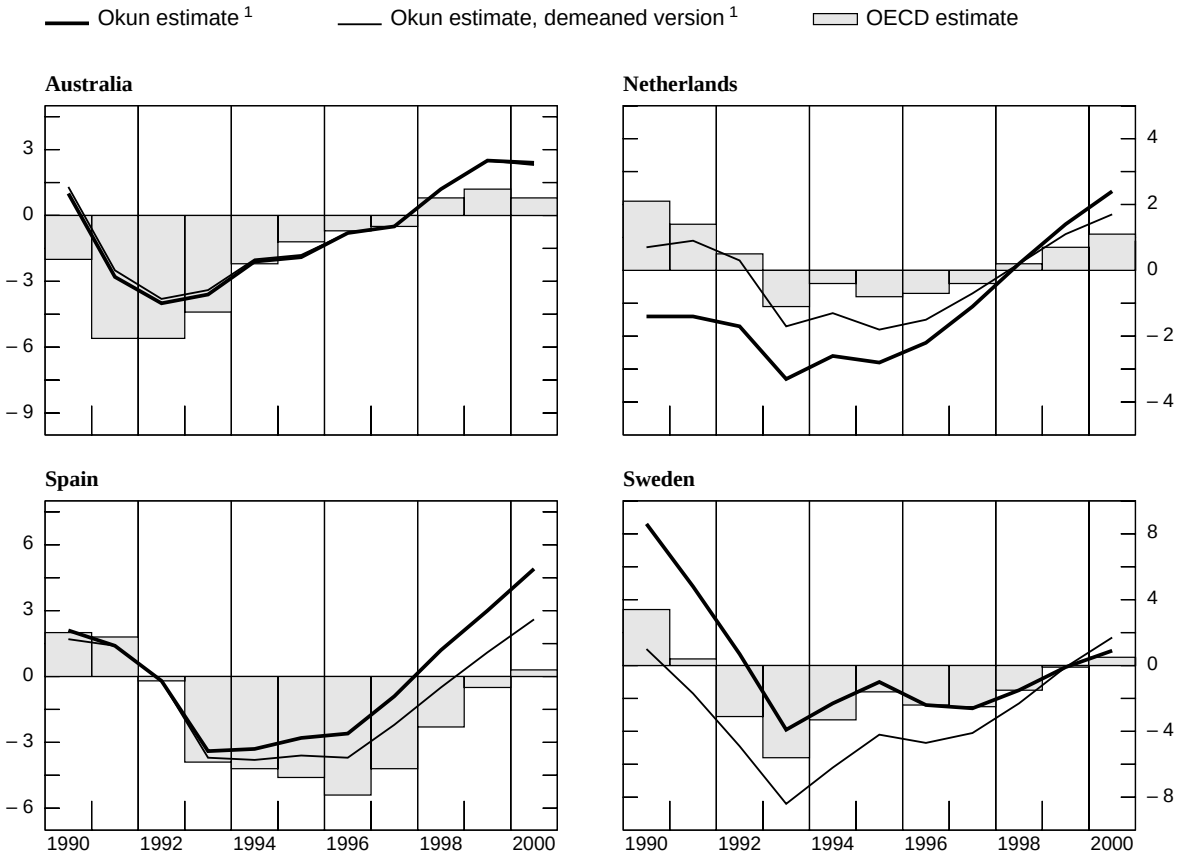
Graph 2a: Measures of the output gap (annual)



[1] For the 1990s. Starting point for the application of the estimated 'Okun trends' was the period in which the OECD output gap was close to zero. Trend growth rates based on estimates using annual data. [2] Different trend growth rates applied for subperiods.

Sources: OECD; own estimates.

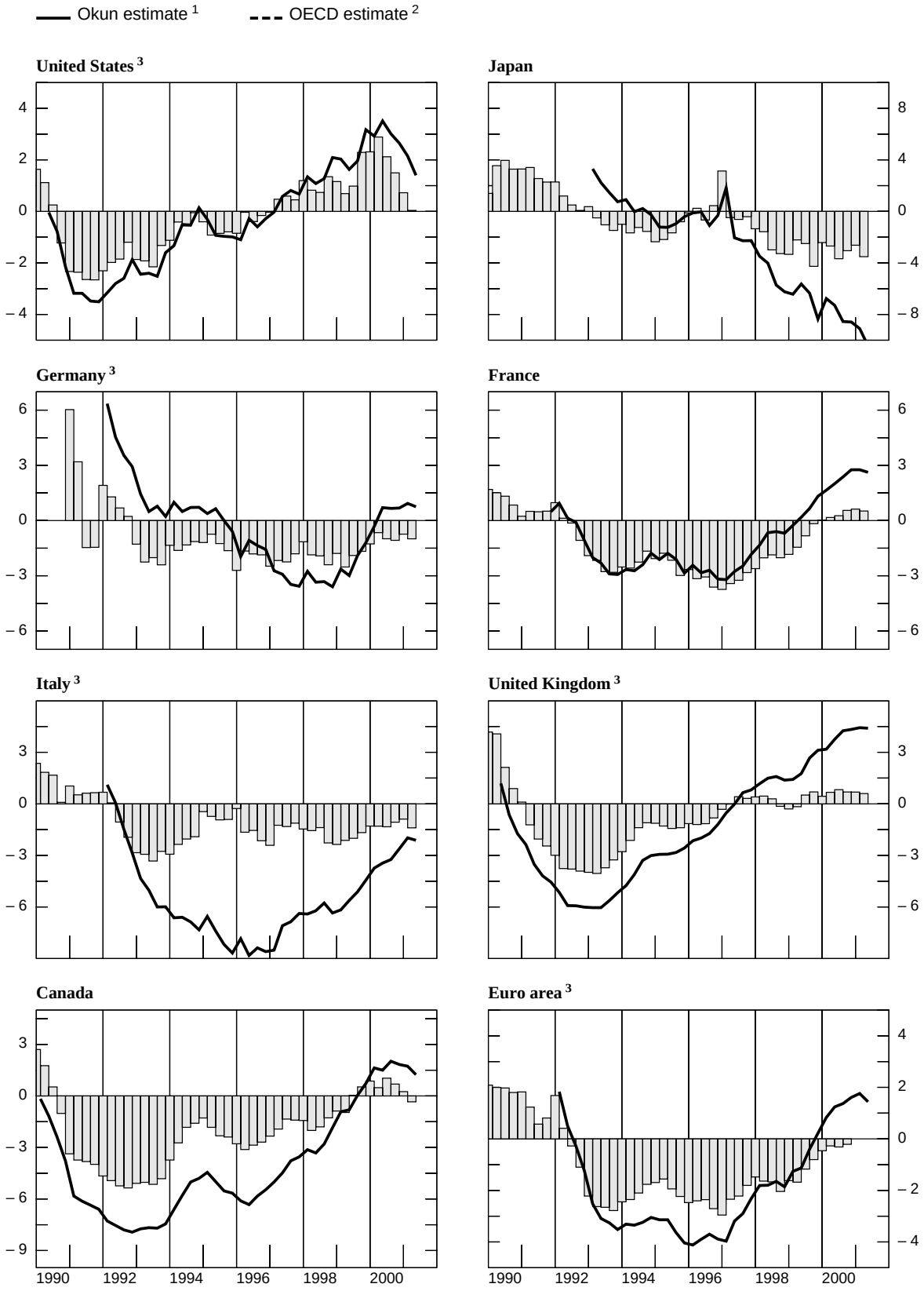
Graph 2b: Measures of the output gap (annual)



[1] For the 1990s. Starting point for the application of the estimated 'Okun trends' was the period in which the OECD output gap was close to zero. Trend growth rates based on estimates using annual data.

Sources: OECD; own estimates.

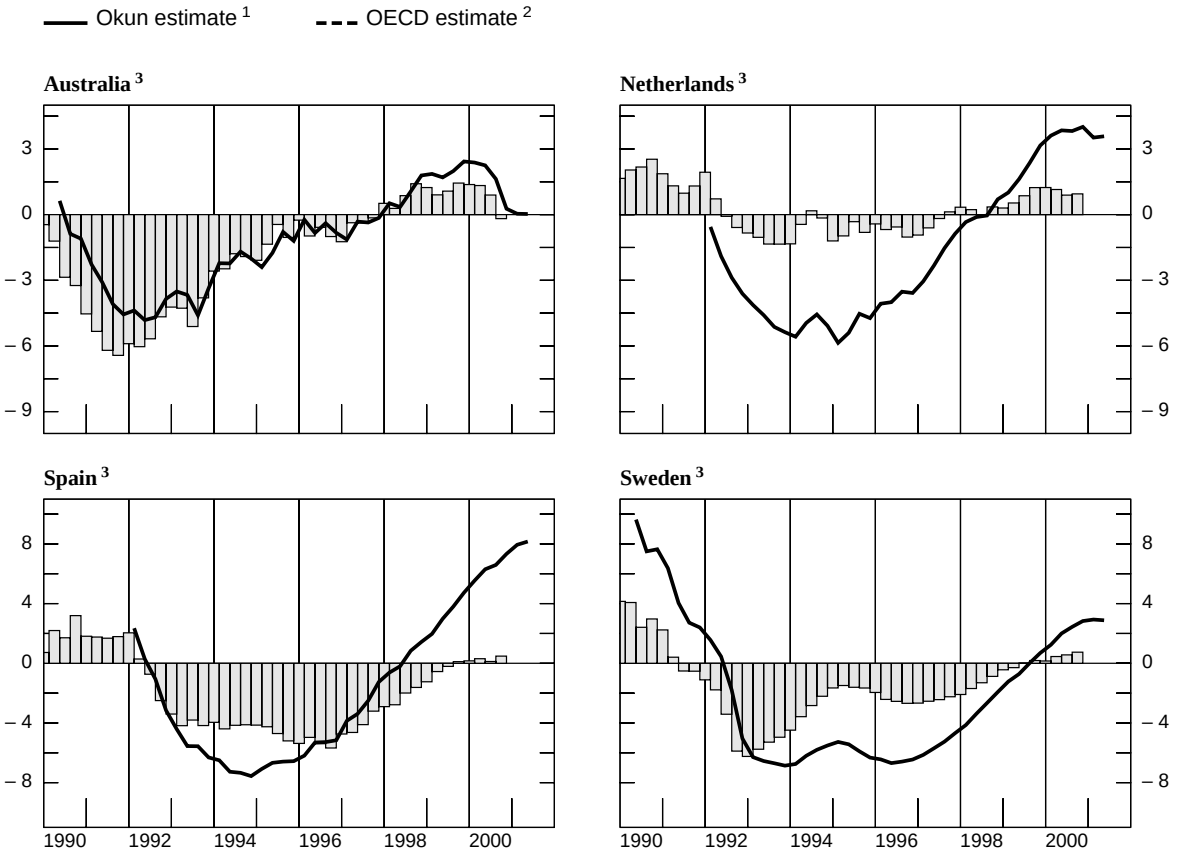
Graph 3a: Measures of the output gap (quarterly)



1 For the 1990s. Starting point for the application of the estimated 'Okun trends' was the period in which the OECD output gap was close to zero. Trend growth rates based on estimates using quarterly data. 2 Annual or semiannual data interpolated using Ginsburgh method. 3 Different trend growth rates applied for subperiods.

Sources: OECD; own estimates.

Graph 3b: Measures of the output gap (quarterly)



1 For the 1990s. Starting point for the application of the estimated 'Okun trends' was the period in which the OECD output gap was close to zero. Trend growth rates based on estimates using quarterly data. 2 Annual or semiannual data interpolated using Ginsburgh method. 3 Different trend growth rates applied for subperiods.

Sources: OECD; own estimates.

Annex Tables

Annex Table 1
Trend growth for GDP: Okun estimates[1]

Table 1a
United States

Period	Average trend growth		Regression results, Okun estimate				
			Coefficients[2]			Statistics	
	Actual	Estimate	Constant	GDP	GDP_{t-1}	R^2	DW
1954-2000	3.3	3.3	1.38 (9.82)	–0.42 (–11.57)		0.738	1.97
Subperiods[3]				–0.44 (–13.21)	–0.11 (–3.20)	0.806	2.09
				–0.44 (–13.21)	–0.12 (–3.38)	0.793	2.15
1954-60	2.4	3.2	1.69 (7.82)				
		2.7	1.37 (6.31)				
1961-73	4.3	4.0	2.20 (9.54)				
		4.1	2.31 (9.73)				
1974-81	2.5	3.2	1.73 (8.17)				
		2.6	1.42 (6.63)				
1981-89	3.3	2.8	1.54 (6.92)				
		2.8	1.87 (8.21)				
1990-2000	3.2	2.9	1.55 (7.59)				
		3.1					
1990-94	2.4	2.6	1.36 (5.58)				
		2.4	1.15 (4.68)				
1995-2000	4.1	3.2	1.78 (6.77)				
		3.8	2.12 (8.01)				

Table 1b
Japan[4]

Period	Average trend growth		Regression results, Okun estimate				
			Coefficients[2]			Statistics	
	Actual	Estimate	Constant	GDP	GDP_{t-1}	R^2	DW
1962-2000	4.8	7.0	0.26 (5.40)	–0.04 (–4.13)		0.297	1.58
Subperiods[3]			0.55(10.32)			0.715	1.78
				–0.05 (–3.75)	–0.05 (–4.30)	0.420	1.72
1962-73	8.4	8.5		–0.03 (–2.33)	–0.03 (–2.93)		
		8.5	0.89 (5.43)				
1974-92	3.7	4.0		–0.06 (–4.59)	–0.07 (–5.79)		
		3.6	0.38 (5.07)				
1993-2000	1.2	2.6		–0.12 (–3.59)	–0.09 (–2.81)		
		1.2	0.12 (2.31)				

[1] Regression using annual data: $\Delta u_t = \Sigma\alpha_j + \Sigma\beta_j y_i + \varepsilon$; Δu = change in the unemployment rate; α = constant; Δy = change in log GDP, where $i = t, t\text{-}1\ldots$ and j = number of subperiods. The second lines give the estimation results of $\Delta u_t - \Delta\underline{u} = \Sigma\alpha_j + \Sigma\beta_j y_i + \varepsilon$, where $\Delta\underline{u}$ = mean change in the unemployment rate in each of the subperiods. [2] t-values in brackets. [3] Start and endpoints are defined by conjunctural peaks. [4] Non-demeaned version estimated with time-varying slope coefficient.

Annex Table 1 (cont)

Table 1c

Germany[4]

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1964-2000	2.6	3.4	0.73 (5.22)	-0.27 (-6.62)		0.543	1.12
Subperiods[3]			1.06 (8.02)			0.635	1.90
				-0.32 (-8.07)	-0.11 (-2.83)	0.686	1.51
1964-73	4.2	4.4		-0.24 (-6.00)			
		4.3	1.84 (7.29)				
1974-79	2.4	3.3		-0.33 (-4.87)			
		2.3	0.95 (4.39)				
1980-91	2.4	2.9		-0.37 (-6.60)			
		2.4	1.02 (5.87)				
1992-2000	1.5	2.1		-0.52 (-5.05)			
		1.5	0.64 (3.89)				

Table 1d

France

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1966-2000	2.8	4.3	0.72 (3.92)	–0.17 (–3.11)		0.203	0.96
Subperiods[3]				–0.36 (–7.66)	–0.23 (–4.68)	0.737	2.38
				–0.36 (–7.40)	–0.23 (–4.64)	0.696	2.29
1966-73	5.2	5.3	3.24 (8.98)				
		5.0	3.11 (8.35)				
1974-79	2.8	3.9	2.35 (9.83)				
		2.9	1.79 (7.27)				
1980-91	2.1	2.7	1.59 (9.24)				
		2.2	1.32 (7.46)				
1992-2000	1.9	1.8	1.04 (6.59)				
		1.7	1.02 (6.29)				

Note: For footnotes, see Annex Tables 1a and 1b.

Annex Table 1 (cont)

Table 1e

Italy

Period	Average trend growth		Regression results, Okun estimate				
			Coefficients[2]			Statistics	
	Actual	Estimate	Constant	GDP	GDP_{t-1}	R^2	DW
1962-2000	3.2	4.1	0.59 (3.08)	–0.06 (–1.24)	–0.08 (–1.76)	0.126	1.12
Subperiods[3]				–0.14 (–2.45) –0.14 (–2.44)	–0.16 (–2.96) –0.16 (–2.95)	0.200 0.200	1.24 1.24
1962-74	5.1	5.2 5.5	1.56 (3.58) 1.65 (3.79)				
1975-81	2.9	3.7 3.1	1.09 (3.33) 0.91 (2.80)				
1982-91	2.3	3.0 2.3	0.88 (3.40) 0.67 (2.61)				
1992-2000	1.6	2.1 1.5	0.63 (2.75) 0.44 (2.23)				

Table 1f

United Kingdom

Period	Average trend growth		Regression results, Okun estimate					
			Coefficients[2]				Statistics	
	Actual	Estimate	Constant	GDP	GDP_{t-1}	GDP_{t-2}	R^2	DW
1963-2000	2.4	2.5	1.24 (6.92)	–0.19 (–3.63)	–0.31 (–5.83)		0.634	1.12
Subperiods[3]				–0.27 (–5.73) –0.26 (–5.42)	–0.26 (–5.66) –0.27 (–5.59)	–0.15 (–3.33) –0.15 (–3.19)	0.773 0.754	1.74 1.72
1964-73	2.9	3.0 3.0	2.06 (8.02) 2.04 (7.78)					
1974-79	2.3	2.5 2.1	1.68 (6.82) 1.36 (5.41)					
1980-90	3.1	2.6 2.4	1.80 (8.21) 1.66 (7.39)					
1991-2000	2.3	1.7 2.0	1.17 (5.70) 1.37 (6.50)					

Note: For footnotes, see Annex Tables 1a and 1b.

Table 1g

Canada

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1963-2000	3.7	3.6	1.19 (5.49)	–0.33 (–6.43)		0.514	0.79
Subperiods[3]				–0.37 (–8.32)	–0.14 (–3.03)	0.720	1.36
				–0.37 (–8.33)	–0.14 (–3.04)	0.720	1.36
1963-80	4.7	4.8	2.46 (8.61)				
		4.8	2.45 (8.56)				
1981-89	3.0	3.0	1.50 (6.33)				
		3.0	1.50 (6.33)				
1990-2000	2.5	2.3	1.20 (5.76)				
		2.5	1.26 (6.08)				

Table 1h

Euro area

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1966-2000	2.9	3.5	0.89 (5.12)	–0.23 (–4.50)		0.361	0.50
Subperiods[3]			1.32 (10.63)			0.755	1.94
				–0.38 (–9.50)	–0.21 (–5.18)	0.783	1.09
1966-74	4.9	5.2		–0.25 (–7.67)			
		4.9	2.92 (9.94)				
1975-79	2.7	4.9		–0.27 (–4.99)			
		2.7	1.57 (7.97)				
1980-91	2.3	2.8		–0.48 (–8.35)			
		2.3	1.39 (8.90)				
1992-2000	2.0	2.1		–0.63 (–9.51)			
		1.9	1.11 (7.60)				

Note: For footnotes, see Annex Tables 1a and 1b.

Table 1i
Australia[4]

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1961-2000	3.9	4.1	1.48 (6.68)	–0.36 (–6.88)		0.543	1.35
Subperiods[3]			1.64 (7.99)			0.654	1.87
				–0.44 (–8.26)	–0.15 (–3.33)	0.672	1.77
1961-73	5.4	5.3		–0.31 (–6.53)			
		4.9	2.93 (7.75)				
1974-81	2.8	3.8		–0.43 (–4.71)			
		2.9	1.70 (6.25)				
1982-90	3.4	3.4		–0.49 (–7.53)			
		3.2	1.92 (6.43)				
1991-2000	3.3	3.2		–0.51 (–7.41)			
		3.4	2.02 (7.13)				

Table 1j
Netherlands

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1970-2000	2.6	2.6	1.75 (5.23)	–0.41 (–3.89)	–0.26 (–2.63)	0.506	0.64
Subperiods[3]				–0.50 (–6.73)	–0.40 (–5.64)	0.772	1.34
				–0.50 (–6.79)	–0.40 (–5.67)	0.760	1.32
1970-74	3.7	4.4	3.98 (8.90)				
		4.0	3.64 (8.16)				
1975-80	2.2	2.5	2.27 (7.12)				
		2.3	2.08 (6.59)				
1981-91	2.1	2.2	2.00 (8.08)				
		2.1	1.88 (7.63)				
1992-2000	2.9	2.5	2.22 (7.00)				
		2.8	2.54 (8.05)				

Note: For footnotes, see Annex Tables 1a and 1b.

Annex Table 1 (cont)

Table 1k

Spain

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1965-2000	3.5	4.2	1.78 (4.74)	–0.42 (–4.68)		0.374	0.63
Subperiods[3]				–0.61 (–6.67) –0.60 (–6.42)	–0.34 (–4.03) –0.33 (–3.75)	0.763 0.715	1.71 1.58
1965-74	6.4	6.2 6.2	5.92 (9.07) 5.76 (8.59)				
1975-79	1.6	3.2 1.7	3.01 (7.44) 1.54 (3.70)				
1980-91	2.7	3.3 2.7	3.11 (9.18) 2.56 (7.36)				
1992-2000	2.7	2.3 2.5	2.13 (5.83) 2.34 (6.24)				

Table 1l

Sweden

Period	Average trend growth		Regression results, Okun estimate				
	Actual	Estimate	Coefficients[2]			Statistics	
			Constant	GDP	GDP_{t-1}	R^2	DW
1961-2000	2.5	2.9	0.72 (4.88)	–0.25 (–5.50)		0.428	0.91
Subperiods[3]				–0.26 (–5.21) –0.26 (–5.21)	–0.12 (–2.26) –0.12 (–2.25)	0.513 0.499	1.08 1.08
1961-76	3.7	3.7 3.7	1.41 (5.26) 1.40 (5.25)				
1977-79	1.3	1.4 1.0	0.52 (1.65) 0.38 (1.20)				
1980-90	2.1	2.1 2.2	0.81 (3.78) 0.82 (3.84)				
1991-2000	1.7	2.5 1.6	0.93 (4.69) 0.62 (3.12)				

Note: For footnotes, see Annex Tables 1a and 1b.

Annex Table 2

Trend growth for GDP: quarterly Okun estimates for the most recent cycle[1]

Table 2a

Country	Period	Average growth[2]		Coefficients[3]							Statistics	
		Actual	Trend estimate	Constant	Dummy	GDP	GDP_{t-1}	GDP_{t-2}	GDP_{t-3}	GDP_{t-4}	R^2	DW
United States	1990:3-94:4	2.3	2.3	0.28	0.13	–0.12	–0.19	–0.05	–0.02	–0.12	0.605	1.19
	1995:1-01:2	3.5	3.3	(6.24)	(2.71)	(–3.38)	(–5.0)	(–1.38)	(–0.62)	(–3.18)		
Japan	1993:2-01:2	1.0	2.8	0.13			–0.05	–0.06	–0.04	–0.05	0.535	1.21
				(8.77)			(–4.03)	(–4.53)	(–2.96)	(–4.13)		
Germany	1992:2-01:2	1.4	1.8	0.28		–0.09	–0.13	–0.16	–0.13	–0.10	0.447	0.69
				(5.49)		(–1.87)	(–2.82)	(–3.54)	(–3.02)	(–2.33)		
	1992:2-96:4	1.1	2.4	0.28	1.6	–0.07	–0.10	–0.13	–0.10	–0.07	0.682	1.17
	1997:1-97:4	1.7	3.8	(7.10)	(1.98)	(–1.74)	(–2.71)	(–3.73)	(–2.76)	(–2.06)		
	1998:1-01:2	1.8	0.6		–0.21							
					(–3.7)							
France	1992:2-01:2	1.9	1.7	0.23			–0.27	–0.27			0.701	1.35
				(6.28)			(–5.37)	(–5.26)				
Italy	1992:1-01:2	1.7	1.9	0.19		–0.08	–0.08	–0.10	–0.12		0.276	0.56
				(3.74)		(–1.49)	(–1.46)	(–1.85)	(–2.18)			
	1992:1-96:4	1.1	3.2	0.30	–0.24	–0.13		–0.18			0.443	2.30
	1997:1-01:2	2.2	0.7	(4.88)	(–3.27)	(–2.09)		(–2.80)				
United Kingdom	1990:3-1:2	2.1	1.8	0.25			–0.25	–0.32			0.728	1.16
				(6.81)			(–3.91)	(–5.02)				
	1990:3-94:4	1.3	2.3	0.35	–0.13	–0.14	–0.14	–0.19	–0.14		0.881	0.81
	1995:1-01:2	2.6	1.5	(12.25)	(–3.28)	(–3.08)	(–2.64)	(–3.67)	(–3.02)			
Canada	1990:2-01:2	2.6	2.4	0.26		–0.25	–0.18				0.547	1.97
				(5.02)		(–3.54)	(–2.53)					

[1] Regression using quarterly data: $\Delta u_t = \alpha + \Sigma d_j + \Sigma \beta_i y_i + \varepsilon$; Δu = change in the unemployment rate against previous quarter; α = constant; d = dummy; Δy = quarterly change in log GDP, where $i = t$, t-1. [2] Subperiods according to column 2. [3] t-values in brackets.

Annex Table 2 (cont)

Table 2b

Country	Period	Average growth[2]		Coefficients[3]							Statistics	
		Actual	Trend estimate	Constant	Dummy	GDP	GDP_{t-1}	GDP_{t-2}	GDP_{t-3}	GDP_{t-4}	R^2	DW
Euro area	1992:1-01:2	1.9	1.9	0.31		–0.20	–0.19	–0.13	–0.13		0.798	0.80
				(9.76)		(–4.81)	(–4.52)	(–3.22)	(–3.42)			
	1992:1-95:4	1.2	2.5	0.34	–0.14	–0.15	–0.16	–0.13	–0.10		0.870	0.94
	1996:1-01:2	2.5	1.5	(12.91)	(–4.34)	(–4.15)	(–4.84)	(–3.86)	(–3.32)			
Australia	1990:3–95:4	2.7	3.1	0.53	0.09	–0.15	–0.17	–0.11	–0.18	–0.08	0.671	1.14
	1996:1–01:2	3.9	3.7	(8.37)	(1.44)	(–3.34)	(–3.67)	(–2.52)	(–3.75)	(–1.75)		
Netherlands	1992:2–01:2	2.8	2.4	0.47		–0.23	–0.0	–0.18	–0.18	–0.19	0.391	2.22
				(4.02)		(–2.61)	(–0.0)	(–1.93)	(–2.04)	(–2.21)		
	1992:2–94:4	2.1	3.5	0.45	–0.23	–0.18	0.02	–0.13	–0.13	–0.12	0.451	2.53
	1995:1–01:2	3.1	1.7	(4.07)	(–2.10)	(–2.06)	(0.28)	(–1.47)	(–1.41)	(–1.26)		
Spain	1992:2–01:2	2.6	2.3	0.62		–0.36	–0.35	–0.39			0.757	1.24
				(7.41)		(–3.83)	(–3.65)	(–4.09)				
	1992:2–94:4	0.5	4.3	0.68	–0.51		–0.31	–0.34			0.738	1.13
	1995:1–01:2	3.6	1.1	(7.18)	(–3.34)		(–2.99)	(–3.24)				
Sweden	1990:3–01:2	1.7	2.2	0.26			–0.18	–0.30			0.596	1.26
				(5.25)			(–2.58)	(–4.46)				
	1990:3–95:4	0.5	3.5	0.35	–0.25		–0.14	–0.27			0.659	1.39
	1996:1–01:2	2.8	1.0	(6.35)	(–2.93)		(–2.21)	(–4.27)				

Note: For footnotes, see Annex Table 2a.

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