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Estimating the UK's historical output gap

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Estimating the UK's historical output gap

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Abstract

An important consideration for the assessment of the economic outlook is the size of the output gap - the difference between the current level of output and the potential level consistent with stable inflationary pressures. The Office for Budget Responsibility's approach to estimating the output gap has been to combine a range of indicators of the cyclical position of the economy using two different methods, although to date the OBR has applied these techniques only back to 2007. This paper develops and extends these approaches to estimate a historical output gap series. The estimates produced by the cyclical indicator methods appear to give a plausible representation of UK business cycle history and are broadly in line with estimates based on alternative approaches.

JEL references: C22, C38, E32
Keywords: Filtering, Factor Analysis, Business Cycles

I am grateful for comments from colleagues at the Office for Budget Responsibility.

Contents

1 Introduction

1.1 The Office for Budget Responsibility has been tasked with producing economic and fiscal forecasts over a five year time horizon, and with using these forecasts to assess whether the government is on course to achieve the medium-term fiscal targets that it has set it itself. Both require us to estimate the 'output gap', the difference between the current level of activity in the economy and the potential level it could sustain while keeping inflation stable in the long term.

1.2 There is a wide range of methods of estimating potential output and the output gap. The approach used by the Office for Budget Responsibility (OBR) has been to assess the size of the current output gap by combining a range of indicators of the cyclical position of the economy. Estimating the history of the output gap using this method is not straightforward, partly because many of the indicators used in estimating the size of the output gap have a short time series. To date the OBR has applied these techniques back to 2007.

1.3 This paper explores methods of extending the cyclical indicator approach over the past to produce a historical series for the UK output gap, and compares this with historical series produced using other approaches.

1.4 An analysis of the historical evolution of the output gap can be instructive in assessing the prospects for the economy. Estimates of the output gap during comparable stages of previous business cycles, for example, can be helpful in evaluating the plausibility of estimates of the current degree of spare capacity and the way in which the output gap might be expected to evolve. Importantly, developing a time series for the output gap will make it possible to reassess the historical effect of the economic cycle on the public finances. To date, OBR estimates of the cyclically-adjusted fiscal aggregates have used the coefficients set out in previous Treasury analysis.[1] Constructing a historical output gap series will allow us to reassess the size of these coefficients. Undertaking this analysis has also led us to refine the methodology we use to produce estimates of the current output gap.

1.5 Chapter 2 briefly summarises the cyclical indicator approach and describes how the methodology has been developed and extended to estimate a historical

[1] Farrington et al (2008).

output gap series. Chapter 3 sets out the estimates of the historical output gap using this approach, and compares the results with other estimates. Chapter 4 concludes.

1.6 Any output gap estimate remains highly uncertain, even when it relates to the past: the level of potential output is never observed, and while a longer run of data undoubtedly helps the identification of cyclical and trend fluctuations in output,[2] estimates of the historical output gap remain sensitive to the assumptions, data and methodology used to construct the series. Similarly the estimates presented in this paper are subject to significant uncertainty and remain work-in-progress.

[2] Orphanides and van Norden (2002) cite a number of reasons why the emergence of new data allows output gap estimates to be refined over time. First, revisions to output data may affect point estimates of the output gap; data for subsequent quarters may make it easier to distinguish the cyclical position of the economy with the benefit of hindsight; and new data may lead researchers to review their existing models.

2 The cyclical indicator approach

2.1 There are a number of approaches to estimating the output gap. Commonly used methods include statistical filters and production function approaches (see chapter 3). The cyclical indicator approach combines a large number of variables from various surveys and ONS data to construct an estimate of the output gap. This chapter briefly summarises the cyclical indicator methodology used by the OBR to derive output gap estimates, and describes how the approach has been developed and extended to generate a historical output gap series.

Aggregate composite approach

2.2 Aggregate composite estimates of the output gap combine survey-based indicators of spare capacity using information on factor and income shares. These indicators, listed in Table 2.1, include measures of recruitment difficulties and capacity utilisation from the Bank of England Agents' Summary of Business Conditions, the Confederation of British Industry's (CBI) Industrial Trends Survey and the British Chambers of Commerce (BCC) Quarterly Economic Survey.

2.3 The aggregate composite measure of the output gap is generated by first constructing an aggregate indicator of recruitment difficulties and an aggregate indicator of capacity utilisation, using information from all three surveys. The aggregate composite measure of the output gap is then derived as a weighted average of the aggregate recruitment difficulties and capacity utilisation indicators, with weights determined by the labour share of income. To ensure indicators from different surveys are expressed in comparable units of measurement, each variable is 'standardised' prior to estimation i.e. expressed in terms of the number of standard deviations from the mean of the series.[1] Full details of the methodology are set out in *Briefing paper No.2: Estimating the output gap*.

2.4 Extending the aggregate composite approach over the past is not straightforward as many indicators have a relatively short time series (Table 2.1). While indicators

[1] Specifically, for any given variable x, the standardised value of that variable ($\hat{x}$) is given by the expression $\hat{x} = (x - \bar{x})/\sigma_x$, where $\bar{x}$ denotes the sample mean of the series and σ_x the standard deviation.

from the CBI Industrial Trends Survey are available back to the early 1970s, indicators from the Bank of England Agents' Summary of Business Conditions are only available back to 1997 or 1998. Indicators from the BCC survey start in 1989 but the sample has been restricted to the period since 1995 to account for the negative skew of the indicators over the full sample.[2]

Table 2.1: Variables used in aggregate composite estimates

Source	Variable	Start date
Bank of England Agents' Summary of Business Conditions[1]	Recruitment difficulties	1997
Bank of England Agents' Summary of Business Conditions[1]	Capacity utilisation: manufacturing	1998
Bank of England Agents' Summary of Business Conditions[1]	Capacity utilisation: services	1998
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing recruitment difficulties	1995[2]
BCC Quarterly Economic Survey	Percentage of services firms experiencing recruitment difficulties	1995[2]
BCC Quarterly Economic Survey	Percentage of manufacturing firms operating at full capacity	1995[2]
BCC Quarterly Economic Survey	Percentage of services firms operating at full capacity	1995[2]
CBI Industrial Trends Survey	Percentage of firms experiencing skilled labour recruitment difficulties	1972[3]
CBI Industrial Trends Survey	Percentage of firms experiencing other labour recruitment difficulties	1972[3]
CBI Industrial Trends Survey	Percentage of firms operating at full capacity	1972[3]

[1] The monthly scores from the Bank of England Agents' reports are transformed into quarterly observations by taking the average of the three months relating to that quarter.

[2] Although BCC survey indicators extend back to 1989 the sample has been restricted to the period since 1995 to account for the negative skew of the indicators over the full sample. See footnote 2 in the main text.

[3] Data available for the full four quarters of the year from 1972. Data are also available for June, October and February between 1958 and 1972.

[2] One criterion for the period used to calculate the 'normal' level of an indicator is whether the series is symmetrically distributed. Recent analysis of the cyclical indicators found that a number of the indicators from the BCC survey were negatively skewed (i.e. the indicators were asymmetrically distributed) since the start of the series in 1989. By contrast, the BCC survey indicators generally showed stronger evidence of a symmetric distribution when the sample was restricted to the period from 1995. See HM Treasury (2008).

2.5 With only the CBI survey available back to the early 1970s it is necessary to modify the approach to produce a historical aggregate composite series. The approach adopted here generates a historical series by combining a pre-1995 series generated using CBI survey variables with a post-1995 series using all available survey variables. In particular:

- the pre-1995 series has been constructed by taking the weighted average of CBI capacity utilisation and recruitment difficulties indicators;[3]
- the post-1995 series has been constructed using all available indicators, weighted together using factor and income shares.[4]

The pre-1995 series and post-1995 series have then been combined to produce a historical aggregate composite series, set out in chapter 3.[5] Table 2.2 summarises the variables used to construct each series.

2.6 One limitation of this approach is that the CBI Industrial Trends Survey - which is used exclusively to generate the series prior to 1995 - relates to the manufacturing sector only. As a result, aggregate composite estimates of the output gap prior to 1995 reflect the degree of spare capacity or excess demand in the manufacturing sector and do not take into account other information on whole economy capacity pressures.

[3] These variables are standardised using the mean and standard deviation of each series between 1972 and 1995; the raw aggregate composite series is then transformed to an appropriate output gap scale by scaling to the mean and standard deviation of the OECD's historical output gap series (from Economic Outlook No.89) over this period. This procedure is consistent with that used for the post-1995 series, although the post-1995 series is standardised and transformed using post-1995 means and standard deviations, and is scaled to the post-1995 OECD output gap series. See *Briefing paper No.2: Estimating the output gap* for more details.

[4] As indicators from the Bank of England Agents' Summary are only available from 1997 or 1998, the aggregate composite estimates between 1995 and 1998 are based on indicators from the BCC and CBI surveys only.

[5] To overcome possible discontinuities at the point at which the two sub-samples are combined the pre-1995 estimates are assumed to converge gradually to the post-1995 estimates. Firstly, both the 'pre-1995' and the 'post-1995' samples are used to estimate the output gap for the period after 1995. The output gap estimate from 1995 is then set equal to a weighted average of estimates based on the pre-1995 sample and estimates based on post-1995 sample, with the weight on the former declining to zero after two years.

Table 2.2: Variables used in aggregate composite sub-samples

Source	Variable	Pre-1995 series	Post-1995 series
Bank of England Agents' Summary of Business Conditions	Recruitment difficulties	No	Yes
Bank of England Agents' Summary of Business Conditions	Capacity utilisation: manufacturing	No	Yes
Bank of England Agents' Summary of Business Conditions	Capacity utilisation: services	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms experiencing recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms operating at full capacity	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms operating at full capacity	No	Yes
CBI Industrial Trends Survey	Percentage of firms experiencing skilled labour recruitment difficulties	Yes	Yes
CBI Industrial Trends Survey	Percentage of firms experiencing other labour recruitment difficulties	Yes	Yes
CBI Industrial Trends Survey	Percentage of firms operating at full capacity	Yes	Yes

Principal components estimates

2.7 Principal components analysis (PCA) is a commonly used statistical technique that enables the identification of the common determinant of a number of variables. In the case of a set of cyclical indicators, the PCA technique can be used to distinguish the common cyclical component from other components (such as the trend) of a set of indicators.[6] To identify the cyclical component from a set of indicators, the PCA chooses the weights (also referred to as 'loadings') for each

[6] See Altissimo et al (2001) for an application of a principal components approach to estimating the Euro Area business cycle in real time (the 'EuroCOIN' indicator).

indicator.[7] The combination of indicators based on these weights can then be used to construct a series for the output gap. Further details are set out in *Briefing paper No.2: Estimating the output gap*.

2.8 One advantage of the principal components approach is that it is able to accommodate non-survey measures of spare capacity, such as measures of wage inflation. Unlike the aggregate composite approach, it is therefore possible to incorporate wider measures of the cyclical position of the economy to produce estimates of the output gap prior to 1995.

2.9 As with the aggregate composite approach, estimating the history of the output gap using principal components analysis is complicated by the short history of the time series. Table 2.3 sets out the set of indicators used in the OBR's principal components analysis to date, along with the start date of each variable. Time series of Average Weekly Earnings growth currently extend back to 2001, while the CBI/PricewaterhouseCoopers Financial Services Survey variable is available from 1989. In addition, indicators from the BCC survey - which comprise around half of the cyclical indicators used in the PCA- are restricted to the period from 1995.[8]

[7] Principal components analysis specifies a number of different linear combinations of the underlying variables which (i) are uncorrelated with each other and (ii) contain the maximum variance. The first principal component is the linear combination which has the greatest variance. This component is interpreted as a proxy for the output gap, based on the assumption that the output gap is the most important common determinant of the cyclical indicators.

[8] See footnote 2.

Table 2.3: Variables used in principal components analysis to date

Variable	Start date
BCC Quarterly Economic Survey variables[1]	1995[2]
CBI Industrial Trends Survey variables[3]	1972[4]
CBI/PricewaterhouseCoopers Financial Services Survey: percentage balance of financial services firms with levels of business above normal	1989
Average Weekly Earnings growth: total pay, private sector	2001
Average Weekly Earnings growth: total pay, manufacturing	2001
Average Weekly Earnings growth: total pay, services	2001
Unit wage costs, per cent change on a year earlier	1960
Real unit wage cost growth (unit wage costs deflated by RPIX), per cent change on a year earlier	1976
Total compensation of employees divided by Gross Value Added (GVA)	1955
Total wages and salaries divided by GVA	1955
Deviation of unemployment from OECD estimate of the NAIRU	1971

[1] The principal components analysis includes twelve indicators of recruitment difficulties and capacity utilisation from the BCC Quarterly Economic Survey. The full list of variables is set out in Table 2.4.

[2] Although BCC survey indicators extend back to 1989 the sample has been restricted to the period since 1995 to account for the negative skew of the indicators over the full sample. See footnote 2 in the main text.

[3] The principal components analysis includes three indicators of recruitment difficulties and capacity utilisation from the CBI Industrial Trends Survey. The full list of variables is set out in Table 2.4.

[4] Data available for the full four quarters of the year from 1972. Data is also available for June, October and February between 1958 and 1972.

2.10 Consistent with the procedure used to construct aggregate composite indicator, the series has been split into pre-1995 and post-1995 sub-samples.[9] The variable set used in the PCA has also been refined and simplified from the variable set used in previous OBR principal components estimates:

[9] In principle, multiple sub-samples could be re-estimated depending on the availability of different indicators, although this would involve splicing together a large number of time series. The choice to split the sample at 1995 is a pragmatic one, based on the availability of BCC survey indicators - which constitute a significant proportion of the variable set – at this point.

- indicators of unit wage cost growth (both real and nominal) and indicators of the labour share of income (wages and salaries as a share of GVA and compensation of employees as a share of GVA) have been removed from the variable set. These indicators had negligible weights in previous principal component estimation. Indicators of the labour share of income have exhibited a downward trend over the past forty years (Chart 2.1), making it difficult to identify cyclical changes in the labour share that could relate to the cyclical position of the economy;[10]

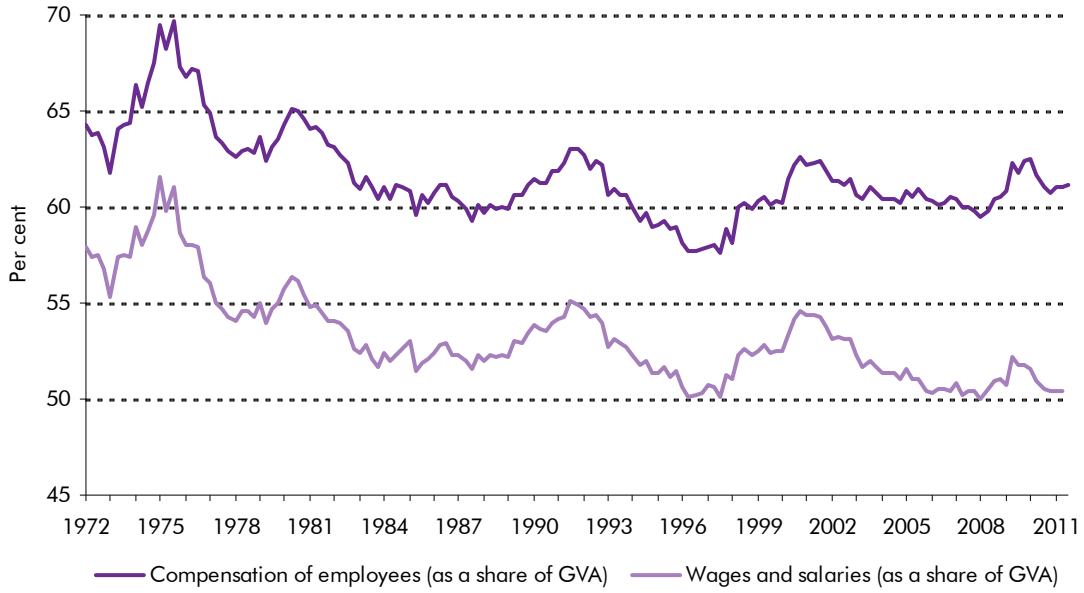
- indicators of nominal earnings growth have been replaced with measures of real earnings growth. As with the labour share, nominal earnings growth has exhibited a marked downward trend since the 1970s (Chart 2.2), consistent with a significant reduction in the level of price inflation. Accordingly fluctuations in nominal earnings growth relative to a constant mean will reflect the general downward trend in earnings growth and provide little information on the evolution of cyclical position of the economy over this period. By definition, real earnings growth is unaffected by the disinflation over this period and does not exhibit evidence of a strong downward (or upward) trend;

- to ensure a greater degree of consistency in the type of indicator used in the PCA the deviation of the unemployment rate from the OECD NAIRU has been excluded from the dataset.[11]

[10] The downward trend labour income share over the period 1972-1995 means that deviations around a constant mean of the series are likely to provide little information on the cyclical position of the economy. An alternative approach would be to attempt extract a 'trend' labour income share over the period and compare deviations in the actual share to the trend share. Such an extension would add a further degree of subjectivity over the method of trend extraction and appropriate smoothing parameters, and would be inconsistent with the approach adopted for other variables in the principal components analysis.

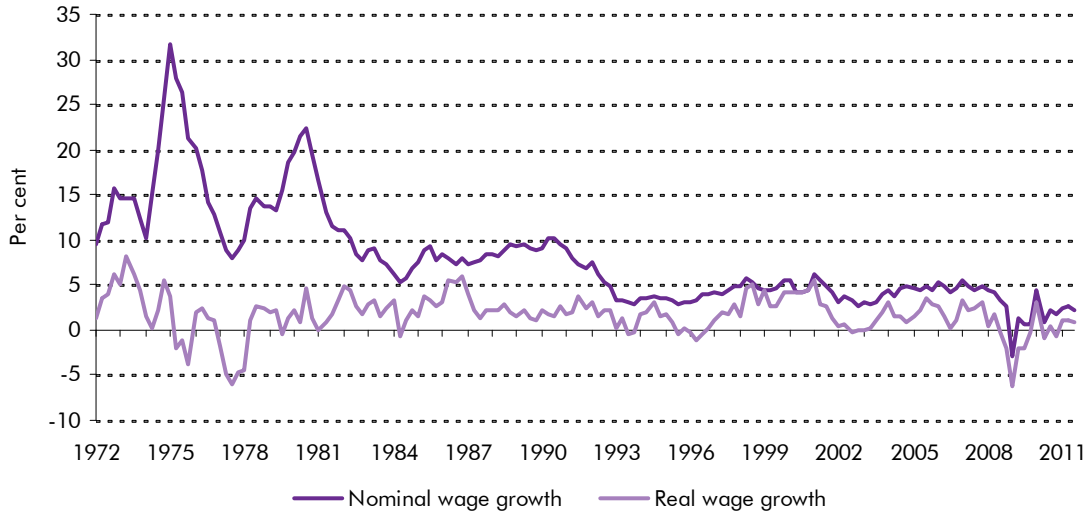
[11] The deviation of the unemployment rate from the OECD NAIRU represents an estimated component of the output gap, rather than a more general indicator of the degree of spare capacity or excess demand.

Chart 2.1: The labour share of income



Source: ONS.

Chart 2.2: Earnings growth (annual)



Nominal wage growth equal to Average Weekly Earnings growth (total pay, whole economy) from 2001; and growth of the Average Earnings Index (total pay, whole economy) between 1972 and 2001. Real wage growth equal to nominal wage growth deflated by the GVA deflator.
Source: ONS, OBR.

2.11 The sub-samples for the principal components estimates have been constructed in the following way:

- the series corresponding to the period 1972 to 1995 has been constructed using whole economy real wage growth and indicators from the CBI Industrial Trends Survey;

- the post-1995 series has been constructed using indicators of real wage growth in private sector, manufacturing sector and services sector as well as indicators from the CBI Industrial Trends Survey, CBI/PricewaterhouseCoopers Financial Services Survey and the BCC Quarterly Economic Survey.

2.12 Table 2.4 summarises the variables used in each sub-sample. The pre-1995 series and post-1995 series have been combined to produce a historical principal component series, set out in chapter 3.[12] The derived weight on each indicator is set out in Annex A.

[12] As with the aggregate composite estimates, the pre-1995 estimates are assumed to converge gradually to the post-1995 estimates. See footnote 5.

Table 2.4: Variables used in PCA sub-samples

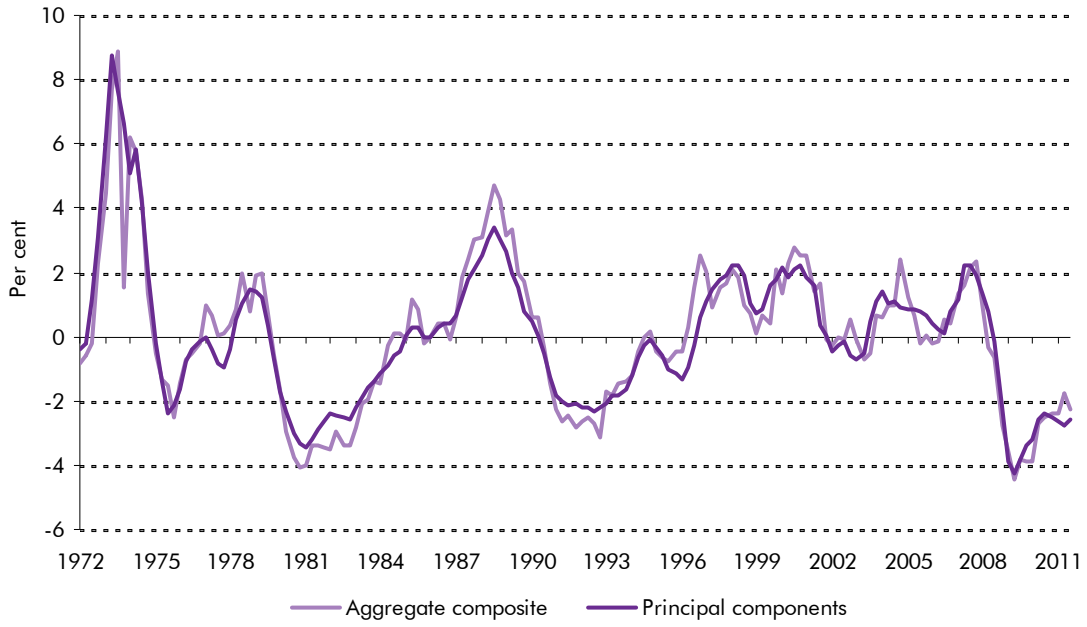
Source	Variable	Pre-1995 series	Post-1995 series
BCC Quarterly Economic Survey	Percentage of services firms experiencing recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms experiencing clerical labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms experiencing semi/unskilled labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms experiencing skilled manual labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms experiencing professional/managerial manual labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing clerical labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing semi/unskilled labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing skilled manual labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing professional/managerial labour recruitment difficulties	No	Yes
BCC Quarterly Economic Survey	Percentage of services firms operating at full capacity	No	Yes
BCC Quarterly Economic Survey	Percentage of manufacturing firms operating at full capacity	No	Yes
CBI Industrial Trends Survey	Percentage of firms experiencing skilled labour recruitment difficulties	Yes	Yes
CBI Industrial Trends Survey	Percentage of firms experiencing other labour recruitment difficulties	Yes	Yes
CBI Industrial Trends Survey	Percentage of firms operating at full capacity	Yes	Yes
CBI/PricewaterhouseCoopers Financial Services Survey	Percentage balance of financial services firms with levels of business above normal	No	Yes
Office for National Statistics	Average Weekly Earnings growth: total pay, private sector, deflated by the GVA deflator[1]	No	Yes
Office for National Statistics	Average Weekly Earnings growth: total pay, services, deflated by the GVA deflator[1]	No	Yes
Office for National Statistics	Average Weekly Earnings growth: total pay, manufacturing, deflated by the GVA deflator[1]	No	Yes
Office for National Statistics	Average Weekly Earnings growth: total pay, whole economy, deflated by the GVA deflator[1]	Yes	No

[1] Average Weekly Earnings growth series start in 2001. Prior to 2001 the comparable Average Earnings Index (AEI) series is used as a measure of nominal earnings growth.

3 Estimates of the historical output gap

3.1 Chart 3.1 sets out historical estimates of the output gap using the approaches set out in the previous chapter. The aggregate composite and principal components estimates are closely correlated, as might be expected given the similarities in the underlying dataset: a number of the indicators used in the aggregate composite measure also have a relatively high weight in the PCA.[1]

Chart 3.1: Cyclical indicator estimates of the output gap



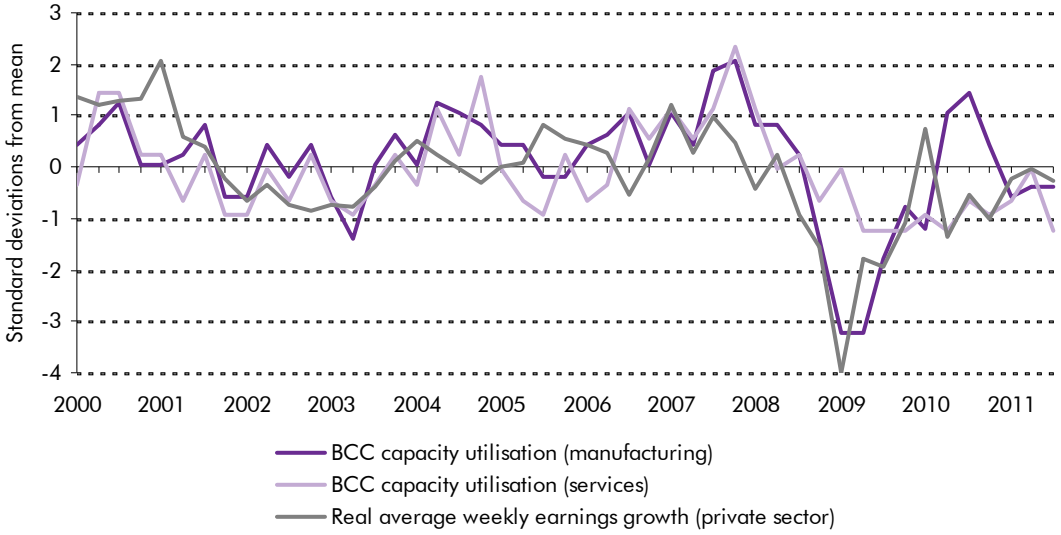
Source: OBR.

3.2 The estimates produced by the cyclical indicator methods appear to give a plausible representation of UK business cycle history. Both estimates indicate periods of above-trend output during the period most commentators consider to

[1] The variable with the largest weight by the post-1995 principal component estimate is the BCC survey indicator of recruitment difficulties in the service sector (see Annex A for the derived weights on each indicator in the PCA), which also has one of the largest implicit weightings in the aggregate composite indicator. See *Briefing paper No.2: Estimating the output gap*.

have been 'booms' in economic activity of the early 1970s and the late 1980s, and periods of negative output gaps around the recessions of the mid-1970s, early 1980s, early 1990s and 2008-2009. Both approaches also suggest the economy was operating moderately above trend prior to the recent recession, although the size of the suggested output gap is relatively modest compared to previous business cycles. The positive output gap over this period reflects the fact that a number of key survey indicators-most notably BCC measures of capacity utilisation – were relatively elevated in the run up to 2008 (Chart 3.2). A number of measures of real wage growth – used in the principal component analysis – were also above their post-1995 average during this period.

Chart 3.2: Selected cyclical indicators



Source: OBR, ONS, BCC. Chart shows standard deviation of each indicator from the post-1995 mean. Real earnings growth defined as Average Weekly Earnings (AWE) growth deflated by the GVA deflator. Prior to 2001 AWE growth is calculated using the Average Earnings Index.

3.3 By combining estimates of the output gap with estimates of actual output it is also possible to 'back out' estimates of potential growth over time. Table 3.1 sets out the average potential growth rates implied by the two cyclical indicator output gap series and latest actual output data. The implied potential growth rate picked up from under 2 per cent in the 1970s to around 2.4 per cent in the following two decades. Both indicators imply that potential output grew by just under 2½ per cent over the decade from 2000, although both approaches suggest a deceleration in potential growth within this period. The principal component estimate, for example, implies a potential growth rate of over 3 per cent in the first half of the decade; by contrast, potential growth averages 1.3 per cent on this measure between 2005 and 2010. Both approaches imply a long-term average potential growth rate of 2.3 per cent between 1972 and 2010.

3.4 One feature of the cyclical indicator approach is that it is not based directly on measures of output. A result of this is that implied estimates of potential growth will tend to display volatility at quarterly frequencies, partly reflecting the fact that irregular movements in output and the cyclical indicators are unlikely to be well correlated. In addition, estimates of the output gap using this approach are less likely to be influenced by revisions to National Accounts data than methods that rely more heavily on estimates of output. The stability of the output gap estimate means that revisions to actual output data will instead be reflected in revisions to the potential output level implied by the estimate of the output gap and latest output data.

Table 3.1: Implied potential output growth (per cent)[1]

		Aggregate composite	Principal components
1972-1980		1.8	1.8
1980-1990		2.4	2.5
1990-2000		2.4	2.4
2000-2010		2.4	2.4
	2000-2005	*3.5*	*3.4*
	2005-2010	*1.3*	*1.3*
1972-2010		2.3	2.3

[1] Non-oil Gross Value Added basis.

3.5 Because the PCA is based on a wider range of variables, it is arguably a more comprehensive measure of the output gap than the aggregate composite estimate. Importantly, the use of ONS data on average earnings growth in the pre-1995 sample means that the pre-1995 series is not exclusively based on manufacturing-only survey data, unlike the aggregate composite series. As with any series, survey data may be subject to limitations as an indicator of the degree of spare capacity or excess demand;[2] it is therefore helpful to complement survey data with non-survey cyclical indicators.

[2] For example, survey measures typically report the balance of firms operating below or above capacity but not the extent of spare capacity within firms. See the Bank of England's *Inflation Report,* August 2011 for a discussion of some of the issues in interpreting survey measures of spare capacity.

Other approaches

Statistical filter estimates

3.6 There is a wide range of other approaches to estimating the output gap and potential output. One commonly used method to extract the trend from various time series is a statistical filter. A statistical filter attempts to extract the underlying trend by fitting a smoothed line to the raw data series. Unlike a simple linear trend, a statistical filter typically allows for changes in the slope of the trend over time. To apply a statistical filter it is typically necessary to specify specific parameters in advance, such as the desired degree of smoothness of the extracted trend.

3.7 One of the most widely used examples of a statistical filter is the so-called Hodrick-Prescott (HP) filter.[3] Letting a_t represent the raw series at time t, and x_t the trend of series, the HP filter extracts a trend which minimises the following loss function:

$$\sum_{t=1}^{T}(a_t - x_t)^2 + \lambda\sum_{t=2}^{T-1}\left[(x_{t+1} - x_t) - (x_t - x_{t-1})\right]^2$$

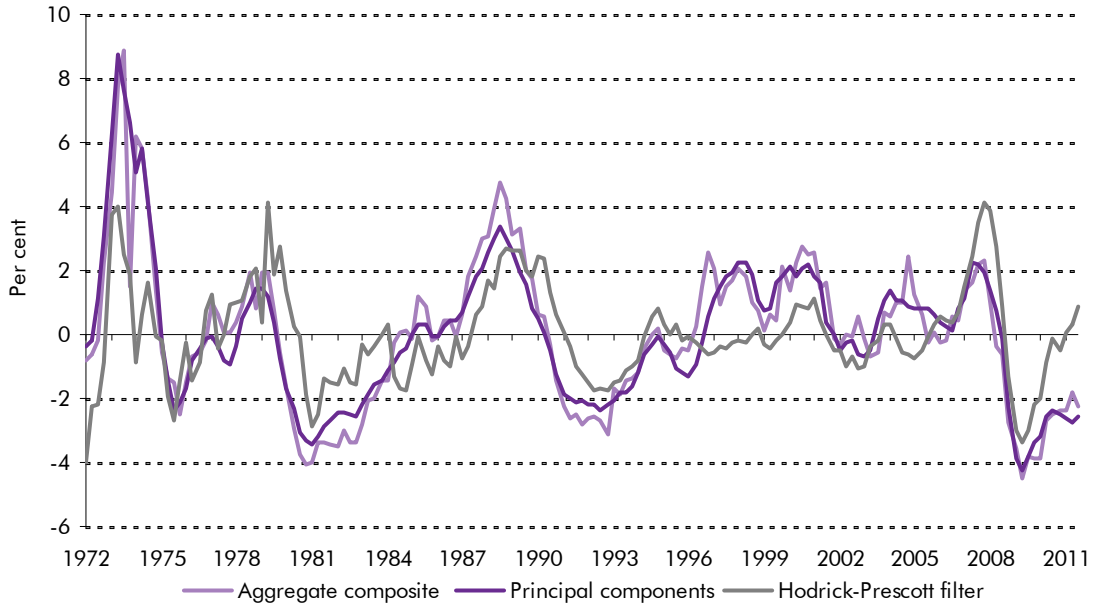
3.8 The left hand side of the loss function represents the sum of the squared deviations of the trend from the actual data: it captures how close the extracted trend is to the raw series. The right hand side of the function represents the extent to which the slope of the trend changes between successive observations: the lower this value, the 'smoother' the trend. In practice there is a trade-off between the extent to which a trend matches the data and the smoothness of the trend. A very smooth trend will only loosely match the raw series, while a trend that matches the raw series very closely will display a much greater degree of volatility.

3.9 The degree of weight that is placed on the smoothness of the trend relative to deviations from the actual data is captured by the smoothing parameter, λ. A smoothing parameter equal to zero means that no weight is placed on the smoothness of the trend. In this case the extracted trend will be simply equal to the raw series. On the other hand, large smoothing parameters will tend to produce very smooth trends, with the HP trend converging to a simple linear trend as the smoothing parameter approaches infinity. In most studies the smoothing parameter is set in line with existing conventions: for quarterly data, for example, the smoothing parameter is typically set to 1600, consistent with Hodrick and Prescott's original study.

[3] Hodrick and Prescott (1997).

3.10 Chart 3.3 compares the cyclical indicator estimates of the output gap with those produced by an HP filter using standard smoothing parameters. While the series observe similar peaks and troughs it is notable that the HP output gap has a lower amplitude, in turn reflecting the tendency of the HP trend to move more closely with actual output.

Chart 3.3: Statistical filter estimates of the output gap: Hodrick-Prescott filter



Source: OBR. Output gap defined on a non-oil GVA basis.

3.11 An alternative type of statistical filter is the 'band-pass' filter. A band-pass filter extracts the trend and cycle of a series by filtering out data according to its frequency. Band-pass filters typically identify three components of a time series, corresponding to different frequencies: the 'trend', which corresponds to low frequency components; the 'cycle', which corresponds to the frequency range specified as cyclical; and the 'irregular' or 'noise' element, which correspond to high frequency components. For example, if business cycle fluctuations are assumed to observe a frequency of two to eight years, components corresponding to frequencies below two years would be usually assigned as irregular; those between two and eight years would be identified as cyclical; and those above eight years as trend movements. Again, the frequency range is typically set in line with existing conventions.

3.12 A commonly used example of the band-pass filter is the Baxter-King (BK) filter.[4] The BK filter operates as a centred (symmetrical) moving average, with the span of the moving average determined by the pre-specified cycle frequency. As a centred moving average it cannot extract the trend or cycle components at the beginning or end of the sample, as there are insufficient observations on either side of data. Accordingly the trend series is 'trimmed' at the start and end of the sample. The Christiano-Fitzgerald (CF) filter[5] is an alternative to the BK filter which uses the entire time series to estimate the trend and cyclical components and is capable of extracting the trend and cycle at the beginning and end of the sample.

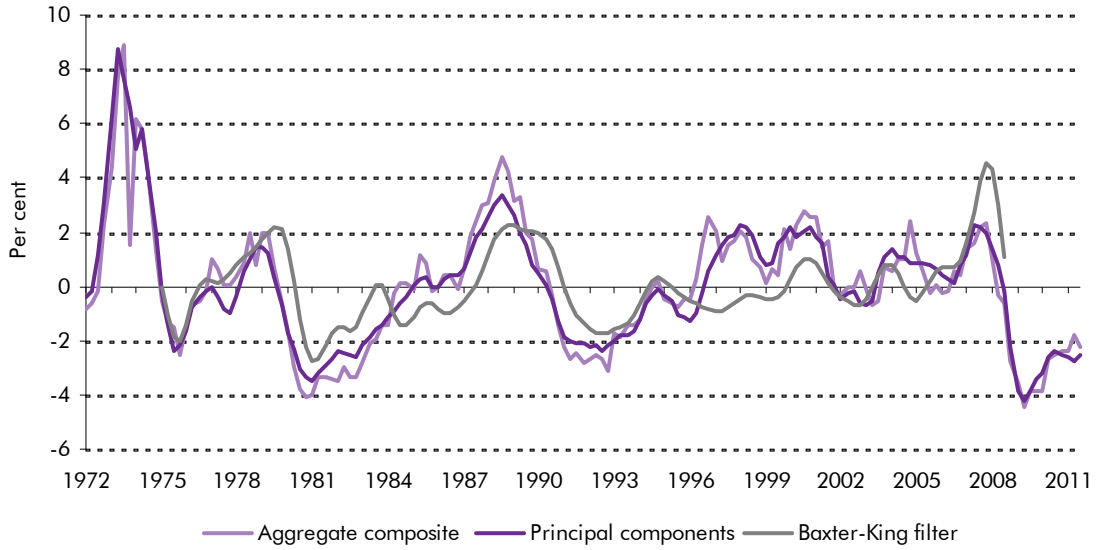
3.13 Charts 3.4 and 3.5 set out estimates of the output gap using the BK and CF filters. In both cases, the specified cycle frequencies are set in line with the length of cycle identified in the original studies.[6] The BK filter estimates suggest similar turning points in the output gap to those implied the cyclical indicator estimates, although the CF estimates exhibit higher frequency fluctuations. As with the HP filter, the BK and CF filter estimates display lower amplitude than those based on the cyclical indicators.

[4] Baxter and King (1995).

[5] Christiano and Fitzgerald (2003).

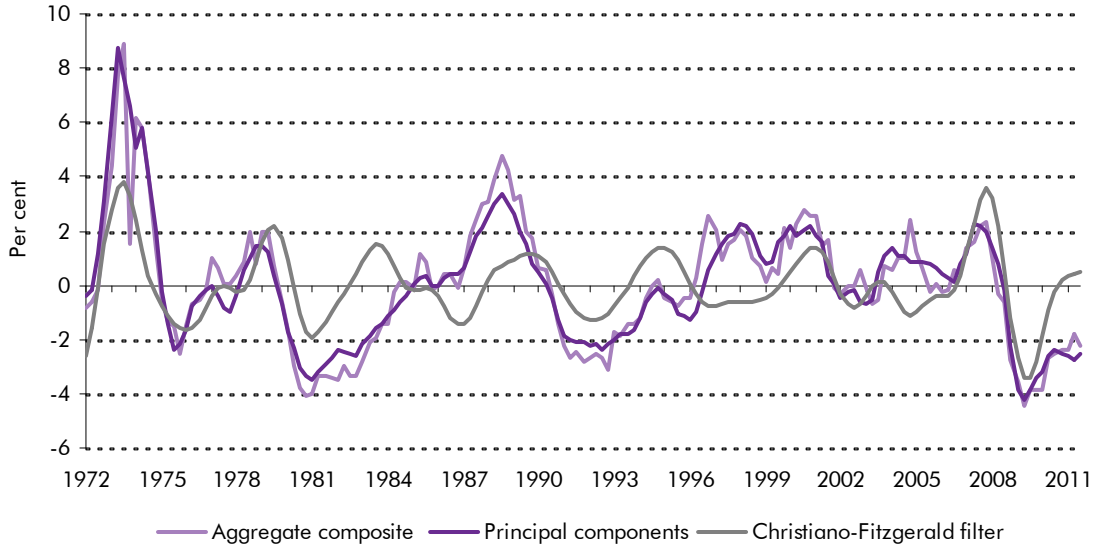
[6] The frequency range for the cyclical component has been set to one and a half to eight years for the Baxter-King filter; and two to eight years for the Christiano-Fitzgerald filter.

Chart 3.4: Statistical filter estimates of the output gap: Baxter-King filter



Source: OBR. Baxter-King output gap estimates equal to the estimated cyclical component of output as a share of the non-cyclical component of output (non-oil GVA basis).

Chart 3.5: Statistical filter estimates of the output gap: Christiano-Fitzgerald filter



Source: OBR. Christiano-Fitzgerald output gap estimates equal to the estimated cyclical component of output as a share of the non-cyclical component of output (non-oil GVA basis).

3.14 While simple to understand and apply, statistical filters suffer from a number of drawbacks. The trend series that is extracted using a statistical filter – and the size of the implied output gap – depends crucially on the choice of parameters to calibrate the filter. For example, the HP filter requires the user to set the desired smoothness of the extracted trend. The choice of this parameter is largely arbitrary, and is typically set according to existing conventions. In addition, statistical filters tend to produce biased estimates at the end of the sample: the estimated trend at the end of the time series is disproportionately affected by the most recent data point. While supplementing the existing series with forecasts can partly alleviate this problem, it leaves the accuracy of the estimated trend conditional on the accuracy of the forecast.

Multivariate filters

3.15 Conventional statistical filter approaches to measuring the output gap are based on the application of the filter to a single time series of output. Alternatively, estimates of the output gap can be derived from a 'multivariate' filter approach. Multivariate methods derive estimates of the output gap a set of conditioning relationships that link the output gap and other variables. Examples of conventional conditioning relationships used in multivariate analysis include the relationship between inflation and the output gap (the Phillips curve) and the relationship between the output gap and disequilibrium unemployment (Okun's law). Together with assumptions about the behaviour of the equilibrium variables in the model (such as the NAIRU, or potential growth rate), these relationships can be used to extract an estimate of the output gap.

3.16 An advantage of the multivariate approach is that it explicitly draws on well-established relationships between the output gap and other macroeconomic variables. A much larger wider set of information can be used than approaches based on a single variable. Nevertheless, estimates produced using this approach are inevitably subject to the set of conditioning relationships and assumptions that need to be imposed in advance.

3.17 In a recent study[7] the IMF use a multivariate filter model to derive estimates of the UK output gap. The model incorporates a series of conditioning relationships, including a Phillips curve, an Okun's law relationship, and separate equations linking the output gap to monetary policy and the rate of capacity utilisation. The IMF's latest estimates using this approach point to an output gap of around -2

[7] IMF (2010).

per cent at the end of 2010, narrowing from just under -3 per cent at the end of 2009.[8]

Production function estimates

3.18 Another frequently used method to estimate potential output is using a production function, which relates the level of output at any time to the level of factor inputs (typically capital and labour) and Total Factor Productivity (TFP), the 'efficiency' with which factor inputs are used.[9] The production function approach is used by a number of institutions to estimate potential output, including the OECD and the European Commission (EC). [10]

3.19 Estimates of potential output are derived from assumptions about the potential levels of factor inputs and TFP. In practice, these are extracted using a variety of approaches:

- labour input is usually split out into several components, typically comprising average hours, the unemployment rate, the participation rate and the working-age population.[11] The trend levels of each component are then extracted separately, typically using a variety of techniques. For example, both the OECD and European Commission identify the trend unemployment rate (NAIRU or NAWRU) using a Phillips Curve approach, while the trend participation rate is extracted using the HP filter;

- capital input assumptions vary between practitioners. The EC define potential capital input as equal to the actual capital stock, while the OECD measure capital input using a de-trended series of 'capital services'; [12]

- the EC estimates potential TFP by relating movements in survey measures of capacity utilisation to cyclical TFP fluctuations. The OECD's production function approach does not include TFP as conventionally defined but

[8] IMF (2011a).

[9] Not all production functions are specified strictly in terms of Total Factor Productivity, although this is a common functional form for many production function estimates of potential output. An alternative form of the production function often used to estimate potential output relates output to factor inputs and labour-augmenting technological progress.

[10] For full details of the production function approaches used by the European Commission and the OECD, see D'Auria et al (2010) and Beffy et al (2006).

[11] This decomposition applies where labour input is defined in terms of total hours. In the case where labour input is defined as total employment then a typical decomposition would comprise the participation rate, unemployment rate and working-age population, with average hours absorbed into the TFP component.

[12] Unlike conventional 'wealth-type' measures of the capital stock, measures of capital services attempt to capture the flow of productive services from capital. See Appleton and Wallis (2011).

instead incorporates a measure of labour-augmenting technological progress, which is extracted using a statistical filter.

3.20 A further consideration is the functional form of the production function. Both the OECD and European Commission use a conventional 'Cobb-Douglas' framework to produce production function estimates. While computationally simple, one feature of the Cobb-Douglas production function is that it implicitly assumes an elasticity of substitution between factor inputs of unity. Recent UK evidence, however, points to an elasticity of substitution significant less than one.[13] A number of other institutions have therefore adopted a Constant Elasticity of Substitution (CES) production function, which allows the elasticity of substitution to be imposed directly.[14]

3.21 Unlike the purely statistical approach of a filter, the production function approach allows changes in the rate of potential growth to be explicitly decomposed into changes in the underlying economic determinants, which can help in assessing the plausibility of the estimated potential growth rate. The production function framework also allows for a variety of techniques and methods to be used in the extracting the trend levels of each component. As with most estimates of potential output, however, production function estimates are highly sensitive to the methods, data and assumptions used. Contemporaneous estimates of potential output following large shocks will often require quantitative judgements about how the shocks have affected the potential output components. Such judgements will inevitably be subject to significant uncertainty given the absence of a long run of data in real time.

3.22 Chart 3.6 sets out the latest output gap estimates produced by the EC, OECD and IMF. The EC and OECD estimates have been derived using a production function methodology, while the IMF's estimates draw on a variety of techniques, including multivariate methods, filters and a production function approach.[15] While the dates of peaks and troughs are similar, there remain large differences in the size of the output gap over time, with the IMF series exhibiting significantly smaller fluctuations through the late 1980s and in the period since 1995: the large differences between the historical output gap series serves to demonstrate the degree of uncertainty that surrounds estimates of the output gap even many years after the event. The cyclical indicator estimates observe a similar profile to

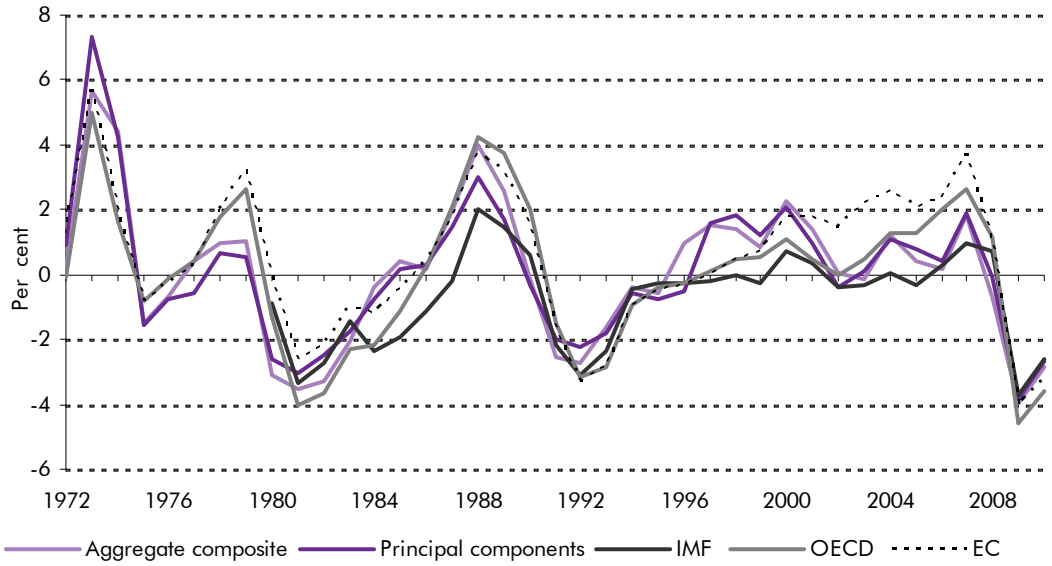
[13] See, for example, Barnes et al (2008) and Barrell and Pain (1997).

[14] See Barrell (2009). The Bank of England's Quarterly Model (BEQM) incorporates a Constant Elasticity of Substitution production function. See Harrison et al (2005).

[15] See IMF (2010) and IMF (2011a).

most other estimates, exhibiting similar turning points and remaining within or close to the range of estimates over the sample period.

Chart 3.6: Estimates of the output gap (annual)



Source:OBR; IMF World Economic Outlook September 2011; European Commission European Economic Forecast-Autumn 2011; OECD Economic Outlook No.89.

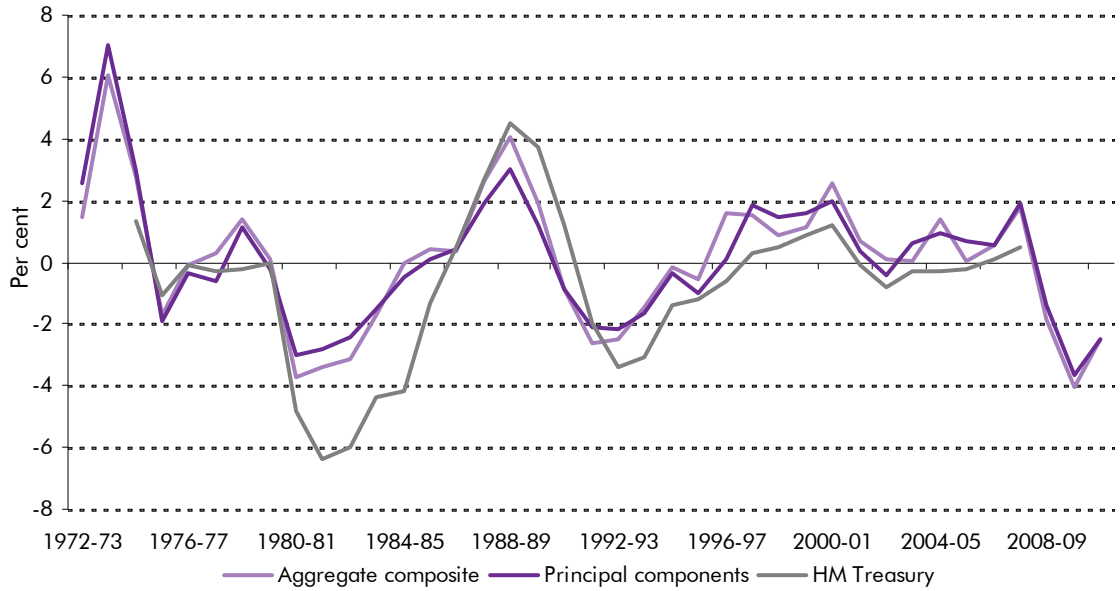
3.23 An alternative to the filter and production function approaches is the 'on-trend point' methodology previously adopted by the Treasury. In this approach, cyclical indicators are used to establish the start or mid-points of economic cycles. Potential output is then assumed to follow a linear trend over the estimated cycle or half-cycle; since the most recent on-trend point, potential growth is projected forward at an assumed rate. Previous analysis of the historical effect of the economic cycle on the public finances – which derived the coefficients used to cyclically adjust the public finances – drew on existing Treasury output gap estimates based on the on-trend point approach.[16]

3.24 Charts 3.7 and 3.8 compare estimates of the output gap using the cyclical indicators with the latest published vintage of the Treasury's output gap estimates based the on-trend point approach. The series point to similar up and down phases of the economic cycle, although there are some marked differences in the size of the output gap: for example, the Treasury's estimates point to a much greater degree of spare capacity following the recession of the early 1980s than

[16] Farrington et al (2008). The updated historical output gap estimates set out in this paper will allow us to reassess the size of the cyclical adjustment coefficients.

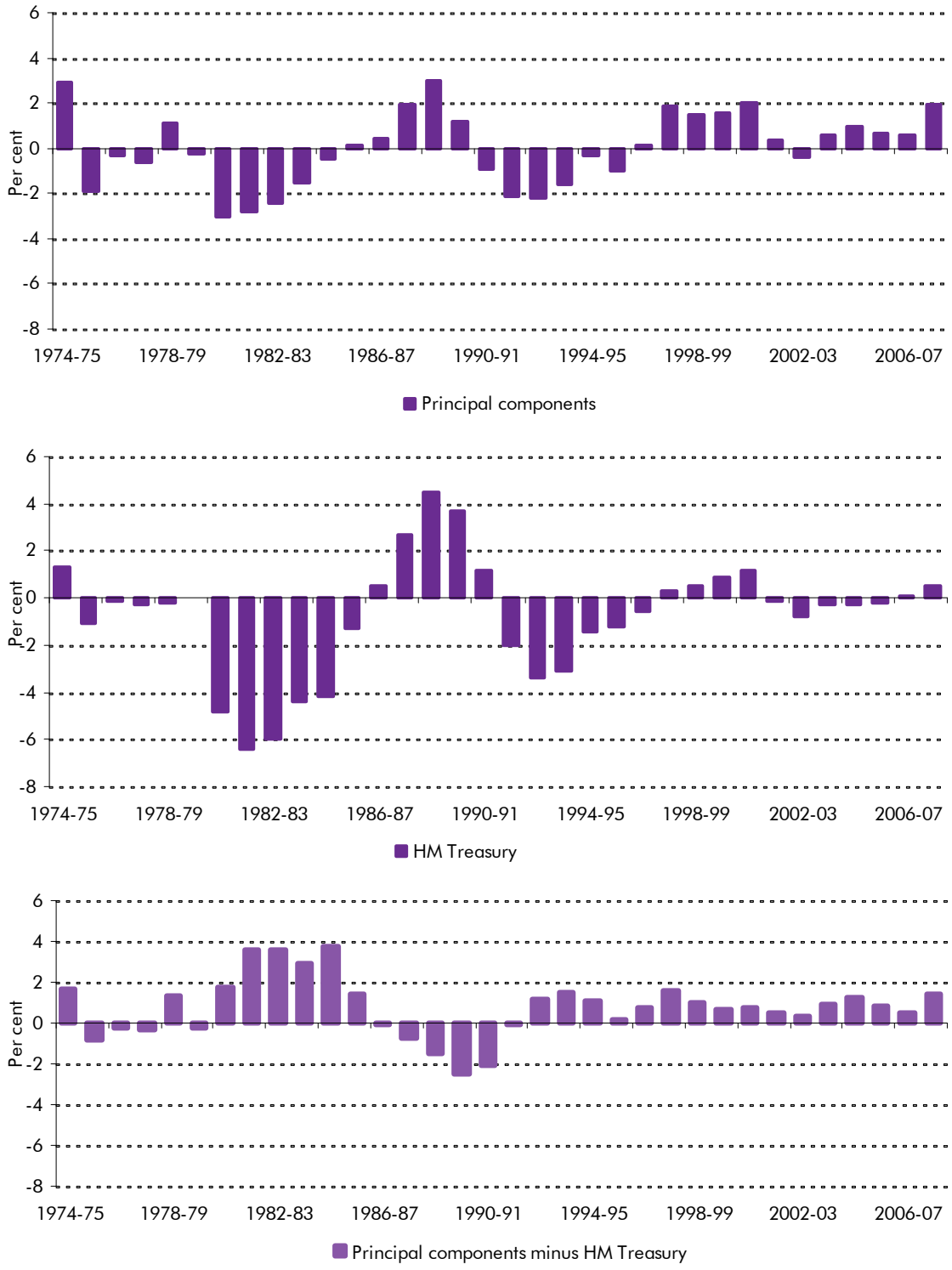
both the cyclical indicator estimates and estimates produced by other organisations. The greater amplitude of the Treasury's estimates over this period relative to other estimates is partly the consequence of the assumed linear trend: with potential output assumed to grow at a constant rate over the cycle, large swings in growth will be interpreted as cyclical, rather than structural.

Chart 3.7: Estimates of the output gap (annual, fiscal year)



Source: OBR, HM Treasury Public Finances Databank.

Chart 3.8: Comparison of output gap estimates (annual, fiscal year)



Source: OBR, HM Treasury Public Finances Databank.

4 Summary and conclusions

4.1 The Office for Budget Responsibility's approach to estimating the output gap has been to combine a range of indicators of the cyclical position of the economy, using two different methods: 'aggregate composite estimates' and 'principal components estimates'. These estimates help to inform the OBR's judgement about the current size of the output gap. To date the OBR has applied techniques back to 2007.

4.2 This paper develops and extends these approaches to estimate a historical output gap series. Estimating a historical series using these approaches is not straightforward as many of the underlying data series have a relatively short history. In both cases it has been necessary to split the series into sub-samples according to the availability of the indicators. The paper also modifies and refines the dataset used in the principal components analysis to date. The principal component approach has a number of advantages over the aggregate composite method as it is based on a wider set of indicators: importantly, it does not rely exclusively on indicators specific to the manufacturing sector prior to 1995.

4.3 The estimates produced by the cyclical indicator methods appear to give a plausible representation of UK business cycle history and remain close to the range of alternative estimates. In line with most other estimates, both approaches suggest the economy was operating moderately above trend prior to the recent recession, although the size of the suggested output gap is relatively modest compared to previous business cycles.

4.4 Any output gap estimate remains uncertain, even when it relates to the past. Similarly the estimates presented in this paper are subject to significant uncertainty and remain work-in-progress. We would therefore welcome any comments or suggestions on the approach and results set out here.

A Principal component variable weights

Table A.1: Principal component variable information and weights: pre-1995 series

Source	Variable	Weights[1]
CBI Industrial Trends Survey	Percentage of firms experiencing skilled labour recruitment difficulties	0.62
CBI Industrial Trends Survey	Percentage of firms experiencing other labour recruitment difficulties	0.59
CBI Industrial Trends Survey	Percentage of firms operating at full capacity	0.46
Office for National Statistics	Average Weekly Earnings growth: total pay, whole economy, deflated by the GVA deflator[2]	0.24

[1] Weights (loadings) for the first principal component, consistent with the estimates set out in chapter 3. The square of the principal components weights sum to one.

[2] Average Weekly Earnings growth series start in 2001. Prior to 2001 the comparable Average Earnings Index (AEI) series is used as a measure of nominal earnings growth.

Table A.2: Principal component variable information and weights: post-1995 series

Source	Variable	Weights[1]
BCC Quarterly Economic Survey	Percentage of services firms experiencing recruitment difficulties	0.31
BCC Quarterly Economic Survey	Percentage of services firms experiencing clerical labour recruitment difficulties	0.29
BCC Quarterly Economic Survey	Percentage of services firms experiencing semi/unskilled labour recruitment difficulties	0.26
BCC Quarterly Economic Survey	Percentage of services firms experiencing skilled manual labour recruitment difficulties	0.26
BCC Quarterly Economic Survey	Percentage of services firms experiencing professional/managerial manual labour recruitment difficulties	0.25
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing recruitment difficulties	0.16
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing clerical labour recruitment difficulties	0.19
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing semi/unskilled labour recruitment difficulties	0.24
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing skilled manual labour recruitment difficulties	0.22
BCC Quarterly Economic Survey	Percentage of manufacturing firms experiencing professional/managerial labour recruitment difficulties	0.19
BCC Quarterly Economic Survey	Percentage of services firms operating at full capacity	0.20
BCC Quarterly Economic Survey	Percentage of manufacturing firms operating at full capacity	0.17
CBI Industrial Trends Survey	Percentage of firms experiencing skilled labour recruitment difficulties	0.24
CBI Industrial Trends Survey	Percentage of firms experiencing other labour recruitment difficulties	0.19
CBI Industrial Trends Survey	Percentage of firms operating at full capacity	0.09
CBI/PricewaterhouseCoopers Financial Services Survey	Percentage balance of financial services firms with levels of business above normal	0.25
Office for National Statistics	Average Weekly Earnings growth: total pay, private sector, deflated by the GVA deflator[2]	0.27
Office for National Statistics	Average Weekly Earnings growth: total pay, services, deflated by the GVA deflator[2]	0.27
Office for National Statistics	Average Weekly Earnings growth: total pay, manufacturing, deflated by the GVA deflator[2]	0.20

[1] Weights (loadings) for the first principal component, consistent with the estimates set out in chapter 3. The square of the principal components weights sum to one.

[2] Average Weekly Earnings growth series start in 2001. Prior to 2001 the comparable Average Earnings Index (AEI) series is used as a measure of nominal earnings growth.

B References

Altissimo, F., Bassanetti, A., Cristadoro, R., Forni, M., Hallin, M., Lippi , M., Reichlin, L. and Veronese, G., *A Real Time Coincident Indicator of the Euro Area Business Cycle*, CEPR Discussion Paper No.3108, 2001.

Appleton, J. and Wallis, G., *Volume of capital services: new annual and quarterly estimates for 1950 to 2009*, Economic and Labour Market Review, Office for National Statistics, May 2011.

Bank of England, *Inflation Report*, August 2011.

Barnes, S., Price, S. and Sebastia Barriel, M., *The elasticity of substitution: evidence from a UK firm-level data set*, Bank of England Working Paper No.348, 2008.

Barrell, R., *Long-term scarring from the financial crisis*, National Institute Economic Review No.210, 2009.

Barrell, R. and Pain, N., *Foreign direct investment, technological change and economic growth within Europe*, Economic Journal Vol.107, 1997.

Baxter, A. and King, R., Measuring business cycles: approximate band-pass filters for economic time series, NBER Working Paper No.5022, 1995.

Beffy, P-O., Ollivaud, P., Richardson, P. and Sedillot, F., *New OECD methods for supply-side and medium-term assessments: a capital services approach*, OECD Economics Department Working Paper No.482, July 2006.

Christiano, L.J, and Fitzgerald, T.J, *The band-pass filter*, International Economic Review Vol.44, 2003.

D'Auria, F., Denis, C., Havik, K., McMorrow, K., Planas, C., Raciborski, R., Roger, W., and Rossi, A., *The production function methodology for calculating potential growth rates and output gaps*, European Economy- Economic Paper No.420, European Commision, July 2010.

European Commission, *European Economic Forecast - Autumn 2011*, 2011.

Farrington, S., McDonagh, J., Colebrook, C. and Gurney, A., *Public finances and the cycle*, Treasury Economic Working Paper No.5, November 2008.

Harrison, R., Nikolov, V., Quinn, M., Ramsay, G., Scott, A., and Thomas, R., *The Bank of England Quarterly Model*, Bank of England, 2005.

HM Treasury, *Evidence on the economic cycle*, November 2008.

Hodrick, R., and Prescott, E.P., *Postwar Business Cycles: An Empirical Investigation*, Journal of Money, Credit and Banking Vol. 29, 1997.

International Monetary Fund, *Estimating the UK's output gap*, in *United Kingdom: Selected Issues Paper*, October 2010.

International Monetary Fund, *United Kingdom: 2011 Article IV Consultation—Staff Report; Staff Supplement; Staff Statement; Public Information Notice on the Executive Board Discussion; and Statement by the Executive Director for the United Kingdom*, July 2011.

International Monetary Fund, *World Economic Outlook*, September 2011.

Office for Budget Responsibility, *Briefing paper No.2: Estimating the output gap*, April 2011, available at: http://budgetresponsibility.independent.gov.uk.

Organisation for Economic Co-operation and Development, *Economic Outlook No.89*, May 2011.

Orphanides, A., and van Norden, S., *The Unreliability of Output Gap Estimates in Real Time*, The Review of Economics and Statistics Vol.84, 2002.

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