# Evidence on the UK economic cycle

July 2005

HM TREASURY

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# EXECUTIVE SUMMARY

**1.** Estimation of the economy's trend growth and cyclical position are central to the Treasury's assessment of economic prospects and the setting of fiscal policy. The Government conducts fiscal policy in accordance with the principles set out in the Code for Fiscal Stability, including the principle of transparency. This paper presents analysis of evidence relevant to the dating of the economic cycle, informing public scrutiny and debate on the issue. Publishing at the present time is a positive response to the view, expressed by the Treasury Committee, that the Treasury should not confine publication of material relating to its assessment of the cycle to Pre-Budget and Budget Reports.[1]

**2.** This analysis is motivated by the recent release of important new datasets relevant to the measurement of the economic cycle since 1997. In June, the Office for National Statistics (ONS) published revisions to GDP and non-oil Gross Value-Added (GVA) – the variant of GDP used by the Treasury to measure the economic cycle – dating back to 1996. New data have also been published recently providing an experimental series for non-oil business output (market sector GVA), which provides an alternative basis for measuring the economic cycle.

**3.** In the light of this new information this paper:

- explains HM Treasury's approach to trend growth and business cycle estimation and compares it with alternative methodologies;
- reviews the identification of UK economic cycles over recent decades and examines their key characteristics;
- considers new evidence bearing on the dating of UK cycles, including latest national accounts revisions, the use of the new ONS non-oil business output series (market sector GVA) as a basis for measuring the cycle, and analysis of the labour share of value added as a cyclical indicator; and
- draws out conclusions for the dating of the current cycle.

## Measuring the economic cycle

**4.** Business cycles are fluctuations in economic activity that abstract from both trend and very short-term irregular movements. Cyclical fluctuations are characterised by successive and distinct up and down phases, and are driven by demand or supply-side shocks that are propagated through the economy and eventually damped as market price and quantity adjustments run their course.

**5.** The paper begins by considering alternative methods of defining business cycles, distinguishing between 'growth' cycle and 'classical' cycle definitions. The paper focuses on the growth cycle approach, which is concerned with movements in output relative to trend and is the approach favoured by policy makers, being the definition used by HM Treasury and international organisations such as the IMF, OECD and EC. This is because the growth cycle approach provides a measure of the output gap, which is important in assessing and setting fiscal policy because it facilitates a judgement on the sustainability of the public finances. All output gap type measures can be classified as growth cycle measures.

[1] See paragraph 30 of the Committee's report on the 2004 Pre-Budget Report, published on 27 January 2005.

**Approaches to analysing cycles**

**6.** There are a wide variety of methods available for decomposing the *level* of output into trend and cyclical components. These methods include purely statistical filtering techniques, the use of cyclical indicators to date on-trend points (as used by HM Treasury), and more explicit economic model based methods, all of which the paper discusses. The Treasury's approach to dating on-trend points and estimating the output gap involves analysing a wide range of economic indicators, and estimating trend growth for complete past cycles as the average rate of growth between adjudged start and end-cycle on-trend points.

**7.** All of these methods can imply that sometimes output reaches an on-trend point without decisively passing through trend. In such cases on-trend points need not necessarily coincide with either the beginning or end of a cycle, because they do not mark an end or start date for a distinct phase of the cycle. For example, if output heads towards trend from above but only touches its trend level before moving back above trend, then the on-trend point may be considered to be within the up-phase of the cycle rather than marking its end.

**8.** The advantage of the Treasury's approach to dating on-trend points is that it tends to give greater stability to estimates of trend output growth. This is because the approach is based on analysis of a much wider range of indicators and is less susceptible to data revisions. A further advantage of economic-based approaches, such as HM Treasury's, is that they can explicitly allow for particular factors affecting trend in the latest cycle and beyond. For example, HM Treasury and production function approaches can readily allow for the impact of predictable changes in the population of working age.

**Results from different approaches**

**9.** The alternative approaches to assessing the cycle all tend to yield a similar general profile for the output gap over time. HM Treasury has previously identified the following complete cycles: 1972Q4 to 1978Q1; 1978Q1 to 1986Q2; 1986Q2 to 1997H1; and provisionally 1997H1 to mid-1999. On the basis of the alternative estimates presented, after the early 1970s there is a clear consensus that the economy went through three major cycles up to the mid to late 1990s, and there is a considerable degree of agreement on the broad dating of some on-trend points. Where there is less consensus on on-trend points, this reflects the greater ambiguity in the data signals affecting the dating of the economic cycle when the economy is close to trend.

**10.** Another key feature of UK cycles over past decades is that they were of higher amplitude in the 1970s, 1980s and early 1990s than either before or after. Moreover, the amplitude in recent years appears to have been lower than in the 1950s and 1960s. This lowering in amplitude has widely been attributed, at least in part, to improvements in the macroeconomic policy framework.

## The UK economic cycle since 1997

**11.** The paper assesses the implications for dating the UK cycle since 1997 of recent national accounts revisions, new market sector output data and new analysis of movements in the labour share of value added.

**12.** The national accounts revisions to GDP and GVA data released by the ONS in June 2005 mark the latest in a run of revisions that provide new evidence on the cyclical development of the economy over recent years. At the time of Budget 2000, the Treasury made the provisional judgement that the economy may have completed a full cycle between 1997H1 and mid-1999. This judgement was provisional because the cycle was clearly indistinct by historical standards. Subsequent data revisions up until Budget 2005 continued to show only an indistinct dip below trend in 1999, so this judgment has remained provisional.[2]

**New evidence**

**13.** The most recent revisions to GVA include a significant upward revision to GVA growth in 1999 of 0.5 percentage points. While at the time of the Budget 2000, non-oil GVA growth in 1999 was estimated to be 1.8 per cent, this had increased to 2.6 per cent prior to the latest revisions and to 3.1 per cent following the latest revisions. These revisions have significantly changed the profile of the economic cycle around 1999. There is now no evidence of a clear dip below trend in early 1999. So the below trend phase of the previously identified 1997H1 to mid-1999 'cycle' now looks non-existent.

**14.** New market sector GVA data released by the ONS in June 2005 re-inforce the view that mid-1999 was not an end or start point of the economic cycle. As discussed in Budget 2005[3], market sector output may provide a better basis than whole economy output for measuring the output gap, because cycles are essentially a feature of the market sector. On the basis of these new market sector GVA data, output did not touch trend in 1999, remaining notably above trend throughout the period from the end of 1997 through to early 2001.

**15.** New analysis by the Treasury of data on the labour share of value added offers further evidence on the dating of the latest cycle. With the exception of mid-1999, there is a close correlation between on-trend points of the economy, as previously assessed by the Treasury, and turning points (i.e. peaks and troughs) in the labour share. The correspondence is all the more striking in that the cyclical indicators based approach used by the Treasury to assess on-trend points has not previously involved taking account of the cyclical behaviour of the labour share.

**Conclusions**

**16.** In conclusion, the recent revisions to GVA provide significant new information on the timing of the economic cycle since 1997. This evidence shows that while the economy was close to trend in 1999, this was not a period when the economy could be judged to have been at the end of a cycle or the beginning of a new one. Therefore, the Treasury's revised judgement, based on this new evidence, is that the current economic cycle began in the first half of 1997, rather than in 1999. This conclusion is corroborated by new data from the ONS for market sector GVA and new analysis of the labour share of value added.

[2] See Budget 2005, page 26, paragraph 2.33.

[3] Box B1, page 223.

# 1 INTRODUCTION

**1.1** Business cycles are often defined as regular economic fluctuations that take the form of persistent deviations from the economy's trend path. Identification of business cycles is integral to the Treasury's methodology for estimating the UK economy's rate of trend growth, and assessing performance against the Government's prudent and transparent fiscal rules which are defined over the cycle as a whole.

**1.2** The purpose of this paper is to:

- explain HM Treasury's approach to trend growth and business cycle estimation and to compare it with alternative methodologies;
- review the identification of UK economic cycles over recent decades and to examine their key characteristics;
- consider new evidence bearing on the dating of UK cycles, including latest national accounts revisions, the use of the new Office for National Statistics (ONS) non-oil business output series (market sector GVA) as a basis for measuring the cycle, and analysis of the labour share of value added as a cyclical indicator; and
- draw out conclusions for the dating of the current cycle.

**1.3** The dating of economic cycles involves a degree of judgement, not least because there is a range of views on exactly how cycles should best be defined and measured. Different methodological approaches can result in different conclusions, although there is often consensus among economic analysts about their broad shape and duration. The judgements reached from applying any one particular approach can also change over time if data are revised or if understanding of how the economy works prompts a re-interpretation of how data relate to the cyclical position of the economy.

**1.4** Moreover, in undertaking identification of business cycles and examining their key dimensions over the long-term, there are a number of practical issues that affect the analysis:

- data availability: quarterly data on UK output are only available back to 1955, which limits how far back quarterly based UK business cycle analysis can go. Moreover, many of the survey indicators used by HM Treasury and others to identify equivalent points in the cycle are only available from the 1970s onwards, which poses a further limit on the application of some approaches to identifying economic cycles. In practice this means that pre-1970 HM Treasury output gap estimates have to rely on statistical filtering rather than the usual on-trend point methodology. Consequently, HM Treasury estimates of the output gap before the 1970s are less soundly based than those for more recent cycles.
- data quality changes: changes in data quality, resulting from improvements to national accounts estimation methods, are also likely to have implications for cycle estimation. This affects the assessment derived from approaches which rely exclusively on national accounts output data and which rely on the statistical properties of the series remaining constant over time.

## OUTLINE

**1.5** This paper is structured as follows:

- Chapter 2 identifies some general issues that have to be considered in cycle identification, and surveys the various alternative methodologies that can be used in the estimation of trend growth and the cycle;
- Chapter 3 sets out estimates of the UK cycle based on the Treasury's approach, and compares these with estimates of other organisations; and discusses assessments of the cyclical position as seen at the time;
- Chapter 4 examines some new evidence and analysis on the UK cycle in recent years, in particular the implications of: recent national accounts revisions; new data for market sector GVA; and analysis of the labour share of value added as a cyclical indicator; and
- Chapter 5 draws out conclusions based on the evidence and analysis presented in the previous chapters, with particular focus on the past decade.

# 2 Methods of identifying and dating cycles – explanation and issues

**2.1** This chapter explains HM Treasury's approach to measuring the cycle and compares it with other methodologies. In doing so it considers general issues relating to the definition and measurement of an economic cycle. The first issue, which is relatively straightforward, is which data series to use for the purposes of cycle identification; the second, more complex issue, is what methodological approach should be adopted to identify cycles in the chosen series.

## General methodological issues

### Defining the business cycle

**2.2** Business cycles are fluctuations in economic activity that, abstracting from short-term noise or high frequency movements, display two distinct complete phases. Full cycles are usually characterised as successive periods of up-phase and down-phase, or slackness and tightness in resource utilisation, that together comprise a complete cycle. The cyclical evolution of the economy is influenced by changes in the nature of shocks, the structure of the economy, and in the behaviour of households and companies, which vary through time. So unsurprisingly no two cycles are ever exactly alike.

**2.3** The most commonly used measure of economic activity is real gross domestic product (GDP), which is published in the UK by the Office for National Statistics (ONS) on a quarterly basis. Real GDP, or a close variant, is generally accepted as the most appropriate measure for dating the cycle by most international and academic organisations (see Box 2.1). The Treasury's preferred variant measure of GDP has been non-oil GVA, i.e. gross value added excluding oil and gas, because, while the oil and gas sector significantly affects output, it has little direct impact on the sustainable level of employment or non-oil economic activity. However, as implied in Budget 2005[1], the business cycle may be better measured by private or market sector rather than whole economy output. Until recently a proper measure of UK market sector output had not been available, but the ONS has now started to publish a series for market sector GVA i.e. excluding government output.

[1] Box B1, page 223: "The output gap…should be determined by factors affecting the cyclical behaviour of the private or market sector of the economy rather than the rate of utilisation within the government or non-market sector".

**Box 2.1: Definitions of alternative measures of economic activity**

**As noted in paragraph 2.3, variant measures of aggregate economic activity are used by different organisations for assessing trend growth and the output gap. The rationale for each of the alternative measures is explained below.**

- **GDP (at market prices): the most widely recognised and frequently quoted measure of economic activity.**
- **GVA: equals GDP minus the basic price adjustment (BPA) ie taxes less subsidies on products (eg VAT, cigarette and petrol duties). The BPA does not directly affect the economy's sustainable capacity, and GVA gives a better measure of output than market price GDP.**
- **Non-oil GVA: excludes value added from oil and gas extraction, which, while at times having significant effects upon output, has little direct impact upon sustainable levels of employment or non-oil economic activity.**
- **Market sector GVA: excludes government output, which, because of its non-marketed nature, ought not be part of the measured business cycle.**

**2.4** The dominant school of thought on the study of business cycles has seen the analysis as requiring that the cycle should be isolated from the trend. A traditional decomposition of the level of output distinguishes between: a trend component, a cyclical component, a seasonal component and an irregular component. Accordingly, most measures of the cycle based on detrending have taken data for output which have already been purged of their seasonality and outliers (irregular components due, say, to strikes or unusual weather conditions). Identification of a trend component then leaves the cyclical component as a residual. Equivalently the cyclical component can be viewed as the series purged of its high frequency (irregular and seasonal) and low frequency (trend) components. However, a series need not necessarily possess a cyclical component e.g. a random walk with drift, and some de-trending methods can infer spurious cycles where no systematic cycle exists.

**Growth cycles**

**2.5** Blinder and Fischer (1981) proposed a definition of the cycle in terms of persistent (ie serially correlated) deviations of output from trend. Elaborating this, the trend can be defined as the component of output driven by permanent shocks, and the cycle is then the component driven by transitory (though persistent) shocks, as suggested by Blanchard and Fischer (1989). Business cycles defined in this way are often referred to as *'growth'* cycles, and all output gap type measures can be classified as such.

**2.6** The growth cycle approach to defining cycles is widely used amongst expert organisations such as the IMF, OECD and EC, and is also the definition used by HM Treasury. However, there is a wide variety of methods available for decomposing the *level* of output into a trend and cyclical component in order to operationalise the definition. These methods include purely statistical filtering techniques, the use of cyclical indicators to date on-trend points (as used by HM Treasury), and more explicit economic model based methods. These approaches are discussed in more detail below.

**2.7** All of these methods can imply that sometimes output reaches an on-trend point without decisively passing through trend. In such cases on-trend points need not necessarily coincide with either the beginning or end of a cycle, because they do not mark an end or start date for a distinct phase of the cycle. For example, if output heads towards trend from above but only touches its trend level before moving back above trend, then the on-trend point may be considered to be an interior point of the up-phase of the cycle rather than marking its end.

**Classical cycles**

**2.8** An alternative to the 'growth' cycle definition is the 'classical' cycle definition. The classical cycle is identified by turning points in the level of output, with an absolute fall in output from a peak marking the end of an expansion phase, resumed expansion from a trough marking the end of a contraction phase, and an expansion phase and a contraction phase together comprising the cycle. Additional requirements may concern the amplitude or duration of what is considered to be a phase of the cycle (as opposed, say, to a blip due to a strike or some other irregular event). There has been a strong tradition, led by the NBER, of business cycle research and analysis based on the use of indicators other than GDP to identify classical cycles, often classifying indicator series into leading, coincident and lagging indicators of turning points.

**2.9** Some economists favour the classical cycle due to problems of de-trending e.g. Harding and Pagan (2004). They argue that the problem with de-trending is that there is no universally agreed best method for identifying the trend or permanent component of output, and there is a wide variety of methods of trend/cycle decomposition, potentially giving rise to different measures of growth cycles. As noted above, it is possible statistically to identify a trend component of a series which, by definition, does not have a trend: for example, a linear trend can always be fitted ex-post to a random walk, and the estimated 'trend' will be wholly sample dependent with no predictive power whatsoever.

**The output gap**

**2.10** While the problem of statistically identifying growth cycles is well recognised, the growth cycles approach tends to be favoured by policy makers and international organisations. Growth cycles provide a measure of the output gap, which is important in assessing and setting fiscal policy because it facilitates a judgement on the sustainability of the public finances. Related to this, concerns for employment and unemployment would also indicate a preference for the growth cycle, since shorter-term changes in employment or unemployment rates are likely to be related to changes in growth relative to trend.

**2.11** The concept of the output gap has become widely used amongst economists, and this may partly reflect a tendency to believe in the self-correcting behaviour of market-based economies. While some shocks may be permanent, and hence affect the trend level of output of the economy, others are likely to prove transitory. Cycles are then the result of transitory demand or supply-side shocks being propagated and so persisting, but ultimately being damped with the economy reverting to trend as market price and quantity adjustments run their course. The role of macroeconomic policy is to stabilise the economy around trend, although in the past there have been occasions when policy mistakes have served as a source of shocks and a factor in propagating them rather than as a stabilising mechanism. Indeed policy mistakes are generally accepted as having been a key factor in contributing to the high amplitude of UK cycles in the 1970s, 1980s and early 1990s, and the much lower amplitude in more recent years has widely been attributed, at least in part, to improvements in the macroeconomic policy framework.

**2.12** Given the importance of growth cycles in the policymaking context, the sections below discuss alternative approaches to dealing with the problem of trend/cycle identification, starting with an explanation of the use of statistical filters, such as the Hodrick-Prescott filter or the Baxter-King band pass filter. This is followed by a description of other approaches including HM Treasury's approach and the production function approach.

## HM TREASURY AND ALTERNATIVE METHODS OF TREND GROWTH ESTIMATION

**2.13** This section considers alternative methodological approaches to measuring the cycle, distinguishing between statistical filter and economic based approaches. Some additional technical details related to the various approaches are included in Annex A.

## STATISTICAL FILTERS

**2.14** Statistical filtering techniques are a common method used to determine trend growth because they are relatively simple to apply and easily replicated. They are used both to estimate trend growth itself, by fitting a trend through the series for actual output, and to smooth variables used within a production function framework. The methods used to fit the trend can be broadly divided into two categories: ad hoc filters and univariate time series models. This section gives only a brief description.

### *ad hoc Approaches*

#### Simple moving average

**2.15** One of the simplest approaches to fitting a trend is to assume that it can be represented by a weighted average of adjacent observations. The most familiar example is a centred equally weighted moving average. Many of the filters that are described later in this section can actually be expressed as some form of (infinite) moving average.

#### The Hodrick-Prescott filter

**2.16** The Hodrick-Prescott filter (HP) is a statistical method to decompose time-series into a growth component and a cyclical component. The filter works by extracting a trend which moves smoothly over time and is uncorrelated with the cycle. The benefit of the HP approach is twofold. First, it can extract the same form of trend from a set of variables. For example, many real business cycle models indicate that all variables will have the same stochastic trend. Alternative filters, such as the Beveridge-Nelson decomposition, discussed later in this section, when separately applied to each variable will not yield the same form of trend for each. Second, it is simple to apply.

**2.17** The HP filter minimises the sum of two components, the deviation from trend and the smoothness of the growth component. The relative weight given to the components is represented by a parameter lambda, the signal-to-noise ratio. The greater the degree of smoothness imposed, the closer the trend path will be to a straight line (i.e. the deterministic trend approach); and the lower the degree of smoothness, the closer the trend series will be to the observed one.

**2.18** In practice, the parameter lambda is chosen arbitrarily, and most studies use the value set in Hodrick and Prescott's (1980) original paper. They suggested a value of lambda of 100 for annual data and of 1,600 for quarterly data.

**2.19** However, the choice of smoothing parameter (lambda) is not the only problem with using HP filters to estimate trend growth. The HP filter method:

- takes no account of information from data series other than output in identifying the trend and cyclical components of growth. For example, changes in inflation might help to identify whether output was above or below trend. Multivariate statistical techniques can be used to overcome this problem, although this comes at the cost of being less straightforward to implement;
- cannot detect structural breaks in trends, but rather spreads the effect of any break over periods both before and after the break. This may generate misleading estimates of trend output; and
- is known sometimes to induce spurious cyclical patterns into the data when there are none. For example, Harvey and Jaeger (1993) showed that the HP filter creates spurious cycles in de-trended random walks, and that the danger of finding large sample cross-correlations between independent but spurious HP cycles is not negligible.

**2.20** Another key problem is that the HP filter is not very reliable at estimating trend output at the end of the sample, as it is unduly influenced by the last data points. This is because the HP filter works as a symmetric two-sided filter in the middle of the sample, but becomes unstable at the end and at the beginning of the sample, although end-point instability is also a weakness of other filters as well. This limits its usefulness for policy-makers, as the recent past is the part of the sample that is of most interest. A common approach to deal with this problem is to add forecasts of output to the historical data. But this just turns the end-point problem into a forecast error problem. Moreover, the forecasts themselves may be dependent upon an assumed trend growth rate (at least when forecasting into the medium term), which leads to an element of circularity.

**2.21** King and Rebelo (1993) and Harvey and Jaeger (1993) discuss the HP filter in detail and subject it to severe criticism, leading them to question its widespread use as a method of trend elimination. In addition to the difficulties outlined here with regard to its calculation, they also argue that the HP filter lacks theoretical foundations.

## Baxter-King band-pass filter

**2.22** Time series can be viewed as comprising high frequency (irregular or noise), medium frequency (cyclical) and low frequency (trend) components. The filter proposed by Baxter and King (1995) is one of a more general class of band-pass filters that aim to identify the cyclical components by filtering out trend and irregular components that do not fall within the cyclical frequency 'band'. So in order to extract the cyclical component of a time-series, it is necessary to specify the frequencies that are to be scored as cyclical. Baxter and King defined the cyclical components of output as those persisting for between 6 and 32 quarters, as originally put forward in Burns and Mitchell (1946).

**2.23** The Baxter-King filter shares many of the other weaknesses of statistical filtering techniques. In particular it takes the form of a centred moving average which sacrifices 12 quarters at the beginning and end of the time-series, thereby seriously limiting its usefulness for analysing contemporaneous data.

## Univariate time-series models

**2.24** This section considers univariate model based methods of trend extraction. Univariate models have in common the assumption that any time-series can be represented as the sum of two components, a trend and cyclical component. The cyclical component is essentially a residual defined by taking out the trend.

## Time trends

**2.25** The simplest and oldest de-trending method consists of specifying the trend as a polynomial in time, which in its most elementary form means a linear time trend.

**2.26** This approach assumes that the trend and cycle of the series are uncorrelated and that the trend is a deterministic process, which can be approximated as a polynomial function of time (any time-series can be fitted with a high enough order polynomial). Despite this, the approach has the advantage that it is easy to compute – all the data points can be used consistently to estimate the trend via conventional techniques.

## ARIMA models

**2.27** The ARIMA (auto-regressive, integrated, moving average) model assumes that any trend components in a time-series can be removed by differencing, and that the resulting cycle and irregular components are a stationary series that can be represented by an autoregressive moving average model.

**2.28** One problem with this approach is that often there are several ARIMA models which fit the sample autocorrelations of a dataset fairly well. However, because ARIMA models having the same short-run properties may have very different long-run features, alternative specifications may also lead to very different decompositions into trend and cycle. Also, because ARIMA models are designed to the fit the short-run properties of the data, they are very ill-suited to capturing their long-run features.

## Beveridge-Nelson decomposition

**2.29** The Beveridge-Nelson (1981) decomposition starts from the observation that a time-series can be decomposed as the sum of a random walk, a stationary process, and an initial condition. The key identifying assumption of Beveridge and Nelson's procedure is that the cyclical component of the series is stationary while the trend component accounts for its non-stationary behaviour. Therefore, the cycle in this definition is the stationary process resulting from the decomposition.

**2.30** The advantage of the Beveridge-Nelson decomposition is that it may be an appropriate method to extract cycles when a series is integrated of first order. However, there are two potentially severe problems with this decomposition. First, since both trend and cycle are driven by the same shock, the decomposition has the striking property that innovations in the trend and cyclical components are perfectly correlated ie the same. Second, application draws on the use of ARIMA models, so the problems inherent to ARIMA models are carried over to this method.

## Unobserved components model

**2.31** Unobserved components (UC) models, or structural time-series models, as they are also known, involve a more general approach than ARIMA models. They are based on defining a time-series as the sum of n uncorrelated components, each with an ARIMA representation. A series is then decomposed into trend, cycle, and irregular components by applying the key identifying assumptions that the trend component follows a random walk with drift and that the cyclical component is a stationary finite order AR process.

**2.32** There are a number of advantages to using the UC model. Non-stationarity can be handled without having to difference the data directly. It also has the clear advantage over the HP filter that the smoothness of the trend is intrinsic in the estimation, rather than having to be determined a priori. However, some judgement must still be applied so as to specify the type of trend in the series. The UC model can also be difficult to estimate (often requiring a Kalman filter approach) in the sense that the results are sensitive to the assumptions of the model.

## Kalman filter

**2.33** The use of the Kalman filter for de-trending data is primarily as an algorithm for estimating ARIMA and UC models, but because it can be generalised to have time varying parameters, potentially it is much more powerful. Its main use is as a forecasting device, since its focus is not on parameter estimation but on prediction using recursive estimation or updating equations. The Kalman filter provides a simple recursive way of recovering estimates of trend that can be updated with each new data observation.

**2.34** However, a disadvantage of Kalman filters is that a key variable in their estimation is the assumption made on the relative smoothness of the unobserved trend, which is governed by the relative size of the model's error variances representing the assumed 'signal-to-noise ratio'. Results are sensitive to this assumption, and to initial condition assumptions.

# ECONOMIC BASED APPROACHES

**2.35** Economic based approaches differ from statistical filtering in bringing economics knowledge and analytical techniques to bear in assessing the cycle.

## HM Treasury on-trend point approach

**2.36** The Treasury's approach to decomposing output into trend and cyclical components starts by identifying the points in the cycle when the economy is judged to be 'on-trend'. When the economy is on-trend, its factors of production are employed at normal rates of utilisation. On-trend points are therefore identified by looking at a wide range of cyclical indicators of factor utilisation in the economy, as referred to below.

**2.37** Having identified comparable on-trend points in the cycle, the permanent component of output is assumed to follow a deterministic linear trend between these points i.e. trend output is just a linear function of time between two on-trend points. So for complete *past* cycles the trend rate of output growth is estimated as the average rate of growth between adjudged start and end-cycle on-trend points.

**2.38** Estimating the trend rate of growth for the latest (incomplete) cycle, which is naturally the cycle of most interest for policy, obviously demands a different approach. As set out in *'Trend growth: recent developments and prospects '* (HM Treasury (2002)), for the latest cycle the Treasury approach involves a projection based on decomposing the change in trend output over past cycles into:

- trend labour productivity measured as output per hour worked;
- trend average hours worked per worker;
- the trend proportion of the working age population in employment (employment rate); and
- the working-age population.

Going forward, the projection for trend growth from the latest on-trend point is built up from the projections of these components.

**2.39** The cyclical indicators used to identify on-trend points (see also 'Fiscal Policy: Public Finances and the Cycle', HM Treasury March 1999) include:

- **business surveys of capacity utilisation,** such as those from the CBI and BCC, which measure firms' assessments of their utilisation of capital and workers. Variations tend to reflect fluctuations in output per worker around trend, hence business survey capacity utilisation indicators provide information mainly on the output per worker component of the output gap (output per hour and average hours components together);
- **business survey indicators of recruitment difficulties**, which relate to companies experiences in recruiting in the external labour market, and hence are informative about the employment rate component of the output gap;
- **other labour utilisation indicators** such as average hours worked, unemployment and vacancy rates; and
- **indicators of inflationary pressure** such as average earnings, unit labour costs and the Consumer Prices Index (CPI).

**2.40** The Treasury's approach to projecting trend growth for the latest cycle is most closely related to the production function approach explained below, but uses a lot of additional information (such as indicators of capacity utilisation) to identify comparable points in the cycle. This helps alleviate the problems involved in identifying a cycle using the more limited information applied by other approaches, especially purely statistical filter methods. Economic based approaches, including HM Treasury's, also have an advantage over statistical filters in terms of making it easier to allow explicitly for particular factors affecting trend in the latest cycle and beyond. For example, HM Treasury and production function approaches can readily allow for the impact of predictable changes in the population of working age.

**2.41** Compared to the alternative approaches, HM Treasury's favoured approach is likely to give rise to greater stability through time in the estimated trend rate of output growth for the latest (incomplete) cycle because the trend estimate is less susceptible to data revisions for the most recent past. Other approaches can lead to trend estimates that display excessive sensitivity to short-term data movements, either in the form of new data or revisions.

**2.42** The use of cyclical indicators to date on-trend points, and in particular the end or start of the cycle, does not always give clear cut signals. When the economy is close to trend any ambiguities can be resolved if output data suggest that the economy was decisively passing through trend. In such circumstances, cyclical indicators and output data are likely to corroborate each other. In contrast, if the economy is hovering relatively close to trend, the judgement on on-trend points is likely to be more uncertain. This is why GDP data and revisions are relevant to the Treasury's assessment of on-trend points and whether they signify the end or start of cycles.

## The turning points approach

**2.43** Trend output is sometimes estimated by fitting linear trends to the series between dates of successive peaks or successive troughs in the cycle, sometimes identified using indicators other than the output series itself, instead of between on-trend points. The supposed attraction of this approach is that peaks and troughs of the cycle are allegedly easier to identify than on-trend points, and an algorithm written by Bry and Boschan (1971), which is a standard one for identifying classical cycles, can be applied in this context. Even so, the corresponding datings of cycles can and do differ, and not only in respect of whether the underlying data series is of high frequency (as with monthly industrial production series) or quarterly as with GDP. Some examples are: Artis, Kontolemis and Osborn (1997), Krolzig and Toro (2001), Harding and Pagan (2001). The Economic Cycle Research Institute (ECRI) engages in identifying classical cycles (as well as growth cycles) following the principles laid down by NBER practice. More importantly, peak to peak or trough to trough methods suffer from the serious drawback that they will give biased estimates of the trend, and hence the cycle, unless the amplitude of the cycle remains unchanged between turning points.

## The production function approach

**2.44** The main benefit of the production function approach (which is described in Annex A) is that it provides a transparent framework to account for growth in terms of the contributions of factor inputs and total factor productivity, and provides an explicit link between potential output and potential employment and so the NAIRU (Non-Accelerating Inflation Rate of Unemployment). It also provides a useful framework for forecasting future growth potential, where assumptions on the impact of demographic, institutional and technology trends on factor inputs and TFP can be incorporated.

**2.45** In addition, while the production function approach will, like all methods, be susceptible to revisions, recent research published by the Italian Ministry of Finance (2003) has shown it to be more stable in the face of such revisions than the HP filter. The production function approach is widely used by international organisations including the IMF, OECD and European Commission (EC) in estimating trend growth across countries.

**2.44** However, while theoretically attractive, the production function approach is prone to estimation problems. Judgements need to be made on the functional form and estimation of the parameters of the production function. Moreover, the approach includes variables that are not directly observable from the data – potential employment, capital, and trend TFP – for which estimates have to be made.

**2.47** Therefore, while the production function approach is consistent with economic theory, it requires a great deal of judgement to be exercised regarding the appropriate functional form and in the estimation of its parameters and inputs. Extracting the trend from the inputs can be problematic, with the possibility of end-point bias and difficulties involved in removing all cyclical elements. This means that production function methods can in practice be inferior to other methods.

### The VAR approach

**2.48** The vector autoregression (VAR) methodology can be a useful way of estimating an economic system when there are feedback effects between the variables, and where it is not clear that a particular variable can be classified as 'independent' and unaffected by the time path of the 'dependent' variables. VAR analysis treats all variables symmetrically, and therefore gets around the issue of variable dependence versus independence.

**2.49** Structural VAR models have the advantage of theoretically overcoming the 'end-point' problem of filtering techniques. In addition, restrictions are not imposed on the short-run dynamics of potential output. This is unlike univariate and multivariate filters, which often assume that the trend component in output is a random walk. Structural VARs allow for a richer diffusion process.

**2.50** However, there is a growing literature questioning the reliability of the inferences drawn from structural VARs based on long-run identifying restrictions. A recent paper by Chari, Kehoe and McGrattan (2005) is particularly critical, arguing that structural VARs with long-run restrictions are very misleading and can give rise to quantitatively large, false inferences. Their main criticism is that structural VARs use too little a priori economic theory. Therefore, in practice, structural VAR approaches remain at most an illustrative or corroborative method in estimating potential output, complementing other approaches.

## CONCLUSIONS

**2.51** The 'growth' cycle definition of business cycles gives rise to output gap type measures and is the definition of most relevance to macroeconomic policy. However, there are a number of different methods of estimation which can to varying degrees yield different results.

**2.52** Compared to the alternative approaches, HM Treasury's favoured approach is likely to give rise to greater stability through time in the estimated trend rate of output growth for the latest (incomplete) cycle because the trend estimate is less susceptible to data revisions for the most recent past. Production function and statistical filter based approaches can lead to trend estimates that display excessive sensitivity to short-term data movements, either in the form of new data or revisions. To the extent that production function and statistical filter based approaches may tend to give trend estimates that show higher frequency movements than HM Treasury's approach, they would tend to identify lower amplitude and shorter duration cycles than HM Treasury.

**2.53** Moreover, when identifying complete past cycles, latest on-trend points and the starting point of the latest cycle, the Treasury's approach brings a much wider range of indicators to bear on the assessment than the production function approach and especially statistical filters.

**2.54** Economic based approaches, including HM Treasury's, also have an advantage over statistical filters in terms of making it easier to allow explicitly for particular factors affecting trend in the latest cycle and beyond. For example, HM Treasury and production approaches can readily allow for the impact of predictable changes in the population of working age.

# 3 Estimates of UK cycles

**3.1** The previous chapter examined various methodological approaches to identifying economic cycles. In this chapter, empirical assessments of economic cycles in the UK are examined in terms of dating, duration and amplitude, drawing out some of the key facts on UK cycles. The chapter discusses how HM Treasury estimates of the output gap compare with those from various external organisations or studies. The Treasury estimates are pre-latest revisions, to make them more comparable with the external estimates.

## Treasury approach

**3.2** As discussed in Chapter 2, the Treasury's approach to trend growth decomposes output into trend and cyclical components by identifying on-trend points and assuming that the permanent component of output follows a deterministic linear trend between such points.

**3.3** As set out in Chapter 2:

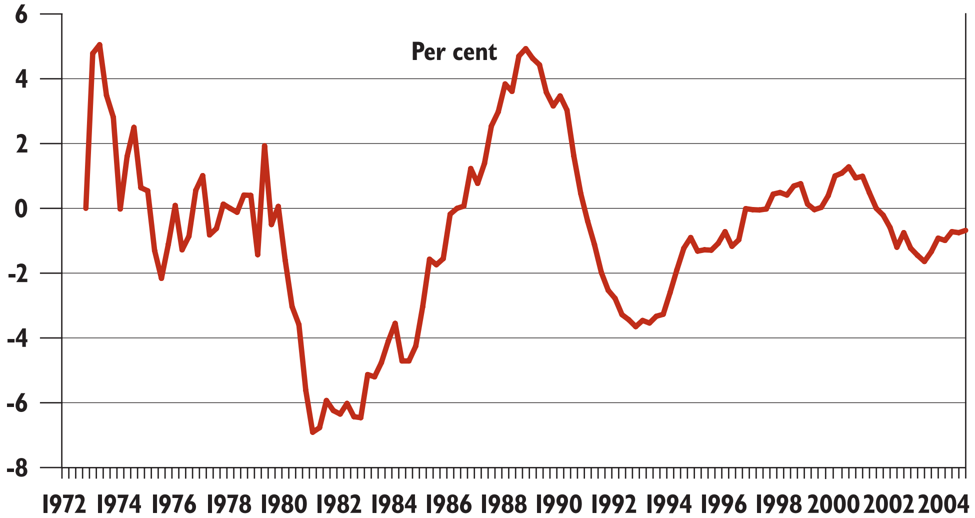
- complete cycles are typically characterised as having two distinct phases, an up-phase and a down-phase;
- when output reaches an on-trend point without decisively passing through trend the on-trend point need not necessarily coincide with either the beginning or end of a cycle, because it does not mark an end or start date for a distinct phase of the cycle;
- ambiguities in the use of cyclical indicators data for the dating of on-trend points are less likely to be resolved by output data when the economy is hovering close to trend, rather than passing decisively through. So in these circumstances the judgement on on-trend points is likely to be more uncertain.

### The cycle pre-1997

**3.4** HM Treasury commenced regular publication of quantitative assessment of the economy's cyclical position in the July 1997 Financial Statement and Budget Report. In two papers, *'Fiscal Policy, Public Finances and the Cycle' (March 1999)* and *'Trend Growth: Prospects and Implications for Policy',* (November 1999), the Treasury identified the following full cycles:

- 1972Q4 to 1978Q1
- 1978Q1 to 1986Q2
- 1986Q2 to 1997H1

**3.5** Chart 3.1, based on the data available at the time of the 2005 Budget, illustrates the Treasury's assessment of the UK cycle since the early 1970s.




**3.6** The whole 1972Q4 to 1978Q1 cycle shows a very volatile path from quarter to quarter. With output judged to have been on-trend in 1972Q4, very strong growth in the UK in 1973 was estimated to have pushed the economy significantly above trend. Output then generally declined and a sizeable negative output gap opened up by mid-1975. The subsequent recovery through 1976 and 1977 – set against an estimated trend rate of growth of around $1^1/_4$-$1^1/_2$ per cent – was then estimated to have returned the economy back to trend by the beginning of 1978.

**3.7** The estimated cycle from 1978Q1 to 1986Q2 was dominated by the period of below-trend activity following the recession of the early 1980s. After the start of the cycle in 1978Q1, output dipped below trend again before peaking in 1979Q2. It then passed decisively through trend in early 1980. Notable declines in output in 1980 and 1981 were estimated to have pushed the economy around 7 per cent below trend and, with growth only recovering to around trend rates in 1982, this large negative output gap persisted for a time.

**3.8** The economy returned to trend in 1986Q2, which marks the end point of the cycle. Above-trend growth continued through the mid-1980s taking the economy from a position of considerable slack to an estimated positive output gap of nearly 5 per cent by the end of 1988. However, the slowdown in growth in 1989, followed by the early 1990's recession, took the economy significantly below trend again, only returning to trend by the first half of 1997.

**3.9** Thus the economy is judged to have gone through three full cycles between 1972 and 1997, with the amplitude of the cycle increasing in the 1970s, and particularly large through the 1980s and early 1990s.

## The cycle post-1997

**3.10** Output grew above trend from mid-1997 to mid-1998, then slowed significantly at the end of 1998 and during the first half of 1999, only to pick up again to leave output just above trend by the third quarter of 1999. The assessment in Budget 2000[1] was that:

*"Output fell below trend towards the end of 1998, but only for a very short time, before returning to trend again in the middle of 1999. Thus, early indications suggest the economy may have completed a full economic cycle – albeit a short and shallow one by historical standards – since*

[1] Paragraph 2.37.

*1997-98. Given the closeness to trend and possible measurement errors, this conclusion can only be provisional at this stage."*

Indicators of capacity utilisation supported the assessment that the economy was close to trend in early 1999. However, at the time of Budget 2000, the output data only fell below trend for a short time in early 1999. This is why the judgement that the cycle ended in mid-1999 was provisional.

**3.11** Output growth remained buoyant until the second quarter of 2001, and at the time of Budget 2002 the economy was assessed to be on-trend again in 2001Q3, completing the first half of the cycle, provisionally judged to have started in mid-1999. A wide range of evidence was used to corroborate the assessment of 2001Q3 as an on-trend point, including surveys of capacity utilisation by the BCC and the CBI. The BCC services indicators were close to the level observed at recent on-trend points, as were indicators of recruitment difficulties in both the manufacturing and services sectors. One of the clearest indicators that the economy reached an on-trend point in 2001Q3 was the subsequent decline in average earnings growth, which fell significantly from late 2001.

**3.12** Since 1997 the amplitude of the cycle has been much lower than in preceding cycles since the early 1970s, and also lower than experienced in the 1950s and 1960s. Box 3.1 discusses the UK cycle in international context.

### Box 3.1: International comparisons of economic cycles

**The UK economic cycle reflects both UK influences and the impact of other countries' economic cycles, for example through variations in the expansion of world trade, commodity prices and developments in international capital markets.**

**An IMF study shows that cycles among G7 countries have largely remained synchronised since the early 1970s, when most major currencies adopted flexible exchange rates, and as trade and financial links among G7 economies have increased (Artis (2003) also reviews the correlation between the UK cycle and the cycle in other countries). This was particularly the case during 2000-2001, when the major seven advanced economies all saw a broadly synchronised downturn in growth. Unlike all other G7 economies, the UK managed to avoid a period of negative growth. The IMF has also found that correlation of growth rates increased, while volatility of output, consumption and investment decreased, over the same period. Furthermore, recessions have become shallower and expansions longer.**

**OECD (2002) research similarly suggests that over the past three decades, the amplitude of cycles has declined, particularly during the 1990s, implying that recessions and expansions have become shallower, although there is no clear evidence that the length of cycles has changed. Further research by the US Federal Reserve (Doyle and Faust, (2002)) and NBER (Bordo and Helbling, (2003)) echoes the findings of the OECD and the IMF: linkages are becoming stronger and this has led to reduced volatility and greater growth correlation between the G7 economies.**

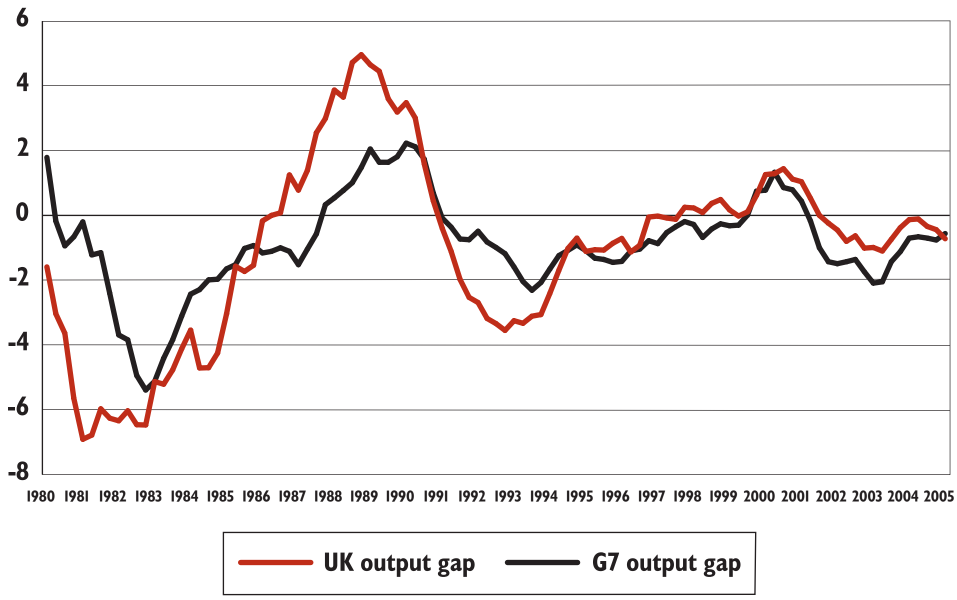
**There are a number of explanations for this: advances in global telecommunications, proliferation of private risk sharing instruments, changing output composition, further forward-looking macro policy, greater trade, and the other effects of globalisation. However, whilst the transmission of cycles across economies would be expected to have increased, particularly through the greater integration of financial and product markets, most evidence does not point to large changes in the synchronisation of cycles, though**

***continued on next page***

there has been some reduction in the divergence of growth. Changes in the nature of shocks, and their transmission across and within countries, may also explain the characteristics of international cycles. A reduction in country-specific shocks, or an increase in global shocks, would both result in an increase in growth correlation. For example, the supply-side oil price shocks of the 1970s were large shocks compared with the relatively short and contained shocks of the 1990s. On the other hand, a number of factors have strengthened the way shocks are transmitted between economies, including:

- the increasing contribution of services to output, which in turn results in better management of inventory control and therefore output;
- greater stability of domestic demand because of more stable private consumption, in addition to reduced stock variability;
- the dampening effect of net trade, since domestic demand tends to have a greater effect on imports than exports, so that net exports tend to be counter-cyclical; and
- macroeconomic frameworks with a medium-term focus, which generate greater stability in inflationary expectations, prices and wage setting.

Chart a: UK and G7 output gaps




Source: HM Treasury and OECD

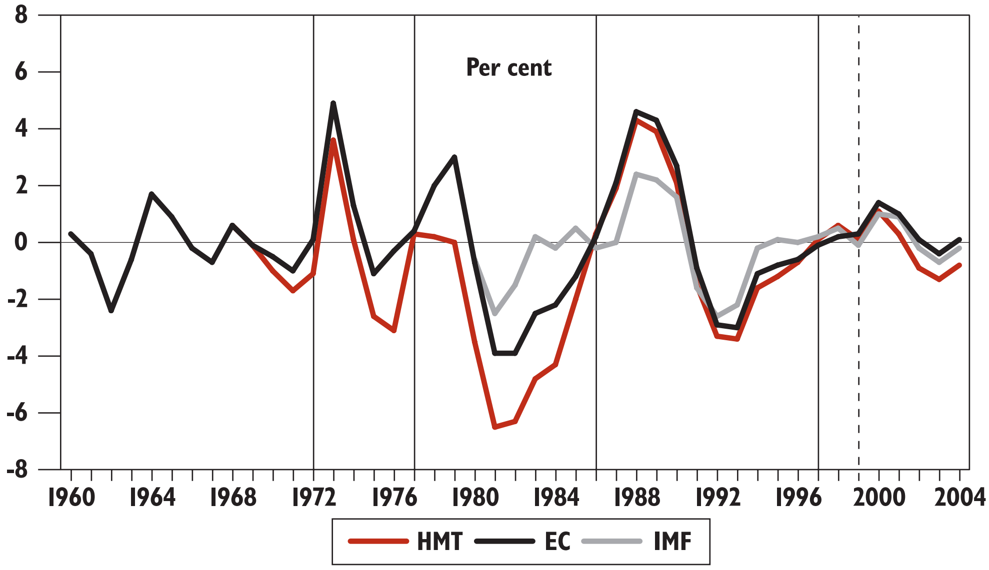
## EXTERNAL STUDIES

**3.13** This section compares HM Treasury's view of the economic cycle with those of the EC, IMF and OECD and some other external studies.

### Studies by international organisations

**3.14** Chart 3.2 shows Treasury output gap estimates and the production function based estimates of the IMF and the European Commission (EC) on an *annual* basis over recent decades.

## Chart 3.2: Comparisons of annual output gap estimates[1]



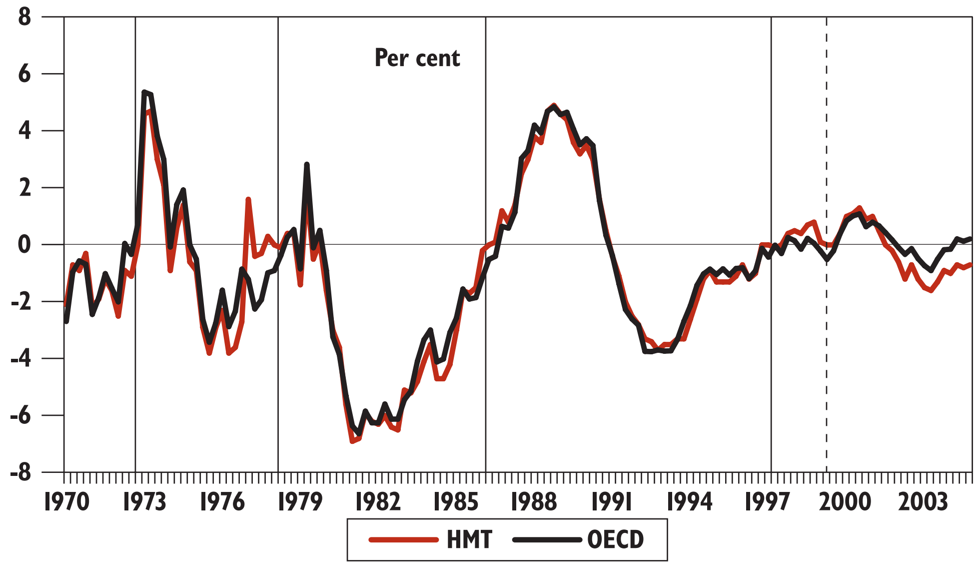

[1]Vertical lines denote end/start cycle points previously identified by HM Treasury.

**3.15** The respective estimates all show a broadly similar pattern, with the economy moving up and down through trend at roughly similar points on all three estimates. The main outlier is the IMF's estimate of the position of the output gap around the mid-1980's. They judge that the output gap, built up during and carried over from the early 1980's recession, had been fully absorbed by around 1983 or 1984 with the economy operating at or close to trend in these years. By contrast, Treasury output gap estimates imply that the economy did not eradicate its remaining excess capacity until 1986, with EC estimates corroborating this judgment. Indeed, the IMF view of this period is rather difficult to square with the economy's actual rates of growth at the time. For example, the IMF estimate that the economy had a positive output gap in 1985 but that a small degree of slack re-emerged in 1986. Yet in 1986 the economy grew by 4 per cent, which would appear to imply a rather implausible rate of trend growth.

**3.16** All these estimates show the economy close to trend in mid-1999, but not distinctly passing through trend, before rebounding quickly above trend. For 2004 on average the IMF and EC estimates show the economy close to trend, whereas HM Treasury estimates show a modest negative output gap.

**3.17** Some organisations, and in particular the OECD, also publish quarterly output gap estimates like HM Treasury. In line with the IMF and EC, the OECD use a production function approach in forming their judgements on the output gap.

## Chart 3.3: Comparison of quarterly output gap estimates[1]




[1] Vertical lines denote end/start cycle points previously identified by HM Treasury.

**3.18** Chart 3.3 compares Treasury estimates of the output gap on a quarterly basis with those of the OECD. There is a close correlation between the OECD and HM Treasury estimates through most of this period. In general, the magnitude of difference between HM Treasury and OECD estimates of the output gap has become smaller over time, possibly reflecting greater macroeconomic stability and improved statistical quality. On balance, though, the difference between the two estimates has widened a little over the more recent past, with Treasury estimates of a positive output gap in the late 1990s above those of the OECD but Treasury figures implying a more negative output gap of late. Over the most recent quarters (through late 2004) the OECD judge the UK economy to have been operating a little above trend while Treasury estimates continue to imply some residual slack in the economy's productive capacity. This may reflect the tendency of production function based estimates of trend to be unduly influenced by the short-term path of the economy.

## Other estimates of the economic cycle

**3.19** Artis (2002) argues that using quarterly economic statistics for the purposes of dating the economic cycle means that the data are potentially 'coarse'.

**3.20** Artis therefore uses NIESR's 'innovative' series of monthly GDP to identify the economic cycle in the UK. The analysis differentiates between two types of economic cycle: the 'classical' cycle and the 'deviation' or growth cycle, as described in Chapter 2. What Artis calls the 'deviation' or 'growth' cycle corresponds most closely to the Treasury's approach to the economic cycle. Artis identifies eight full economic cycles in the UK in the past 31 years using this methodology.

**3.22** The Hodrick-Prescott filter approach employed by Artis implies the economy moving up and down through trend with much higher frequency than Treasury estimates. This important difference aside, there is a strong correlation between some of the estimated on-trend points of the two methods. In particular the analysis:

- identifies that the economy moved through trend during the second half of 1977 and into 1978, consistent with the Treasury dating of 1978Q1 as an on-trend point;

- estimates the economy was at or close to trend for most of 1985, with the economy dipping slightly below trend a little in 1986 but closing this small output gap in the first half of 1987. This diverges a little from the Treasury judgement that the economy remained consistently below trend until 1986Q2, which is identified as an on-trend point;
- shows the economy moving from a position well above capacity during 1990 and moving through trend in late 1990 and early 1991, and consistent with the Treasury's dating of 1990Q4/1991Q1 as an on-trend point; and
- shows the economy at trend in early 1997, in line with the Treasury judgement that 1997H1 was an on-trend point, dipping below trend in 1999. Both analyses appear to share a common identification of 2001Q3 as the economy's latest on-trend point.

**3.23** One of the Treasury's 18 EMU Assessment technical studies (Artis (2003)) included a detailed examination of UK business cycles, in the course of assessing the degree of convergence between the UK economy and the rest of the European Union. Part of this involved applying both Baxter-King and Hodrick-Prescott filters to examine the duration and amplitude of business cycles in the UK, European Union and the US.

**3.24** The Baxter-King filter analysis showed the economy passing through trend on rather more occasions than yielded by the Treasury's approach. Nonetheless, there were broad similarities between the results and those arising from application of the Treasury's method. In this analysis:

- the economy was on-trend in 1978, with a cyclical peak in output in 1980 and a subsequent trough in 1982. This is broadly consistent with the Treasury's method, which judges 1978Q1 to have been an on-trend point and 1981Q1 to have been a cyclical trough;
- the economy was on-trend in 1988, a little later than the Treasury's adjudged on-trend point in 1986Q2, although the Baxter-King filter also yielded an earlier temporary on-trend point in 1984. Both approaches judge the output gap to have peaked around late 1988 or early 1989 and to have passed through trend again around 1991; and
- the early 1990s' trough in output occurs around 1993, with subsequent on-trend points in 1997 and 2001. The Baxter-King filter showed the economy on average just above trend in 1999.

**3.25** The analysis using HP filters in the Artis paper also gave broadly similar results to those derived using the Treasury's method of estimating the output gap, especially in terms of the duration of UK business cycles, although again there were some differences:

- the economy moved up through trend around 1976/1977, a little before the dating suggested by the Treasury's methodology. Subsequently, the economy was estimated to have dipped back below trend in 1980, slightly later than HM Treasury's estimate;
- the economy is judged to have been on-trend around 1986/87, close to the Treasury's view of 1986Q2; and

- the Treasury's methodology shows the economy moving below trend in early 1991, around a year before identified in the Artis analysis. There is close agreement between the two methods on the subsequent trough in the economy being reached in late 1992, with the economy picking back up to trend in 1997.

## REAL-TIME OUTPUT GAP ESTIMATES

### Analysis based on historical economic commentary

**3.26** Examination of real-time economic commentary is a useful way of highlighting the degree of judgement surrounding cyclical movements in the economy, at a given point in time, and their important role in underpinning policy.

**3.27** For example, writing in the 1960s, Dow (1964) aimed to assess the cyclical position of the economy between 1946 and 1960 and compare with the views prevailing at the time. He concluded that the post-War boom persisted much longer than policy makers had anticipated (to 1951), and more generally that judgements on spare capacity in the 1950s were sometimes wide of the mark and subject to substantial uncertainties.

**3.28** Similarly, Blackaby (1978) reported that macroeconomic policy in 1973 and 1974 was premised on the view that the UK economy was carrying very significant excess capacity, which the National Institute estimated at the time to be around 6 per cent of GDP. Moreover, Bank of England commentary in their quarterly bulletin in early 1973 noted that the continued fast rise in output at the time should not be immediately hampered by bottlenecks, and that there ought to be little risk of general labour shortages rapidly developing to constrain supply. Further Bank commentary later in the year suggested there may still have been a degree of slack left in the economy, albeit not much.

**3.29** With hindsight, these judgements appear to have been seriously flawed. For example, the OECD currently estimate that the UK had a positive output gap in 1973 of almost 4$^1/_2$ per cent, while HM Treasury estimates suggest it was around 3$^1/_2$ per cent.

**3.30** A formal way of evaluating such episodes is through a statistical analysis of the output gap derived from the most up-to-date quarterly statistics compared with historical estimates made at the time i.e. real-time estimates. Nelson and Nikolov (2001) took this approach in order to examine the effects of real-time output gap mismeasurement by policy makers on inflation through the 1970s and 1980s. Their real-time output gap series was constructed on the basis of inference from comparing (largely qualitative) statements from policy makers of the day with a real-time GDP series.

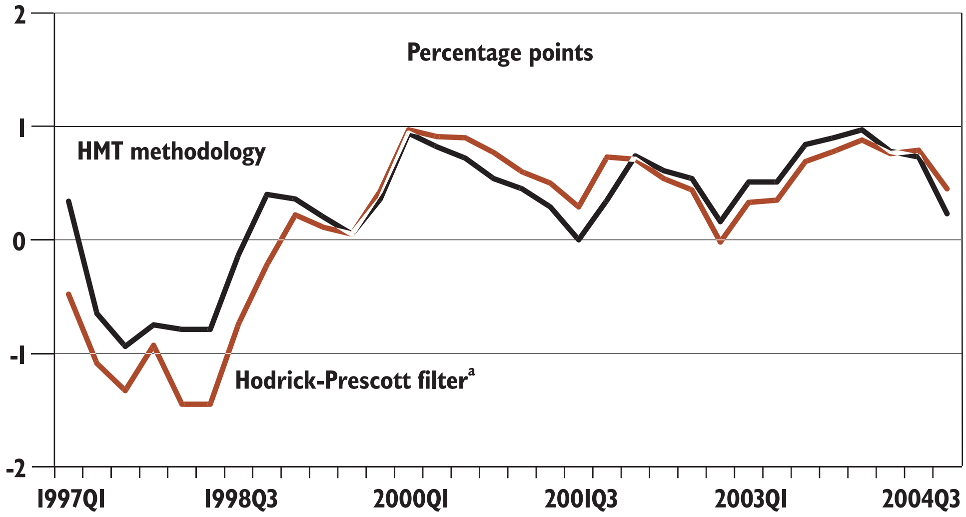
**3.31** Their discussion of the 1973 episode suggests that errors in both GDP measurement and output gap assessment contributed to overestimation of the extent of the negative output gap, with the size of the gap thought to have been about -4 per cent at the time.

**3.32** The picture in the 1980s and early 1990s tells a similar story. However, Nelson and Nikolov concluded that during these periods output gap errors mainly reflected inaccurate judgements regarding potential growth, unlike the 1970s when GDP mismeasurement was also a major factor. They judged GDP measurement error to be less of a problem at present owing to improved statistical methodology.

## Analysis based on revisions to real-time output gap estimates

**3.33** One method of evaluating the reliability of alternative methods of assessing the output gap in more recent periods is to compare their estimates of the output gap derived from the most up-to-date quarterly statistics with corresponding real-time estimates based on the data available at the time. This analysis suggests that HM Treasury's estimates have been relatively accurate.

**Chart 3.4: Revisions to real-time output gap estimates**




[a]Includes forecasts which produce more plausible estimates of the output gap than simply running a Hodrick-Prescott filter up to the latest data observation available at that time.

**3.34** Historical Treasury forecasts can be used to construct a real-time output gap series for the UK which can then be benchmarked against latest economic data to see how accurately or how poorly real-time estimates captured the degree of slack in the economy at that point in time. It is also useful to compare the performance of the Treasury's historical real-time output gap estimates with those constructed using alternative methods. Chart 3.4 shows revisions to HM Treasury and HP filter real-time output gap estimates since 1997.

**3.35** This analysis of real-time output gap estimates suggests that:

- the Treasury's real-time estimates have tracked latest estimates reasonably well, especially given the difficulties and uncertainties that are inevitably involved in coming to a judgement on the size of the output gap; and
- the uncertainties surrounding the Treasury's real-time estimates of the output gap have been lower than those surrounding estimates based on HP filters, which have been more prone to revision. This is illustrated by average absolute revisions to Treasury estimates of 0.55 percentage points from 1997 to 2004, compared to 0.74 percentage points for HP based estimates.

## CONCLUSIONS

**3.36** This chapter has compared HM Treasury estimates of the business cycle over time with estimates derived by external organisations and studies. HM Treasury has previously identified the following complete cycles: 1972Q4 to 1978Q1; 1978Q1 to 1986Q2; 1986Q2 to 1997H1; and provisionally 1997H1 to mid-1999.

**3.37** On the basis of the alternative estimates presented, after the early 1970s there is a consensus that the economy went through three major cycles up to the mid to late 1990s, and there is a considerable degree of agreement on the broad dating of some on-trend points. For some other on-trend points there is less consensus. Ambiguities in the dating of on-trend points appear to occur more during periods when the economy is assessed to be relatively close to trendw.

**3.38** Another key feature of UK cycles over past decades is that the amplitude increased in the 1970s and again in the 1980s, and that the cycles of the 1970s, 1980s and early 1990s were of much higher amplitude than either before or after. Moreover, the amplitude in recent years appears to have been lower than in the 1950s and 1960s. This lowering in amplitude has been widely attributed, at least in part, to improvements in the macroeconomic policy framework.

**3.40** Real-time estimates of the output gap appear to have been particularly wide of the mark at important junctures during the 1970s, 1980s and early 1990s. Such errors probably contributed to macroeconomic policy mistakes and the amplitude of the cycle, which illustrates the importance and positive role of judgement in assessing the cyclical position of the economy. More recently HM Treasury real time-output gap estimates have been subject to less revision, and have been somewhat less prone to revision than HP statistical filtering based estimates.

# 4 New evidence on the post-1997 UK cycle

**4.1** This chapter looks at the implications for dating the cycle of latest national accounts revisions, new market sector output data (i.e. excluding government output), and evidence on the relationship between movements in the labour share of value added and the output gap, focusing particularly on recent years.

## National accounts revisions

**4.2** The Quarterly National Accounts release for 2005Q1 published by the Office for National Statistics on the 30 June contained revisions from 1996 onwards. While revisions to GDP growth between 1996 and 2001 were relatively small, with GDP growth being revised by up to 0.1 percentage points each year, revisions to non-oil GVA (gross value added), which is the measure used by the Treasury to calculate the output gap, were more significant over this period. In particular non-oil GVA growth was revised up 0.5 percentage points in 1999.

**4.3** There were also revisions to GDP and non-oil GVA growth from 2002 onwards: GDP growth was revised up by 0.2 percentage points in 2002, 0.3 percentage points in 2003 and 0.1 percentage points in 2004. Non-oil GVA growth was similarly revised up over this period, by 0.2, 0.4 and 0.0 percentage points. There were downward revisions to quarterly growth for the most recent quarters.

**4.4** As described in Chapter 2, the Treasury's approach to dating on-trend points and estimating the output gap involves analysing a wide range of indicators in the economy, and then calculating trend growth as the average rate of growth between adjudged start and end-cycle on-trend points. Analysis of these indicators was set out in 'Fiscal policy; Public Finances and the Cycle'. Most of the indicators used to date on-trend points are not subject to significant revision, unlike GVA data. In Budget 2000 HM Treasury provisionally judged mid-1999 to have been an on-trend point, implying a very short full cycle between 1997H1 and mid-1999 of just over 2 years. It was recognised that output only dipped below trend for a short time in early 1999 which, together with the possibility of measurement errors, was why the judgement that the economy completed a short and shallow full cycle in mid-1999 was a provisional one, as explained in Chapter 3.

### Table 4.1: Non-oil GVA growth estimates

| | Post Blue Book 2005 | Pre Blue Book 2005 | Budget 2000 |
|---|---|---|---|
| 1997 | 3.2 | 3.3 | 3.4 |
| 1998 | 3.4 | 3.5 | 2.4 |
| 1999 | 3.1 | 2.6 | 1.8 |
| 2000 | 4.2 | 4.1 | $2\frac{3}{4}$(F) |

*(F) = forecast*

[1] Page 224.

**4.5** Data revisions over recent years have changed the profile of growth around mid-1999 significantly. By the time of Budget 2005 output only showed an indistinct dip below trend. The latest data revisions, which raised 1999 GVA growth from 2.6 per cent to 3.1 per cent, now have significantly changed the profile of the economic cycle around 1999. There is now no evidence of a clear dip below in 1999. So the below trend phase of the previously identified 1997H1 to mid 1999 'cycle' now looks non-existent. Chart 4.1 compares HM Treasury estimates of the output gap before the latest data revisions against the path implied by imposing the latest data revisions on the unchanged trend growth assumptions, and against the estimates made in Budget 2000.

**4.6** As such, while the economy is currently estimated to have been operating very close to trend at that time, the evidence now suggests that mid-1999 was not a period when the economy could be judged to have been at the end of a cycle, or at the beginning of a new one.

**4.7** Revisions to growth in non-oil GVA from 2000 onwards have been largely the same as those to GDP. As a result of the upward revisions to growth from 2002 through to early 2004, the negative output gap which opened up after the global slowdown in 2001 is now estimated to have narrowed notably more quickly than indicated by the previous dataset. Indeed, the output gap is now estimated to have narrowed to close to zero in the first half of 2004, although not passing through trend.

**4.8** However, with the dataset revising growth downwards in each of the last four quarters, the latest data imply a widening degree of slack recently opening up again in the UK economy. Indeed, by 2005Q1, the implied output gap is currently only marginally narrower than estimated before the latest revisions.

**4.9** Chart 4.2 shows the output gap estimates from the past few years in a historical context. Given that the earliest on-trend point identified using the Treasury's cyclical indicators approach to dating is 1972Q4, estimates of the output gap prior to then in Chart 4.2 are constructed using a HP filter, and so are less soundly based.

**Chart 4.1: Output gap estimates**

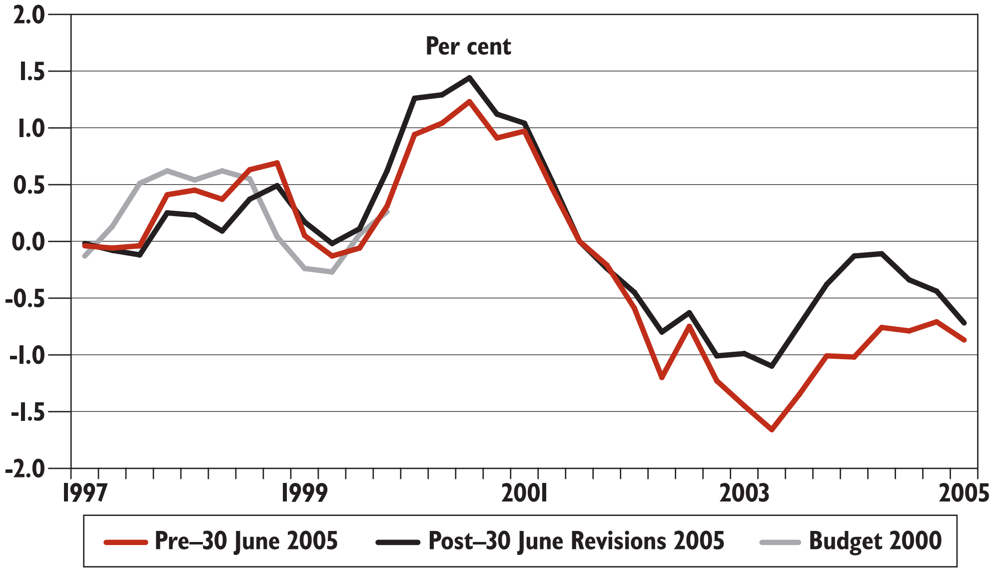
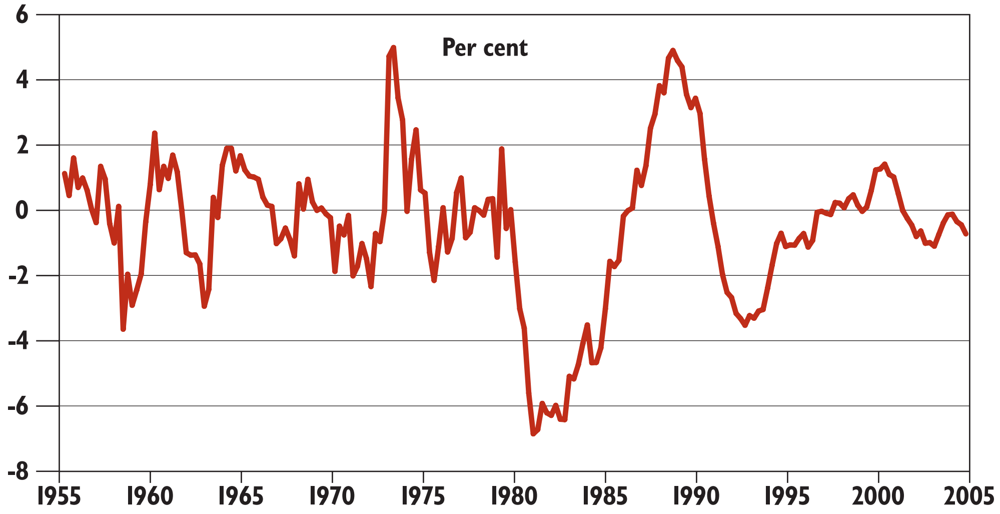


Chart 4.2: HM Treasury output gap estimates




## MARKET SECTOR GVA

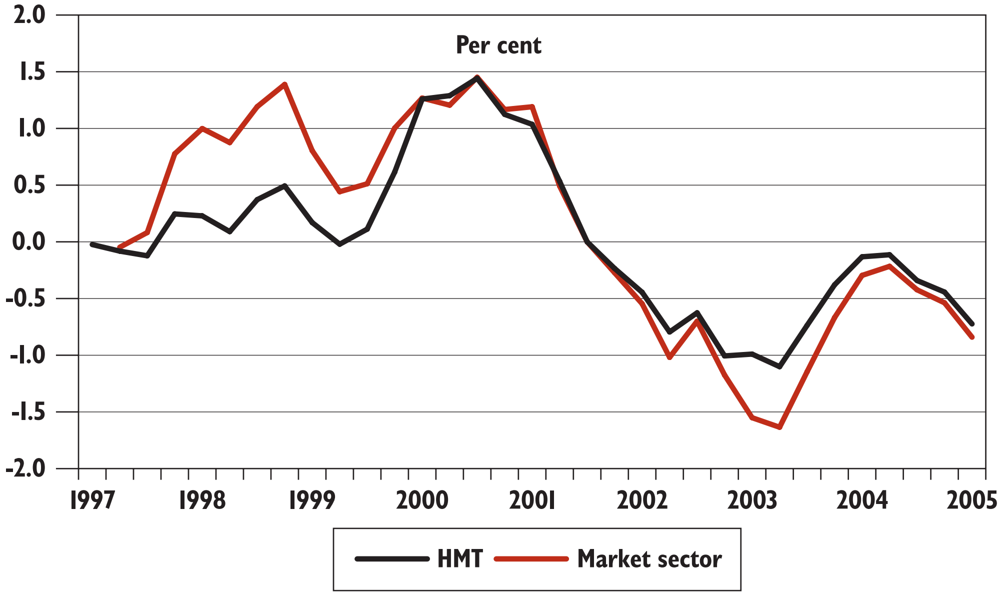
**4.10** The Treasury currently measures trend growth and the output gap on a whole-economy non-oil GVA basis. However, Budget 2005[2] discussed the rationale for why the measurement of government output ought not to change estimates of the output gap. The output gap should measure fluctuations in activity arising from the business cycle, and as such it should be determined by factors affecting the behaviour of only the private or market sector of the economy. Thus the output gap may be better measured by private or market sector rather than whole economy output, and it should at least be instructive to consider measures constructed on this basis alongside the more familiar whole economy non-oil based measures. Indeed Budget 2005 noted that *"consideration will be given to introducing such refinement in time for future output gap assessments"*.[2]

**4.11** The OECD already use a business sector definition as the basis for estimating output gaps, and the European Commission is considering the feasibility of doing likewise. The US also publishes data on a business sector basis.

**4.12** Until recently the feasibility of adopting a business sector definition for measuring the UK output gap was limited because a proper measure of UK market sector GVA was not available. However, on 30 June 2005 the ONS published an experimental series for market sector GVA, dating back to 2003. Subsequently this time-series has been extended back to 1995, and also calculated on a non-oil basis, enabling an output gap to be constructed dating back to 1997H1. Chart 4.3 compares output gap estimates from the beginning of 1997 calculated on both a whole economy non-oil GVA and market sector non-oil GVA basis on the assumption that both 1997H1 and 2001Q3 were on-trend points, but not constraining mid-1999 to be on-trend.

[2] Box B1, page 223.

**Chart 4.3: Whole economy and market sector output gap estimates (excluding oil)**




**4.13** On a market sector non-oil GVA basis, output is estimated to have remained notably above trend from the end of 1997 through to early 2001. In contrast, on a whole economy non-oil basis, output is estimated to have remained much closer to trend from 1997 to mid-1999, only moving significantly above trend through the second half of 1999.

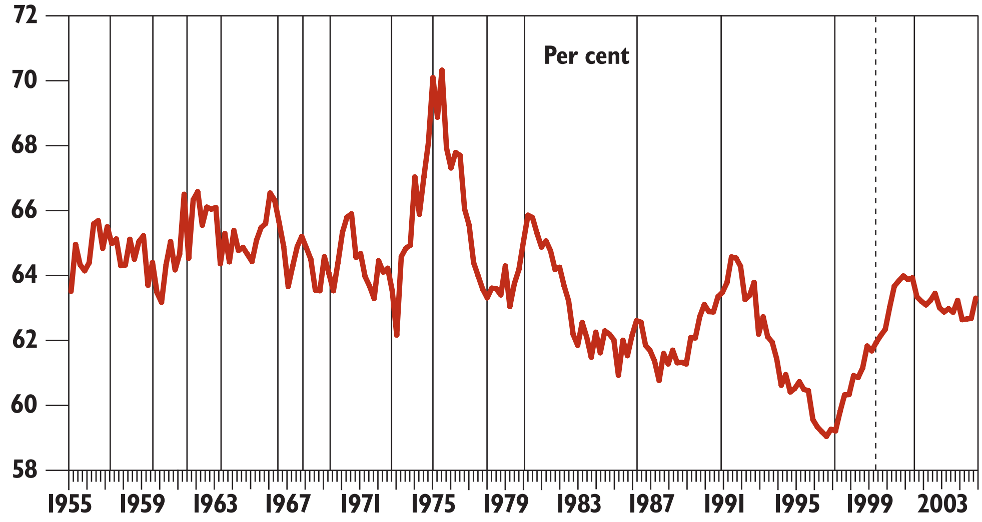
**4.14** Consequently, considering market sector GVA as an alternative basis for assessing the cycle and estimating the output gap provides further support for the judgement that mid-1999 should not be retained as an explicit on-trend point.

**4.15** Since 2001Q3, the output gaps constructed on either a market sector or non-oil whole economy basis show very similar profiles. So again, this alternative basis for assessing on-trend points and estimating the output gap supports the view that the negative output gap is estimated to have narrowed to close to zero in 2004H1 – though not reaching zero – and that a degree of slack in the economy has opened up over the last three quarters.

## LABOUR SHARE AS A CYCLICAL INDICATOR

**4.16** Chart 4.4 and Table 4.1 reveal a close correlition between on-trend points of the economy, as previously assessed by the Treasury, and turning points (i.e. peaks and troughs) in labour share, as measured by whole economy compensation of employees as a percent of total nominal GVA i.e. the share of national income that is paid to workers. The correspondence is all the more striking in that the cyclical indicators based approach used by the Treasury to assess on-trend points has not previously involved taking account of the cyclical behaviour of the labour share. Consequently, if there were plausible reasons to explain why turning points in the labour share should coincide with points when the economy was passing through trend, then the evidence would appear to provide strong independent corroboration of the Treasury's approach and judgement in dating on-trend points.

## Chart 4.4: Labour share




*Vertical lines represent on trend points previously identified by HM Treasury.*

**4.17** From chart 4.4 and table 4.1 it is clear that previously identified on-trend points typically correspond with peaks and troughs in the labour share series to within a few quarters. Moreover there is a consistent pattern of:

- Peaks in the labour share corresponding closely with the economy passing down through trend (downswing);
- Troughs in the labour share corresponding closely with the economy moving up through trend (upswing).

### Table 4.1: Previously identified on-trend points and peaks and troughs in labour share

| Labour share peaks and troughs | | HMT on-trend points | |
|---|---|---|---|
| **Trough** | **Peak** | **Upswing** | **Downswing** |
| | 2001H1 | | 2001Q3 |
| 1997Q2 | | 1997H1 | |
| | 1991H2 | | 1990Q4/91Q1 |
| 1987Q3 | | 1986Q2 | |
| | 1980Q2/3 | | 1979Q4 |
| 1979Q2 | | 1978Q1 | |
| | 1975Q4 | | 1975H1 |
| 1973Q1 | | 1972Q4 | |
| | 1970H2 | | 1969Q2/3 |
| 1968H2 | | 1967Q4/68Q1 | |
| | 1966H1 | | 1966Q3 |
| 1963Q2 | | 1963Q2/3 | |
| | 1962Q1 | | 1961Q3 |
| 1960Q1 | | 1959H2 | |
| | 1956Q3 | | 1957Q2/Q3 |

4.18 However, the mapping between on-trend points and peaks and troughs in the labour share is not completely one-for-one: there have been some less pronounced local peaks and troughs in the labour share that the Treasury has not judged to be on-trend points; and there are instances of on-trend points that the labour share series suggests were not points when the economy clearly passed through trend. This appears consistent with the observation made in Chapter 2 (paragraph 2.7) that an on-trend point need not necessarily coincide with either the beginning or end of a cycle if at that point output does not decisively pass through trend, because in that case the on-trend point does not mark an end or start date for a distinct phase of the cycle.

4.19 Notably, the mid-1999 on-trend point previously identified by the Treasury does not match up with a turning point in the labour share. In this case the labour share temporarily stabilised while the economy hovered close to trend without decisively passing through it, and the labour share then resumed an upward path as the output gap widened clearly into positive territory. More generally it would seem that there is some evidence that the labour share has tended temporarily to stabilise around periods when the output gap has been judged little changed, for example during 1994 when some methods of estimation put the economy close to trend.

## CONCLUSIONS

4.20 In conclusion, the recent revisions to GVA, provides significant new information on the timing of the economic cycle since 1997. This evidence shows that while the economy was close to trend in 1999, this was not a period when the economy could be judged to have been at the end of a cycle or the beginning of a new one. Therefore, the Treasury's revised judgement, based on this new evidence, is that the current economic cycle began in the first half of 1997, rather than in 1999. This conclusion is corroborated by new data from the ONS for market sector GVA and new analysis of the labour share of the value added.

# 5 Conclusions on dating of UK cycles

**5.1** This chapter draws out conclusions based on the evidence and analysis presented in the previous chapters, with particular focus on the post-1997 period.

**5.2** HM Treasury has previously identified three complete cycles between 1972 and 1997, and the present study has not found any reason to change this assessment.

**5.3** This paper has assessed the implications for dating the UK cycle since 1997 of recent national accounts revisions, new market sector output data and new analysis of movements in the labour share of value added.

**5.4** The national accounts revisions to GDP and GVA data released by the ONS in June 2005 mark the latest in a run of revisions that provide new evidence on the cyclical development of the economy over recent years. At the time of Budget 2000, the Treasury made the provisional judgement that the economy may have completed a full cycle between 1997H1 and mid-1999. This judgement was provisional because the cycle was clearly indistinct by historical standards. Subsequent data revisions up until Budget 2005 continued to show only an indistinct dip below trend in 1999, so this judgment has remained provisional.[1]

**5.5** The most recent revisions to GVA include a significant upward revision to GVA growth in 1999 of 0.5 percentage points. While at the time of the Budget 2000, non-oil GVA growth in 1999 was estimated to be 1.8 per cent, this had increased to 2.6 per cent prior to the latest revisions and to 3.1 per cent following the latest revision. These revisions have significantly changed the profile of the economic cycle around 1999. There is now no evidence of a clear dip below trend in early 1999. So the below trend phase of the previously identified 1997H1 to mid-1999 'cycle' now looks non-existent.

**5.6** New market sector GVA data released by the ONS in June 2005 re-inforce the view that mid-1999 was not an end or start point of the economic cycle. As discussed in Budget 2005[2], market sector output may provide a better basis than whole economy output for measuring the output gap, because cycles are essentially a feature of the market sector. On the basis of these new market sector GVA data, output did not touch trend in 1999, remaining notably above trend throughout the period from the end of 1997 through to early 2001.

**5.7** New analysis by the Treasury of data on the labour share of value added offers further evidence on the dating of the latest cycle. With the exception of mid-1999, there is a close empirical correspondence between on-trend points of the economy, as previously assessed by the Treasury, and turning points (i.e. peaks and troughs) in the labour share. The correspondence is all the more striking in that the cyclical indicators based approach used by the Treasury to assess on-trend points has not previously involved taking account of the cyclical behaviour of the labour share.

**5.8** In conclusion, the recent revisions to GVA, provides significant new information on the timing of the economic cycle since 1997. This evidence shows that while the economy was close to trend in 1999, this was not a period when the economy could be judged to have been at the end of a cycle or the beginning of a new one. Therefore, the Treasury's revised judgement, based on this new evidence, is that the current economic cycle began in the first half of 1997, rather than in 1999. This conclusion is corroborated by new data from the ONS for market sector GVA and new analysis of the labour share of value added.

[2] See Budget 2005, page 26, paragraph 2.33.

[3] Box B1, page 223.

# A CYCLE ESTIMATION METHODS: TECHNICAL DETAIL

**A.1** This annex provides additional technical detail on statistical filters and other approaches to cycle estimation to supplement the material in Chapter 2.

## The Hodrick-Prescott filter

**A.2** The Hodrick-Prescott filter can be expressed as:

$$\min_{g(t)} \sum_{t=1}^{N} \left\{ (y_t - g_t)^2 + \lambda[g_{t+1} - g_t) - (g_t - g_{t-1})]^2 \right\}$$

where y is the original series, g the growth component and (y-g) the cyclical component. The filter aims to minimise two components, the deviation from trend and the smoothness of the growth component. The first term represents the deviation (more precisely, the sum of the squared deviations), and the second term (in squared brackets) the smoothness of the growth component. The parameter lambda is the signal-to-noise ratio, and weights the relative importance of the two conflicting goals in the loss function. The greater the degree of smoothness imposed, the closer the trend path will be to a straight line (i.e. the deterministic trend approach); and the lower the degree of smoothness, the closer the 'trend' series will be to the observed one i.e. with lambda at infinity the filter collapses to a linear trend, and when lambda is zero the filter gives the original series.

## Baxter-King (BK) band-pass filter

**A.3** Relative to the HP filter, the band-pass filter proposed by Baxter and King (1995) is characterised by the imposition of some more economic structure[1]. Roughly speaking a band pass filter is a non-structural approach that aims to decompose a time-series in the frequency domain rather than the time domain. Time series can be viewed as comprising high frequency (irregular or noise), medium frequency (cyclical) and low frequency (trend) components. In order to distinguish between the trend and cyclical components of a time-series, the band pass approach entails carefully identifying and filtering out all of these components. Thus cycles in a 'band', given by a specified lower and upper bound are 'passed', or extracted, and the remaining components are 'filtered' out. So in order to extract the cyclical component of a time series, it is necessary to specify the frequencies that are to be scored as cyclical. Baxter and King defined the cyclical components of output as those persisting for between 6 and 32 quarters, as originally put forward in Burns and Mitchell (1946).

**A.4** Technically, the form of band pass filter proposed by Baxter and King is a linear filter that takes a two-sided, weighted, moving average of the data. When applied to quarterly data, this takes the form of a 24-quarter centred moving average. However, it is important to note that because the Baxter-King filter is defined as a centred moving average, 12 quarters are sacrificed at the beginning and end of the time series. This has the effect of seriously limiting its usefulness for analysing contemporaneous data.

[1] A band-pass filter with similar properties to the Baxter-King filter may be constructed by using two HP filters in combination.

## ARIMA models

**A.5** The ARIMA (auto-regressive, integrated, moving average) model assumes that any deterministic trend component in a time series, and all its unit roots, can be removed by differencing and that the resulting stationary series can be represented by an autoregressive moving average model. The auto-regressive component (AR) in ARIMA is designated as p, the integrated component (I) as d, and the moving average (MA) as q. The AR component represents the lingering effects of previous observations. The I component represents trends. And the MA component represents lingering effects of previous random shocks (or error). The ARIMA (p,d,q) model is defined as:

$$\sum_{s=0}^{p} \alpha_s \Delta^d x_{t-s} = \gamma + \sum_{s=0}^{q} \beta_s e_{t-s}$$

where $e_t$ is an iid(0, $\sigma^2$) process. The intercept $\gamma$ allows for the possibility of a deterministic trend: more generally, $\gamma$ may be replaced with a polynomial in t. Nevertheless it is common to assume in ARIMA models that $\gamma = 0$, when the deterministic trend disappears, leaving only the stochastic trend.

**A.6** To fit an ARIMA model to a time series, the order of each model component must be selected. Usually a small integer value (0, 1, or 2) is found for each component. The goal is to find the most parsimonious model with the smallest number of estimated parameters needed adequately to model the patterns in the observed data.

## Unobserved components model

**A.7** A more general approach than the ARIMA model is the use of unobserved components (UC) models, or structural time-series models, as they are also known. The UC has the advantage that it handles non-stationarity without having to difference the data directly. It is based on the idea of decomposing a time-series into trend, cycle, and irregular components, and applying the key identifying assumptions that the secular component follows a random walk with drift and that the cyclical component is a stationary finite order AR process.

**A.8** The idea here is to define $y_t$ as the sum of n uncorrelated components with each component having an ARIMA representation. If there are only two components then the assumption that they are uncorrelated is sufficient to identify them. A common choice of the UC model is:

$$y_t = y_t^T + y_t^C + e_t$$
$$y_t^T = v + y_{t-1}^T + \varepsilon_t$$
$$y_t^C = \phi(L)\xi_t$$

**A.9** To make the three components uncorrelated, $e_t$, $\varepsilon_t$ and $\xi_t$ are defined to be distributed independently of each other and to ensure the cycle is stationary $\phi(L)$ must have its roots on or outside the unit circle. Thus, apart from its lack of correlation with the other components, the trend component is similar to that in the Beveridge-Nelson model. In fact, once the UC model is modified to allow correlated trend and cycle innovations, the UC model coincides exactly with the Beveridge-Nelson decomposition, and both approaches generate identical trend and cycle estimates.

## Kalman filter

**A.9** The use of the Kalman filter for de-trending data is primarily as an algorithm for estimating ARIMA and UC models, but because it can be generalised to have time varying parameters, potentially it is much more powerful. Its main use is as a forecasting device, since its focus is not on parameter estimation but on prediction using recursive estimation or updating equations.

**A.10** The Kalman filter consists of two equations: a 'measurement' or 'observation' equation:

$$y_t = z_t^{'}\alpha_t + \varepsilon_t$$

and a 'transition' or 'state' equation:

$$\alpha_t = T_t\alpha_{t-1} + R_t\eta_t$$

where $a_t$ is nx1 and is called the state vector, $z_t$ is an nx1 non-stochastic vector, $T_t$ and $R_t$ are nxm non-stochastic matrices, $\varepsilon_t$ and $\eta_t$ are, respectively, a scalar and an mx1 vector of disturbances which are distributed independently of each other. It is usually assumed that the disturbances and the initial state vector are normally distributed. This way of writing the model is known as the 'state space form'.

**A.11** Once the model has been put in state space form, the Kalman filter provides a simple recursive way of recovering optimally the state vector (i.e. trend output), using maximum likelihood techniques. This involves applying a recursive procedure for computing the optimal estimator of the state vector at time t, based on the information available at time t, which has the difficulty of requiring the setting of initial values for the state vector, though the effect of the starting values is soon lost. Once a new observation, $y_t$ , becomes available, it is then possible to update the estimator of the state vector. So, given the initial conditions, the Kalman filter delivers the optimal estimator of the state vector as each new observation become available.

**A.12** However, a key variable in the estimation of Kalman filters is the relative smoothness of the unobserved variable (trend output), which is governed by the relative size of the error variances in the measurement and transition equations. The higher the ratio of the variance of the transition to the measurement equation residuals, which gives the 'signal-to-noise ratio', the more explanatory power is given to the unobserved variable, and the better the fit of the measurement equation. In the limit, for very large values of the variance of $\eta_t$ , the unobserved variable may soak up all the residual variation in the measurement equation. Alternatively if $\eta_t$ is zero, then it will be estimated as a constant, and the filter collapses to a linear trend.

**A.13** All of the univariate models considered above can be written in state space form. In general, however, there is no unique way to do so. For example, under certain assumptions, the UC model can be cast in state space form, and the maximum likelihood estimates of the parameters, as well as the unobserved trend and cycle, can be computed from the Kalman filter. As Morley, Nelson, and Zivot (2003) demonstrate, when the trend and cycle innovations are allowed to be correlated, the estimated trend from the Kalman filter is numerically identical to the Beveridge-Nelson trend.

## Production function

**A.14** The production function approach to trend growth estimation relates the level of output to a combination of the factor inputs and level of technology used to produce it. The most widely used functional form in the economic literature is the Cobb-Douglas production function. Potential output is then defined by:

$$Y_t^* = A_t^* N_t^{*\,a} K_t^{*\,1-\alpha}$$

where Y* is the level of output at full potential at time t, $N^*$ is labour input, $K^*$ the capital stock, and $A^*$ total factor productivity (TFP), all at potential levels. The functional form imposes constant returns to scale, and $\alpha$ is the elasticity of output with respect to labour and$1-\alpha$ is the elasticity of output with respect to capital.

**A.15** The Treasury's methodology for estimating trend output over complete past cycles has little in common with the production function approach, but the Treasury's approach to projecting trend growth for the current cycle can be interpreted as a variant of the production function approach, in the following sense. Dividing the equation above by labour input expresses trend productivity in terms of trend TFP and the trend capital-labour ratio:

$$Y^*_t \,/\, N^*_t = A^*_t \,(K^*_t \,/ N^*_t)^{(1--a)}$$

This equation illustrates the Treasury's preferred approach of subsuming the effects of changes in capital intensity (capital deepening) and TFP into labour productivity growth. This is justified if estimated labour productivity growth is stable relative to growth in TFP and the capital-labour ratio.

**A.16** The key parameter $\alpha$ of the Cobb-Douglas production function can be interpreted as the share of output going to labour in the form of wages (this assumption holds under perfect competition, where the marginal product of labour is equated with the wage rate). Data for the share of wages in total income are readily available. However, direct estimation of the parameter can lead to differing results. This may be because the assumptions do not hold or that estimates are sensitive to the sample period chosen perhaps because the share itself is cyclical. The IMF, OECD and EC differ slightly in their estimates, which range from 0.65 to 0.71.

**A.17** Judgements on potential employment are generally based on estimates of the NAIRU and the trend participation rate (which are also unobservable). Again, opinions differ on the best methodology to use to estimate the NAIRU, thus giving rise to varying estimates across different studies. The OECD and EC use a Kalman filter and the IMF uses a HP filter to estimate the NAIRU. Statistical filters are often used on participation rate data to obtain estimates of the trend.

**A.18** For the purposes of examining trend growth, potential capital estimates need to capture the flow of productive input from capital into potential output. Thus, a measure of capital services rather than wealth type measures of the capital stock is appropriate. However, despite significant advances in recent years, time-series data on capital services are still in their formative stages. Therefore, in practice, capital stock data have often been used. Typically capital stock data are not smoothed or de-trended as the cyclical element is generally assumed to be very small, and that actual capital is regarded as defining the potential capacity. The IMF, OECD and EC all use capital stock data in their assessments of trend growth, with the IMF and EC using whole economy data whereas the OECD use business sector data. Capital stock data can validly be used only if the assumption that capital services are proportional to the asset value of the capital stock holds. However, this assumption is not appropriate when the composition of the stock is changing towards shorter (or longer) life assets, affecting the average life of the stock (for example, as in recent years with a movement towards a higher proportion of shorter-life ICT assets in the overall stock).

**A.19** Estimates of the trend rate of technological progress are often derived using filtering techniques. A series for TFP is obtained by assessing how much actual factor inputs can explain movements in actual output. The residual, or the component in the series that is unaccounted for by factor inputs, is then assumed to represent TFP. This residual is then statistically filtered to extract an estimate of trend TFP. The IMF and OECD use a HP filter to estimate trend TFP. The EC have moved to a stochastic trend model for TFP as they consider a stochastic trend as being more compatible with the actual evolution of the TFP series.

**A.20** The use of statistical filtering techniques to estimate trend levels of potential employment and TFP can impair the accuracy of the trend growth assessment, and can therefore require a relatively greater degree of judgement to be exercised. Firstly, a judgement needs to be made on the degree to which the filter should smooth the data. In addition, statistical filters can be unduly sensitive to the last data points and introduce a pro-cyclical bias (the 'end-point' problem), and forecasts are often appended to the actual data in an attempt to tackle this problem. This adds yet a further element of judgement to the production function approach.

**A.21** Different methods of trend extraction for the components of productive potential for the production function approach can give significantly different answers, and all cyclical movements might not necessarily be entirely removed. Indeed Treasury analysis seeking to apply the production function approach has demonstrated the difficulty of eliminating cyclical components from estimated potential output. The problem of potential output estimates gravitating excessively towards the path of actual output tends to be particularly acute for the latest cycle. Compared to production function approaches, the Treasury's on-trend point approach is less susceptible to picking up spurious cyclical components, as it measures a constant potential growth rate over a period of time (along with its determinants), and extrapolates these rates into the future.

## The VAR approach

**A.22** A VAR system can be written in its original structural form, relating each variable to contemporaneous values of other variables in the system as well as allowing for lags. However, the system cannot be estimated directly in this form, due to the feedback inherent within it. Moreover, standard estimation techniques require the regressors be uncorrelated with the error term, which is not satisfied in this case. Rewriting the system into standard VAR form, where each variable is related to lags of all the variables in the system, solves this problem, and ordinary least squares can be used to estimate the system (see Annex B).

**A.23** However, estimating the standard VAR system does not recover all the information contained in the structural VAR system (known as the 'identification' problem). Restrictions need to be made on the parameters in the structural VAR system in order for the value of the parameters to be recovered. Standard VARs on their own are simply a multivariate extension of using simple autoregressions, and hence have been criticised as being devoid of economic content.

**A.24** To give economic meaning to standard VAR estimation, an approach can be taken where economic theory informs restrictions on the original structural VAR. A number of alternative so-called 'structural VAR' approaches have been proposed. The approach by Blanchard and Quah (1989) reconsiders Beveridge and Nelson's (1981) approach (see paragraph [2.53]) to decompose GDP into its permanent and temporary components. They consider a technique which imposes long-run restrictions on the error terms of the structural VAR, which provides a unique decomposition of output into its permanent and temporary components.

**A.25** The Bank of Canada (Rennison(2003) and Dupasquier et al (1997)) and Reserve Bank of New Zealand (Claus (1999)) have used Blanchard and Quah's structural VAR approach to estimate potential output (though it remains an illustrative method, rather than being the main approach for forecasting purposes within these organsiations). The Bank of Canada have used output, consumption and the federal funds rate in their VAR, as well as output and inflation, whereas the Reserve Bank of New Zealand included output, employment and capacity utilisation. Demand shocks are assumed to have only temporary effects on output.

# B STRUCTURAL VERSUS STANDARD VARS

**B.1** Take two variables $y_t$ and $z_t$ which are each affected by current and past realisations of the other variable:

$$y_t = b_{10} - b_{12}z_t + \gamma_{11}y_{t-1} + \gamma_{12}z_{t-1} + \varepsilon_{yt}$$
$$z_t = b_{20} - b_{12}y_t + \gamma_{21}y_{t-1} + \gamma_{22}z_{t-1} + \varepsilon_{zt}$$

This can be written in matrix form:

$$Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \varepsilon_t, \quad \text{(i)}$$

where $B=\begin{pmatrix} 1 & b_{12} \\ b_{21} & 1 \end{pmatrix}$, $x_t=\begin{pmatrix} y_t \\ z_t \end{pmatrix}$, $\Gamma_0=\begin{pmatrix} b_{10} \\ b_{20} \end{pmatrix}$, $\Gamma_1=\begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix}$, $\varepsilon_\tau=\begin{pmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{pmatrix}$

**B.6** However, this system cannot be estimated directly due to the feedback inherent in the system, and standard estimation techniques require the regressors be uncorrelated with the error term.

**B.7** Rewriting the system in standard VAR form, by pre-multiplying by B-1 yields:

$$x_t = A_0 + A_1 x_{t-1} + e_t, \quad \text{(ii)}$$

where

$$A_0 = B^{-1}\Gamma_0\ , \ A_1 = B^{-1}\Gamma_1,\ e_t = B^{-1}\varepsilon_t$$

**B.8** This system can now be estimated using standard ordinary least squares regressions.

# C Relationships between the labour share and the output gap – theory

**C.1** Chapter 4 presented analysis of the labour share of value added as a cyclical indicator. This annex includes some further discussion of the issue, in particular pursuing the issue of what theory of wage and price expectations formation might be consistent with this observed empirical regularity, concluding that the issue should be explored further. Whatever the theoretical rationale for the observed empirical regularity, it is still surprising that it should have prevailed and remained so robust for so long. Past decades have seen marked changes in UK labour market regulation, institutions and behaviour, and monetary policy regimes (affecting expectations), all of which might have been expected to have influenced the cyclical behaviour of the labour share. Yet it appears to have remained immune, at least in terms of the correspondence between turning points of the share and on-trend points of the economy.

**C.2** As shown in Chapter 4, it is clear that previously identified on-trend points typically correspond with peaks and troughs in the labour share series. The empirical evidence in chart 4.4 also implies that the labour share has increased when the output gap has been positive, and decreased when it has been negative. This means[4] that real wages have tended:

- To grow at a faster rate than productivity when the economy has been above trend;
- To grow at a slower rate than productivity when the economy has been below trend.

**C.3** Yet another way of putting this is that growth in unit wage costs has tended to exceed inflation when the economy has been above trend, and vice versa. These implications have a certain intuitive appeal, and various theories of real wages might be consistent with such ouitcomes.

**C.4** By way of comparison, a brief examination of international evidence on the behaviour of the labour share suggests that the UK relationship between the labour share and the cycle does not seem to be shared in other countries, though international variations in wage and price flexibility mean there should be no presumption that it would. Conducting the same sort of analysis for the US, France, Germany and Italy, and using output gaps taken from the OECD (calculated using a production function approach), fails to show any evidence of a similar mapping between on-trend points and turning points in the labour share (here defined relative to nominal GDP rather than GVA) for the mainland European economies. The US evidence looks more like that for the UK, but it is weaker. This suggestion that the relationship is by no means commonplace across countries further underlines the need for more in-depth examination of the issue.

**C.5** The simplest way of formalising this empirical regularity is to use the following model:

$$\Delta s(t) = \alpha + \theta \, ygap(t) + \varepsilon(t) \qquad \ldots(i)$$

where s denotes the labour share (log), ygap denotes the output gap (%), $\varepsilon$ is a white noise error term, and $\Delta$ denotes the first difference. In addition to the features of the empirical evidence already noted, equation (i) also implies that:

- The rate of change of the share is at its maximum at the top of the cycle (when the output gap is most positive), and at its minimum at the bottom of the cycle (when the output gap is most negative).

- The share would only stabilise at its equilibrium value if the economy had experienced a sustained run of being on-trend.

Nevertheless it needs to be recognised that the functional form (i) has been selected only on the basis of being consistent with the relationship between the series at turning points of the labour share, and there should be no presumption that it does a good job of representing the relationship between turning points.

**C.6** Estimating equation (i) by Ordinary Least Squares using data over periods since 1966 (the date which Treasury output gap estimates extend back to) gives statistically significant estimates of the parameter $\theta$, with t statistics of around 2 (rising as the data period is shortened by dropping the earlier years when the output gap estimates are less soundly based). For example:

$\Delta s(t) = 0.0002 + 0.0006\ ygap(t)$

Estimation period: 1997Q1 to 2004Q4

Standard error = 0.9%;

This relationship leaves a lot of the variation in the change in labour share unaccounted for, consistent with the functional form not serving well between turning points in the labour share. However, the statistical significance of the estimated parameter $\theta$ confirms the relationship identified in chart 4.4.

**C.7** On this basis it would appear worthwhile further to explore the form of relationship (i), especially as it is not necessarily what might have been expected on the basis of standard theory.

**C.8** In particular it is natural to investigate what theory of wage and price setting behaviour might underlie the consistent empirical relationship between the change in labour share and the level of the output gap. Economic theory would often tend to suggest that the level of the labour share, rather than its rate of change, should be related to the level of the output gap. Indeed modern macroeconomic theory, and in particular the New Keynesian Phillips Curve literature, while suggesting that the labour share may be a conceptually better indicator of inflationary pressure than the output gap, has under certain assumptions tended to point to a linear mapping between the levels of the share and the gap (eg Gali and Gertler (2000)).

**C.9** The standard Layard-Nickell (1991) accelerationist Phillips curve model makes assumptions that imply a levels relationship between the labour share and the output gap (as often also assumed in the New Keynesian Phillips Curve literature). This can be illustrated using the simplest form of the theory:

Price setting: $p - w^e = -\pi + \beta_0 - \beta_1 u$

Wage setting: $w - p^e = \pi + \gamma_0 - y_1 u$

where p denotes (log) prices, w denotes (log) wages, $\pi$ denotes (log) productivity, u denotes the unemployment rate, and superscript e denotes expectations. These equations can be rewritten in terms of the (log) labour share, denoted s, given that $s = w - p - \pi$, so:

Price setting: $s = -\beta_0 + \beta_1 u + (w - w^e)$ …(ii)

Wage setting: $s = \gamma_0 - \gamma_1 u - (p - p^e)$ …(iii)

**C.10** If wages and prices are in line with expectations ($w=w^e$, $p=p^e$) then equilibrium unemployment (u*) is derived by subtracting (ii) and (iii) to get:

$$u^* = (\beta_0 + \gamma_0)/(\beta_1 + \gamma_1) \qquad \ldots(iv)$$

Also by subtracting (ii) and (iii) in disequilibrium:

$$-(\beta_1 + \gamma_1)(u - u^*) = (w - w^e) + (p - p^e) \qquad \ldots(v)$$

This describes the evolution of prices and wages when unemployment is away from equilibrium, showing the dependence on inflation expectations.

**C.11** An expression for the evolution of the labour share relative to its equilibrium value (s*) can be similarly derived by adding (iii) and (iv) and rearranging to get:

$$(s - s^*) = (\beta_1 - \gamma_1)(u - u^*)/2 + \{(w - w^e) - (p - p^e)\}/2$$

A simple linear mapping between the unemployment gap (u-u*) and the output gap then gives:

$$(s - s^*) = (\gamma_1 - \beta_1)\lambda ygap + \{(w - w^e) - (p - p^e)\}/2 \qquad \ldots(vi)$$

**C.12** This establishes that Layard and Nickell's theoretical derivation of the Phillips curve necessarily implies a linear levels relationship between the labour share and the output gap, because their derivation involves assuming wage and price surprises ($w-w^e$ and $p-p^e$ respectively) are equal.

**C.13** Conversely, wage and price surprises out of equilibrium must be unequal for this theory to be consistent with the empirical evidence of a systematic linear relationship between the rate of change of the share and the output gap. In particular the real wage expectations surprise ($rw-rw^e=w-p-w^e+p^e$) would need to move with the cycle in such a way that equation (vi) is consistent with a relationship (of the form $\Delta$ s= $\theta$ ygap) whereby the labour share peaks (troughs) as the economy passes down (up) through trend. An expression for the real wage surprise that fits this bill can be readily backed out from equation (vi). Taking first differences:

$$\Delta s = (\gamma_1 - \beta_1)\lambda\Delta ygap + \Delta(rw - rw^e)/2$$

So if the change in the real wage surprise conforms to:

$$\Delta(rw - rw^e) = 2\theta ygap - 2(\gamma_1 - \beta_1)\lambda\Delta ygap \qquad \ldots(vii)$$

then $\Delta s = \theta ygap$ as required.

**C.14** Further rearrangement of these equations (noting $\Delta s=\Delta rw-\Delta\pi$) also shows that real wage growth expectations would have to comply with:

$$\Delta rw^e = \Delta\pi - \theta ygap + 2(\gamma_1 - \beta_1)\lambda\Delta ygap \qquad \ldots(viii)$$

**C.15** Thus generally the implications of these equations for the behaviour of real wage growth expectations and surprises will depend on the relative responsiveness of prices and wages to the stage of the cycle i.e. the parameters $\beta_1$ and $\gamma_1$ of the price and wage setting equations. However, if these parameters were roughly equal then equation (viii) would be consistent with:

- Real wages growing faster than expected when the economy is above trend, to an extent proportional to the size of the output gap;
- Real wages growing slower than expected when the economy is below trend;

- Real wages growing in line with expectations when the economy is on-trend.
- Real wage levels in line with expectations at the bottom and top of the cycle (ie when the output gap is at its widest).

**C.16** The implied sequence through the cycle is further illustrated in table B.1.

## Table C1: Sequence of real wage growth through the cycle

| On-Trend point | Below trend downswing | Bottom of cycle | Below trend upswing | On-trend point | Above trend upswing | Top of cycle | Above trend downswing | On-trend point |
|---|---|---|---|---|---|---|---|---|
| $\Delta rw=\Delta rw^e$ | Real wage growth falls short of expectation by a widening margin | $rw=rw^e$ | Real wage growth falls short of expectations by a narrowing margin | $\Delta rw=\Delta rw^e$ | Real wage growth exceeds expectations by a widening margin | $rw=rw^e$ | Real wage growth exceeds expectations by a narrowing margin | $\Delta rw=\Delta rw^e$ |

**C.17** Furthermore, the corresponding cycle for real wage growth expectations would be given by:

$$\Delta rw^e = \Delta\pi - \theta ygap \qquad \ldots(ix)$$

This means:

- Real wage growth expectations in line with productivity growth when the economy is on-trend:
- Real wage growth expectations falling short of productivity growth when the economy is above trend (to the most extent at the top of the cycle), and exceeding productivity growth when the economy is below trend (to the most extent at the bottom of the cycle).

**C.18** Moreover, the labour share relationship (i) implies that actual real wage growth is given by:

$$\Delta rw = \Delta\pi + \theta ygap \qquad \ldots(x)$$

So (ix) and (x) together mean that actual and expected real wage growth deviate from productivity growth by the same amount ($\theta$ ygap) but in opposite directions through the cycle.

**C.19** These conditions would seem to raise questions about the implied theory of the formation of real wage expectations. Indeed it is not easy to rationalise why actual and expected real wage growth should move in different directions relative to productivity growth when the economy is away from trend, though this could just be a symptom of the overly simplified model used for illustration. However, the implications in terms of real wage growth surprises (ie the difference between the actual and expected as in equation (vii)), consistent with the notion that actual real wage growth should exceed expectations when the economy is above trend, and vice versa, are more plausible. Nevertheless the framing of real wage expectations and surprises in terms of rates of change rather than levels raises conceptual issues, such as why real wage levels misalignments might be expected to persist.

**C.20** The theory underpinning the observed empirical regularity would therefore appear to warrant further exploration.

# Bibliography

Artis, M.J. (2003), 'Analysis of European and UK business cycles and shocks', *HM Treasury EMU study.*

Artis, M.J., Kontolemis, Z. and Osborn, D. (1997), 'Business cycles for G7 and European countries', *Journal of Business*, 70:2, April, pp. 249-279.

Baxter, A. and King, R. (1995), 'Measuring business cycles: approximate band-pass filters for economic time series', *NBER Working Paper 5022*.

Beveridge, S. and Nelson, C.R. (1981), 'A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the "Business Cycle', *Journal of Monetary Economics*, 7, pp151-74.

Blackaby, F.T. (ed) (1978), 'British Economic Policy 1960-74', NIESR, Cambridge University Press.

Blanchard, O. and Quah, D. (1989), 'The dynamic effects of aggregate demand and supply disturbances,' *American Economic Review* 79, September, pp. 655-673.

Blanchard, O. J. and Fischer, S. (1989), 'Lectures in Macroeconomics', MIT Press.

Blinder, A.S. and Fischer, S. (1981), 'Inventories, rational expectations and the business cycle', *Journal of Monetary Economics*, 8.

Bordo, M.D. and Helbling, T. (2003), 'Have national business cycles become more synchronized?', *NBER working paper No. 10130*.

Bry, G. and Boschan, C. "Cyclical analysis of time series: selected procedures and computer programs", NBER, 1981.

Burns, A.F. and Mitchell, W.C. (1946), 'Measuring business cycles', NBER.

Chari, V.V., Kehoe P. and McGrattan, E. (2005), 'A critique of structural VARs using real business cycle theory', *Federal Reserve Bank of Minneapolis* working paper 631, February.

Claus, I. (1999), 'Estimating potential output for New Zealand: a structural VAR approach', *Reserve Bank of New Zealand Discussion Paper series*, July, 2000/03.

Dow, J.C.R. (1964), 'The Management of the British Economy 1945-60', NIESR (pp 112-116).

Doyle, B. and Faust, J. (2002), 'An investigation of co-movements among growth rates of the G7 countries', *Federal Reserve Bulletin*, pp. 427-437.

Dupasquier, C, Guay, A. and P. St-Amant (1997), 'A comparison of alternative methodologies for estimating potential output and the output gap,' *Bank of Canada working paper*, February, May.

Gali, J. and Gertler, M. (2000), 'Inflation Dynamics: A Structural Econometric Analysis', *NBER Working Paper* 7551.

Goldman Sachs (2004), 'A Higher Speed Limit for Growth', *UK Economic Analyst,* No. 04/07, October.

Harding, D. and Pagan, A. (2001), 'Extracting, Analysing and Using Cyclical Information', *mimeo*, University of Melbourne.

Harding, D. and Pagan, A. (2004), 'A suggested framework for classifying the modes of cycle research', *CAMA Working Paper No. 5/2004, July*.

Harvey, A.C. and Jaeger, A. (1993), 'Detrending, stylised facts and the business cycle', *Journal of Applied Econometrics,* 8, pp. 231-247.

Helbling, T. and Beyoumi, T. (2003), 'Are they all in the same boat? The 2000-2001 growth slowdown and the G7 business cycle linkages', *IMF Working Paper WP/03/46*.

HM Treasury (1995), 'Public Finances and the Cycle', Martin Hurst and Simon Virley, Treasury Occasional Paper No 4.

HM Treasury (1999a), 'Trend growth: prospects and implications for policy'.

HM Treasury (1999b) 'Fiscal Policy: Public Finances and the Cycle'.

HM Treasury (2002), 'Trend growth: recent developments and prospects'.

HM Treasury (2005), 'Budget 2005'. HC 372, Box B1, page 223.

Hodrick, R. and Prescott, E. (1980), 'Postwar US business cycles: an empirical investigation', Carnegie-Mellon University, *discussion paper* No.451; re-printed in: *Journal of Money, Credit and Banking,* 1997, 29, pp. 1-16.

Hurst, M. and Virley, S. (1995), 'Public Finances and the Cycle', *Treasury Occasional Paper No 4*, September 1995.

IMF World Economic Outlook (2002), 'Recessions and recoveries'.

Italian Ministry of Economy and Finance (2003),'The Statistical Reliability of the Output Gap estimates: a comparative assessment of the Production Function and the Hodrick Prescott approaches'.

King, R. and Rebelo, T. (1993) 'Low frequency filtering and real business cycles', Journal of Economic Dynamics and Control, Vol 17, no.1, pp 207-231.

Krolzig, H.-M. and Toro, J. (2001), 'Classical and modern business cycle measurement: the European case', University of Oxford, *Discussion Papers in Economics*, 60.

Kose, M. et al (2003), 'Volatility and comovement in a globalized world economy: An empirical exploration', *IMF Working Paper WP/03/246*.

Layard, R., Nickell, S. and Jackman, R. (1991), 'Unemployment: Macroeconomic Performance and the Labour Market', Oxford University Press.

Lippi, M. and Reichlin, L. (1994), 'Diffusion of technical change and the decomposition of output into trend and cycle', *Review of Economic Studies*, 61, 19-30.

Morley, J., Nelson, C. and Zivot, E. (2003), "Why are the Beveridge-Nelson and unobserved-components decompositions of GDP so different?" Review of Economics and Statistics 85, pp235-243.

Nelson, E. and Nikolov, K. (2001), 'UK inflation in the 1970s and 1980s: the role of output gap mis-measurement', *Bank of England Working Paper No. 148*.

OECD. (2002), 'Economic Outlook'.

OECD. (2005), 'Economic Outlook'.

Rennison, A. (2003), 'Comparing alternative output-gap estimators: a Monte Carlo approach,' *Bank of Canada working paper*, March, 2003-8.

Report on BoI/CEPR research project (2001) 'A real time coincident indicator of the euro area business cycle', August 2001.

Treasury Committee (2005), 'Report on the 2004 Pre-Budget Report', HC138.

Wickens, M. (1995), 'Trend extraction: a practitioners' guide', *Treasury Working Paper No. 67*.