Dealing with data uncertainty

By James Ashley, Ronnie Driver, Simon Hayes and Christopher Jeffery of the Bank's Conjunctural Assessment and Projections Division.

True values of key macroeconomic variables are unobservable and can only be estimated. A key question for the Monetary Policy Committee is how best to take account of the resultant uncertainty in its economic assessment. Official estimates of economic variables are produced by the Office for National Statistics (ONS), and some private sector organisations publish surveys of business activity that may also give clues as to the underlying state of the economy. This article presents a simple methodology for deriving 'best guesses' of the true values of economic variables by weighting together official estimates and information from business surveys.

In all walks of life, the future is uncertain. But in macroeconomics, the present and past are uncertain too. True values of key macroeconomic variables — for example, GDP — are unobservable. Although the Office for National Statistics (ONS) produces official estimates of such variables, these are derived from surveys and so can only ever be an approximate guide to the true underlying economic state. Of course, as time passes, new information is received and improved methods for estimation are devised and implemented. This gives rise to revisions that are likely to move estimates progressively closer to the unobserved truth. But regardless of their maturity, estimates always contain sampling error. So uncertainty about the past and current behaviour of the economy is a fact of life for policymakers.(1)

A key question for the Monetary Policy Committee is how best to take account of this uncertainty when assessing the state of the economy. This article sets out a simple methodology for deriving 'best guesses' of the true values of economic variables on the basis of a set of imperfect (or 'noisy') indicators of the underlying economic state. It also shows the extent to which this best-guess methodology may mitigate uncertainty about the unobservable truth.(2)

The challenges of dealing with data uncertainty

The primary source of UK macroeconomic data is the ONS, which produces, among other things, the quarterly UK National Accounts and an array of monthly economic indicators such as the Index of Production and the Retail Sales Index. These statistics are produced on the basis of comprehensive surveys of firms and households, with samples that are designed to mimic the pattern of economic activity across the United Kingdom as a whole. For example, the ONS's Monthly Inquiry into the Distribution and Service Sector, from which estimates of service sector output are derived, is sent to nearly 30,000 firms, accounting for around 60% of service sector turnover. All firms with more than 250 employees are included in the sample, while a representative sample of smaller firms is chosen using sophisticated sampling techniques. The response rate is around 80%. This comprehensiveness makes the official data the authoritative guide to UK economic developments.

Monetary policy decisions are made every month, and need to be informed by the best available assessment of economic activity. As a consequence, timely economic data — that is, data that are released soon after the period to which they refer — are of particular value to the MPC. To meet such demands, the ONS publishes early ('preliminary') estimates of key economic aggregates, derived from a subset of survey responses. These estimates will inevitably be revised as more information is received and processed. The trade-off between timeliness and accuracy is inescapable, and one of which policymakers are fully aware. The challenge for

(1) The issue of data uncertainty and policymaking was the subject of three recent speeches by MPC members: see Bean (2005), Bell (2004) and Lomax (2004).
(2) This article focuses on the issue of mitigating the effects of data uncertainty in conjunctural economic assessment. Harrison, Kapetanios and Yates (2004) and Busetti (2001) analyse the implications of data uncertainty for forecasting.

the MPC is to devise procedures that take proper account of the resultant uncertainty. And it is here that other sources of information on economic activity may have a role.

Although the ONS is the primary source of macroeconomic data for the United Kingdom, it is not the only source. For example, several business organisations publish surveys that provide indications of output growth, costs and prices for particular industrial sectors. The main strength of the business surveys is their timeliness — they are available some weeks before the first official estimates of key activity variables. Survey providers are able to process responses quickly because they sample a relatively small number of firms (generally in the region of 500 to 1,000)(1) and they ask simple qualitative questions (eg has your output risen, fallen or been unchanged?).(2)

The simplicity of business surveys, however, gives rise to their main deficiencies. First, small sample sizes mean that respondents' experiences may not accord with those of the sector as a whole. Second, the qualitative information gathered by such surveys may give an inaccurate guide to actual changes in output, since the relationship between the (net) number of firms reporting higher output, for example, and the change in output across all firms can at times be quite weak.(3) Furthermore, some business surveys' samples are chosen purely on the basis of membership of a particular organisation, and so could be unrepresentative of the UK economy.

Notwithstanding these deficiencies, however, the information provided by business surveys may usefully augment that in official estimates, particularly at the earlier stages of the ONS's data production cycle. It is sensible, therefore, to establish methodologies for weighing up the information content of the business surveys relative to the official data.

The remainder of the article presents a method for constructing 'best guesses' of services and manufacturing output, using combinations of official estimates and business surveys. The analysis is split into four sections. First, we discuss characteristics of official data and revisions, with a particular focus on estimates of services and manufacturing output growth. Second, we study the performance of the main business surveys of the services and manufacturing sectors, and construct a 'best' survey-based estimate (SBE). Third, we calculate an overall best guess by assigning relative weights to the official data and the SBE, and show the extent to which this best-guess approach mitigates the uncertainty surrounding early official estimates of economic activity.(4) The final section concludes.

Revisions performance of official estimates

The ONS's own research has established that early official estimates of some key macroeconomic variables have in the past displayed systematic biases. For example, Akritidis (2003) showed that the average total revision to quarterly GDP growth between the first estimates and the latest estimates over the sample period 1993 Q1 to 1999 Q4 was 0.19 percentage points.(5) Does this mean that when an early estimate is observed it is sensible simply to adjust the published figure by the historical bias? To answer that question we need to look in more detail at the revisions process.

As mentioned above, the ONS produces early estimates of certain key macroeconomic data based on incomplete samples. These estimates then tend to be revised in a sequence of publications, each of which incorporates more information than the previous release. For example, GDP growth estimates are published first as preliminary estimates and are subsequently revised over the next two months in the Output, Income and Expenditure, and National Accounts GDP releases. Once a year the ONS produces the *Blue Book*, which reviews and further revises previous data. At this point, some of the information derived from high-frequency surveys is replaced by more accurate and comprehensive information from large-scale annual surveys. Around one year later, the quality of GDP

(1) The *British Chambers of Commerce Quarterly Survey* is somewhat larger, covering around 4,000 service sector companies and around 2,000 manufacturers.
(2) The Bank's use of business survey data has previously been discussed in Britton, Cutler and Wardlow (1999) and Cunningham (1997).
(3) This can be a particular problem when sub-sectors of an industry are experiencing substantial movements in output compared with the rest of the sector. For example, ONS data indicate that falling output in the information, communications and technology (ICT) sector accounted for much of the decline in manufacturing production between 2001 and 2002. However, the dip in the manufacturing survey balances in this period was much less pronounced, consistent with the qualitative nature of the surveys, which meant that ICT firms could record only that their output had fallen and were unable to report the marked degree of the falls they had experienced.
(4) The methodology presented in this article allows us to track the speed with which ONS estimates converge on 'the truth', but not the absolute degree of measurement error in ONS data relative to the unobservable true data. Kapetanios and Yates (2004) present a method for calculating the latter.
(5) Patterns in GDP revisions are also analysed by, among others, Castle and Ellis (2002) and Richardson (2002, 2003).

estimates is improved further by aligning the information gathered on aggregate output, expenditure and income — the 'balancing' process. When a given data point has been put through two sets of *Blue Book* revisions (known as the '*Blue Book* 2 stage'), it is said to be fully balanced.

In the analysis that follows, we use mature official data — defined as data that have undergone at least two sets of *Blue Book* revisions — as a proxy for the unobservable true data. In other words, we assume that mature official data differ from the unobservable true data only by a random error.

Throughout this data production process, the incorporation of new information may generate revisions to previous estimates. But in addition to these information-based revisions, official estimates may be revised because of methodological developments. For example, in the 2004 *Blue Book* the ONS incorporated improved estimates of health output in the public sector, which led to upward revisions to GDP growth in a number of years.

Information-based biases — that is, systematic patterns in revisions as new information is incorporated — may reflect biases inherent in the data collection process. For example, if there is a relationship between firm size and the speed and accuracy with which firms respond to the ONS survey, a systematic pattern in revisions may be apparent. It therefore seems sensible to take this bias into account when forming a best guess of mature official data on the basis of early estimates. In contrast, we are more wary of carrying forward any significant biases in historical data that are attributable to methodological developments. Given the one-off nature of most methodological changes, the average of past effects of methodological change may not be a useful guide to the impact of future methodological developments.

In practice, the revisions process is complex, and there are occasions when information-based revisions and methodology-based revisions interact. To identify the two, therefore, we rely on a simple rule of thumb, which is that those revisions up to and including a given estimate's second *Blue Book* reflect information-based revisions, while revisions thereafter reflect changes in methodology.(1)

As an indication of the extent of information-based bias, Charts 1 and 2 show the relationships between the ONS's first estimates of quarterly services and manufacturing output growth and their corresponding *Blue Book* 2 estimates.(2)(3) The 45° line shows the locus of points along which the first estimates of growth are equal to the estimates at the *Blue Book* 2 stage, while the

Chart 1
Estimated information-based revisions to quarterly services output growth (1993 Q1–2002 Q4)

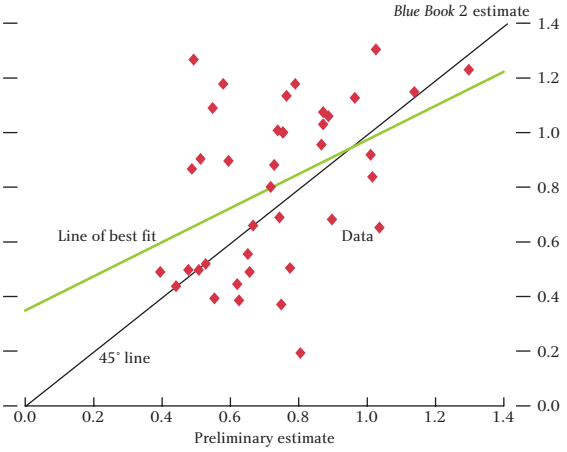
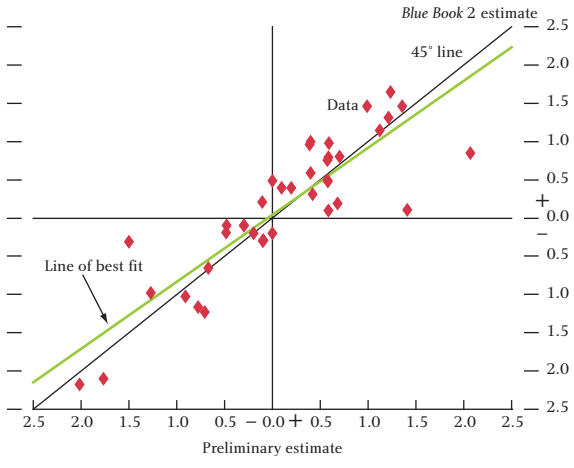


Chart 2
Estimated information-based revisions to quarterly manufacturing output growth (1993 Q1–2002 Q4)



(1) Using the same criterion, Akritidis observes that around half of the bias in estimates of overall GDP growth appears to be due to information-based revisions, and around half due to methodological change.
(2) Prior to this year no explicit estimate of manufacturing output growth was published in the Preliminary GDP release, although estimates for the first two months of the quarter were contained in the monthly Index of Production (IoP) release. We have therefore proxied the preliminary manufacturing estimates with the two months' data from the IoP augmented by an in-house forecast of the third month.
(3) 1993 Q1 is taken as the starting point for the analysis as that was the time that the Preliminary GDP estimate was first published one month after the end of the reference quarter, making way for the Output, Income and Expenditure release in the second month after the reference quarter. The final data point is 2002 Q4 because the subsequent data have not been through two *Blue Books*, and we consider these to be insufficiently mature for this aspect of our analysis.

green line is the least squares line of best fit. Any significant divergence of the line of best fit from the 45° line indicates the presence of a systematic pattern in revisions between the preliminary release and the *Blue Book* 2 estimate.

Chart 1 suggests that revisions to early estimates of service sector output vary systematically with the level of the initial estimate: higher preliminary estimates tend to be revised down, while lower preliminary estimates tend to be revised up. Statistical analysis confirms that this pattern is statistically significant. However, as suggested by Chart 2, there is little pattern in revisions to the first estimates of manufacturing output growth. Indeed, the line of best fit is not statistically distinguishable from the 45° line.(1)

Estimates derived from business surveys

In this section we look at the relationship between mature official estimates and the activity and orders balances of the main business surveys for the services and manufacturing sectors. We then explain how we arrive at 'optimal' survey-based estimates for services and manufacturing output growth.

The surveys we analyse here are: the *Report on Services* and the *Report on Manufacturing* produced by the Chartered Institute of Purchasing and Supply (CIPS); the *Quarterly Survey* produced by the British Chambers of Commerce (BCC); the *Quarterly Industrial Trends* survey, produced by the Confederation of British Industry (CBI); and the *CBI/Grant Thornton Services* survey. The relatively good sample design, coverage and timeliness of these surveys means that they often form an important input into the MPC's economic assessment. In practice, the focus on these surveys is by no means exclusive — the MPC's analysis is informed by an array of other surveys and indicators, including reports from the Bank's regional Agents — but the following analysis provides a good illustration of how such information is assessed and used.

Table A shows the correlations between the survey balances and mature official data.(2)(3) For both the CIPS and the BCC services surveys, lagged activity balances are better indicators of output growth than contemporaneous balances. This seems counterintuitive. But service sector output is difficult to define and measure, and so this relationship may reflect differences in the way that survey respondents classify output when responding to business surveys and the way the ONS defines and measures services output. As expected, lagged orders balances perform better than contemporaneous orders. For manufacturing, the contemporaneous activity balances correlate better with the official data than lagged activity, but the empirical distinction between contemporaneous and lagged orders is rather less apparent than it is for services.

Table A
Correlations between the surveys and mature official data — 1993 Q1–2002 Q4

	Contemporaneous activity	Once lagged activity	Contemporaneous orders	Once lagged orders
CIPS services	0.17	0.43	0.07	0.35
BCC services	0.18	0.41	0.09	0.36
CBI services	0.28	0.22	0.16	0.25
CIPS manufacturing	0.54	0.43	0.49	0.44
BCC manufacturing	0.41	0.35	0.48	0.39
CBI quarterly industrial trends	0.40	0.26	0.36	0.27

We have used these individual survey balances to derive a single 'best' model that transforms the survey information into a best guess of the unobservable true data.(4) The survey balances are generally highly correlated with each other, so in practice there is little to choose between them. However, out-of-sample tests indicated that, for both the services and manufacturing output, the most robust models include solely the corresponding CIPS surveys' activity balance. This is not to say that the other survey information should be discarded — it can still provide valuable corroborative evidence if the signals from early official estimates and the CIPS surveys diverge. But it is not included in the baseline best guess described here.

(1) Nonetheless, we use the line of best fit in Chart 2 to adjust preliminary estimates of manufacturing output growth, since this constitutes our best point estimate of the appropriate adjustment.
(2) Responses to business surveys are usually summarised by diffusion indices or net percentage balances. For example, the CIPS surveys report a diffusion index in which a value of 50 corresponds to no change in the relevant variable compared with the previous period. Values above 50 indicate positive growth, while values below 50 indicate falls. The BCC and CBI surveys report net percentage balances, which take a positive value when the net balance of respondents report positive growth, and a negative value for negative growth.
(3) The CIPS services survey only started in 1996, and the CBI services survey is available only from 1998. We have therefore proxied earlier data for these series using the BCC services balances. However, the qualitative results reported in Table A are unchanged if the period from 1998 is used.
(4) This is done by way of a simple OLS regression of the mature official data on the survey balances.

Constructing a weighted best guess

The preceding sections have shown how we obtain two separate 'best guesses' of manufacturing and services output growth: one that uses the lines of best fit as in Charts 1 and 2 to adust early official estimates (the 'ONS-based best guess'); and one based on business survey balances (the SBE). In this section we show how these forecasts are combined to obtain an overall best guess. We also illustrate the benefits from using this forecast combination methodology in helping to reduce the uncertainty around early official estimates of output growth.

The two separate best guesses are combined using the Bates and Granger (1969) 'variance-covariance' approach to forecast combination. The weight given to each indicator is estimated on the basis of a simple OLS regression of the mature official data (our proxy for the unobservable truth) on the two forecasts, including a constant (see Granger and Ramanathan (1984)).(1) The weights are constrained to be non-negative and to sum to unity. Denoting the mature official data in quarter t as O_t, the ONS-based best guess as ONS_t and the *SBE* as S_t, the following regression is run:

$$O_t - ONS_t = \text{constant} + \alpha(S_t - ONS_t) + \text{error} \qquad \textbf{(1)}$$

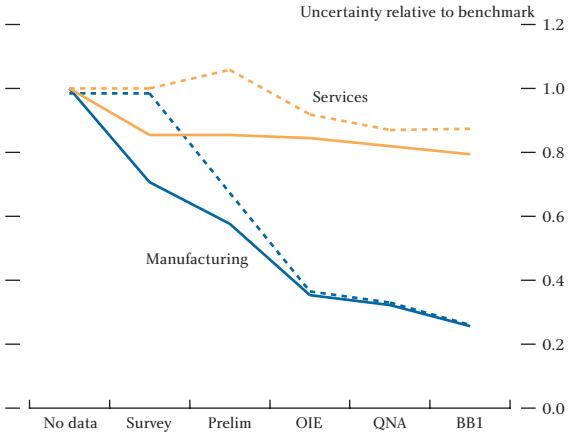
The overall best guess (BG_t) is calculated by applying the estimated weights $1-\hat{\alpha}$ and $\hat{\alpha}$ to the ONS-based best guess and the SBE respectively:

$$BG_t = (1-\hat{\alpha})\, ONS_t + \hat{\alpha}\, S_t \qquad \textbf{(2)}$$

This exercise is repeated for each step in the GDP data cycle — so weights are estimated using ONS-based best guesses at the Preliminary; Output, Income and Expenditure; Quarterly National Accounts; and *Blue Book* 1 stages.

Having devised a methodology for constructing a best guess through forecast combination, a natural question is what benefit is gained by using this best guess rather than simply taking early official estimates at face value? This is illustrated in Chart 3, which shows how uncertainty about the unobservable true growth rate in a given quarter changes as more data become available. The horizontal axis on the chart denotes stages in the data cycle. The left-hand-most point marks the stage at which there are no hard data available for a given quarter. At the next point only business survey data are available. Subsequent points mark the sequential publication of more mature official estimates.

Chart 3
Uncertainty through the data cycle



Notes: The x-axis labels refer to different stages in the data cycle. 'Survey' refers to the point at which only survey data are available. The next four labels refer to the points at which successive ONS data releases are also available: Preliminary (Prelim); Output, Income and Expenditure (OIE); Quarterly National Accounts (QNA); first *Blue Book* (BB1).

The vertical axis shows the level of uncertainty surrounding best guesses derived from any given methodology. As a benchmark, a value of unity corresponds to the variance of mature data outturns. This corresponds to the uncertainty associated with a 'naive' methodology in which the best guess at each point in time is simply set equal to the historical mean of the series. The solid lines show uncertainty at each point in the data cycle under the weighted best-guess methodology presented above: they plot the variance of mature data outturns around the weighted best guesses, as a proportion of benchmark uncertainty. By way of comparison, the dashed lines show how uncertainty evolves (again as a proportion of benchmark uncertainty) if the business survey balances are ignored and the best guess is taken to be the official estimates at each point in the data cycle.

In terms of the weighted best guesses (the solid lines), moving from the point at which no data are available to having the business surveys reduces uncertainty by around 15% in the case of services output growth and around 30% in the case of manufacturing. Uncertainty about services output growth declines only gradually thereafter, indicating that the official data provide

(1) The constant in equation **(1)** will pick up any bias in official estimates at the *Blue Book* 2 stage relative to the mature data. As discussed earlier, we associate this bias with past methodological change and do not wish to carry it forward in our best guess. Hence the constant is absent from equation **(2)**.

relatively limited additional information once the business surveys have been taken on board. The fact that the solid orange line always lies below the dashed orange line shows that accounting for the information content of the business surveys leads to a persistent reduction in uncertainty relative to relying solely on official estimates. In contrast, although the benefit from using the business surveys for manufacturing output growth is initially larger than that for services, the dashed blue line converges with the solid blue line at the Output, Income and Expenditure release. This indicates that the value of the business surveys over and above the official data from this point onwards is negligible.

It is important to recognise that the weighted best guesses derived from equation **(2)** provide only baseline best guesses that are not used in a mechanical way. In particular, the relatively small sample size (40 observations) means that the estimated weights underlying the best guesses are subject to considerable statistical uncertainty and meaningful out-of-sample testing has not been possible. Moreover, the weights will depend on each indicator's average ability to predict mature official data in the past. But at any given point in time supplementary information may suggest that the 'average of the past' is an inappropriate basis for current assessment. For example, on some occasions survey response rates may be unusually low, suggesting that the resultant estimate contains greater sampling uncertainty than normal.(1) In addition, non-quantitative information such as reports from the Bank's regional Agents is also brought to bear on the MPC's analysis. Ultimately, economic assessment is a matter of judgement.

Related to the above, ongoing ONS initiatives to improve the quality of official statistics may over time lead to increasing weight being given to official estimates throughout the data cycle. In particular, the ONS is at the forefront of international efforts to develop better measures of service sector output including better short-term output indicators. Indeed, within the OECD only the United Kingdom and Korea produce a monthly Index of Services, the service sector equivalent of the monthly Index of Production for the industrial sector.(2)(3) To the extent that this work leads to improvements in the quality of service sector output indicators, we may expect to see the two orange lines in Chart 3 fall, and the gap between them narrow.

Concluding remarks and future work

Data uncertainty can be mitigated to a degree by bringing a wider array of information to bear on economic assessment than relying solely on early official data estimates. However, the practical implementation of techniques to reduce the effects of data uncertainty requires assumptions to be made about the nature of that uncertainty. This article has set out a simple method for combining information from business surveys with early official estimates, on the assumption that the true underlying data differ from mature official estimates only by a random error.

Other statistical techniques could be employed to address this issue. One popular approach invokes the Kalman Filter. Observable data are assumed to provide noisy signals of the true unobservable data, and the aim is to filter out the noise to give the best possible indication of the underlying signal. Given an assumption regarding how the unobservable true data evolve over time, the Kalman Filter can be used to obtain a statistically optimal estimate of the true data series. Another promising area of ongoing research involves so-called 'dynamic factor models', in which each economic variable is assumed to be driven by a small number of shocks that are common to all variables, plus an idiosyncratic component. All available data are used in the estimation of the common shocks, and variables are simultaneously decomposed into their 'common' and 'idiosyncratic' components.(4) But in both of these cases, more work is needed to determine whether the underlying assumptions make them suitable for real-time policy assessment, and this is the focus of current research by Bank staff.

(1) For example, when the ONS published the Preliminary estimate of GDP growth for 2004 Q1 it noted that the proximity of its data collection to Easter had resulted in it having received significantly fewer survey responses than normal from its Monthly Inquiry into the Distribution and Service Sector, and that the estimates should therefore be treated with a greater-than-normal degree of caution.
(2) The ONS's Index of Services is currently produced on an 'experimental' basis — that is, it is not yet a fully fledged National Statistic. Drew (2003) provides a statement of the ONS's progress and plans in its construction.
(3) See McKenzie (2004).
(4) See, for example, Altissimo *et al* (2001).

References

Akritidis, L (2003), 'Revisions to quarterly GDP growth', *Economic Trends*, ONS, December.

Altissimo, F, Bassanetti, A, Cristadoro, R, Forni, M, Lippi, M, Reichlin, L and Veronese, G (2001), 'Eurocoin: a real time coincident indicator of the euro area business cycle', *CEPR Discussion Paper 3108*.

Bates, J M and Granger, C W J (1969), 'The combination of forecasts', *Operational Research Quarterly*, Vol. 20, No. 4, pages 451–68.

Bean, C (2005), 'Monetary policy in an uncertain world', *Bank of England Quarterly Bulletin*, Spring, pages 80–91.

Bell, M (2004), 'Monetary policy data uncertainty and the supply side: living with the statistical fog', *Bank of England Quarterly Bulletin*, Winter, pages 510–21.

Britton, E, Cutler, J and Wardlow, A (1999), 'The Bank's use of survey data', *Bank of England Quarterly Bulletin*, May, pages 177–82.

Busetti, F (2001), 'The use of preliminary data in econometric forecasting: an application with the Bank of Italy quarterly model', *Bank of Italy Discussion Paper no. 437*.

Castle, J and Ellis, C (2002), 'Building a real-time database for GDP(E)', *Bank of England Quarterly Bulletin*, Spring, pages 42–49.

Cunningham, A (1997), 'Quantifying survey data', *Bank of England Quarterly Bulletin*, Autumn, pages 292–300.

Drew, S (2003), 'Experimental monthly index of services — an update', *Economic Trends*, ONS, October.

Granger, C W J and Ramanathan, R (1984), 'Improved methods of combining forecasts', *Journal of Forecasting*, Vol. 3, pages 197–204.

Harrison, R, Kapetanios, G and Yates, T (2004), 'Forecasting with measurement errors in dynamic models', *Bank of England Working Paper no. 237*.

Kapetanios, G and Yates, T (2004), 'Estimating time-variation in measurement error from data revisions; an application to forecasting in dynamic models', *Bank of England Working Paper no. 238*.

Lomax, R (2004), 'Stability and statistics', *Bank of England Quarterly Bulletin*, Winter, pages 495–501.

McKenzie, R (2004), 'Development of an OECD Index of Services Production Manual', paper for the Conference of European Statisticians 52nd plenary session. Available at www.unece.org/stats/documents/ces/2004/19.rev.1.e.pdf.

Richardson, C (2002), 'Revisions to GDP: a time profile', *Economic Trends*, No. 584, ONS, July.

Richardson, C (2003), 'Revisions analysis: a time series approach', *Economic Trends*, No. 601, ONS, December.