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MEASURING CORE INFLATION*

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In this paper, we argue that measured (RPI) inflation is conceptually mismatched with core inflation: the difference is more than just 'measurement error'. We propose a technique for measuring core inflation, based on an explicit long-run economic hypothesis. Core inflation is defined as that component of measured inflation that has no (medium- to) long-run impact on real output – a notion that is consistent with the vertical long-run Phillips curve interpretation of the comovements in inflation and output. We construct a measure of core inflation by placing dynamic restrictions on a vector autoregression (VAR) system.

It is widely recognised that movements in the rate of change of the Retail Prices Index (RPI) need not accurately capture the phenomenon known as inflation. Whilst inflation is generally associated with a 'sustained increase in the general price level', the RPI is designed to assess the cost of particular goods and services. Thus, there is a conceptual mismatch between this measure and inflation.

The standard approach in the literature – associated with the work of (among others) Brauer and Wu (1991), Craven and Gausden (1991), and Ganley *et al.* (1991) – has been to remove, in some *ad hoc* manner, the 'unwanted' component (interpretable as just 'noise'). What remains, the researcher hopes, is a reliable estimate of the core or underlying inflation process. (Hereafter, the terms core inflation and underlying inflation are used interchangeably.) Examples of this approach include smoothing (taking a moving average of the one month annualised rates of change), and so-called 'structural time series modelling'. The last of these involves assuming a functional form for the underlying process – almost invariably taking it to be a random walk – and then processing the observed RPI series by a Kalman filter. Arguably, such approaches involve assumptions about core inflation that have little economic interpretation. In particular, there is no economic rationale for assuming that changes in underlying inflation are a random walk; and no justification for believing that core inflation is the product of some arbitrary smoothing procedure.

In this paper an alternative technique for measuring inflation is outlined, based on an explicit economic hypothesis. Core inflation is defined as that component of measured inflation that has no medium- to long-run impact on real output.

This definition captures the commonly held view that (moderate) movements in inflation can be benign for the real economy once financial and wage contracts have been written taking it into account (rewriting those contracts – or adjusting implicit agreements – might be time consuming). This

* The views in this paper are those of the authors and not necessarily those of the Bank of England. We thank participants at the Economics Division seminars for helpful comments. Our thanks also go to Andrew Brigden, David Sclater and Kay Tayler for research assistance. All calculations were performed using the econometrics shell tSrF.

notion is consistent with a vertical long-run Phillips curve interpretation of the comovements in output and inflation.[1] Other researchers (such as Buiter and Miller (1981) and Bryan and Cecchetti (1993)) have defined core inflation in relation to money growth. Although our method is reconcilable with a monetary view of inflation, we do not impose this in our measurement procedure. We prefer to be agnostic on the exact determinants of underlying inflation.

Our approach to the measurement problem is based upon the following interpretation of the relationship between the measure of inflation and its theoretical counterparts. We argue that measured (RPI) inflation is conceptually mismatched with the short-run inflation rate; the difference is more fundamental than 'measurement error'. This short-run rate is unobtainable from the data – theoretical models give us no basis for extracting the relevant information from the measure. In contrast, theory does predict a number of identifying characteristics for long-run inflation; our methodology involves using one of these properties to identify the core.

The estimate of core inflation is obtained using a vector autoregression (VAR) system. We assume that observed changes in the measure of inflation (derived from the RPI) are affected by two types of disturbance, each uncorrelated with the other. The first of these disturbances has no impact on real output in the medium to long run. The second has unrestricted effects on measured inflation and real output, but does not affect core inflation. We construct an estimate of core inflation which, as defined here, corresponds to this disturbance. The identification technique based on dynamic restrictions is similar to that employed by Blanchard and Quah (1989) and Shapiro and Watson (1988).[2]

With our theory-based definition and the identifying restrictions, the following characterisation of underlying inflation is obtained: first, core inflationary disturbances have little impact on the real economy even in the short run; second, 'headline' inflation (the 12 month change in the RPI) overstated inflationary pressures in the late 1980s; and third, core inflation has responded more quickly to the recent inflationary tendencies within the economy than other commonly used measures.

The rest of the paper is organised as follows. In Section I, we review the relationship between the RPI and inflation. In Sections II and III, we analyse identification and the economic interpretation behind our identifying restrictions. We discuss the estimation procedure in Section IV; and present our results in Section V. We outline some proposals for future work in Section VI.

I. RPI AND INFLATION

The rate of change of the RPI index is problematic as a measure of inflation since the RPI is not designed to measure movements in the general price level.

[1] The Phillips curve debate originally focused on the movement of nominal wages and unemployment (see the paper by Phillips (1958) for further details).

[2] Quah (1994) reviews alternative identification methods for vector autoregressions.

The Government's Advisory Committee for the RPI describes the index as a measure of the acquisition cost of goods and services.[3] The resulting series fails to capture the notion of either the cost of living or inflation. The index is constructed by assigning weights to the various components of the given bundle of goods and services. In the cost of living context the weights reflect the preferences of some representative consumer (though a true cost of living index would consider the user cost of durables and not the acquisition cost). In the inflation context the weights are potentially misleading and possibly meaningless. Is a given price change in a good with a higher weight any more inflationary than in a good with a lower one? The answer is unclear. Even if the weight is consistent with aggregate expenditure on that commodity, any number of aggregate, sector- and region-specific disturbances can cause changes in the price of an individual component. These disturbances might have nothing to do with the inflationary process.[4]

As a result, no matter what steps are taken to modify the RPI series, it remains conceptually mismatched with the inflation rate. The traditional approach to this problem is to estimate the underlying or core rate from the RPI series by so-called smoothing or filtering. This has generally been achieved by one of two methods. The first involves calculating a moving average of the one-month percentage changes in the chosen index and seasonally adjusting the resulting series. The appeal of this approach lies in the ease of calculation. Unfortunately, there is no economic rationale behind the measurement of underlying inflation in this manner. There is no reason to believe that the phenomenon has any specific time dimension. The researcher does not know whether to use a 3, 6 or even 9 month moving average.

The second smoothing method, the most familiar example of which is the Kalman Filter, involves hypothesising the functional form of the underlying process and then estimating it from the chosen measure of inflation. Unfortunately, making specific functional form assumptions is no more appealing than making assumptions about the time dimension of underlying inflation; economic theory makes no prediction about either. Core inflation might be an autoregressive integrated moving average (ARIMA) process with lag lengths (2, 1, 3), or, equally plausibly, it might not be.

Partly as a result of dissatisfaction with these techniques, there has been some renewed interest in a third technique: the simple zero-weighting of the (in some sense) undesirable RPI components. For example, in the United Kingdom, the Government has advocated the use of RPIX as a measure of underlying inflation. This excludes – attaches a zero weight to – the housing component (which emphasises mortgage interest payments).[5]

In a similar vein, Bryan and Cecchetti (1993) have proposed the zero

[3] Most of the index is constructed in this way though the treatment of housing costs is an exception. For further details, see Department of Employment (1987) and Ganley *et al.* (1991).

[4] Unfortunately for the researcher, the problems are compounded by distortions that arise in the RPI as a result of technical difficulties with the construction of the index itself (particularly with the housing component). Hill (1988) and Fortin (1990) survey the literature.

[5] Changes in VAT, local authority taxes and excise duties affect RPIX. So, the Bank of England calculates an index (RPIY) which excludes these taxes.

weighting of the RPI components in the tails of the cross-sectional distribution of inflation changes. Such a procedure, may, at times, yield a less distorted measure than the RPI, but it may not: the technique discards useful information on the inflation process.

The approach used in this paper does not involve discarding cross-sectional information; and imposes much weaker assumptions about the structure of inflation than smoothing or filtering. These assumptions are examined in the following section.

II. IDENTIFICATION

The following assumptions are made about the process followed by measured inflation and output. Two types of exogenous shock potentially influence the behaviour of measured inflation. These disturbances are distinguished by their effect on output. The first kind of disturbance has no impact on output after some fixed horizon. The second kind might have significant medium- to long-run effects on output. These disturbances are assumed to be uncorrelated at all leads and lags. Core inflation is then defined as the underlying movement in measured inflation associated only with the first kind of disturbance. Note that core inflation is identified as being output-neutral in the medium to long run, but may affect output at shorter horizons. The interpretation given to the disturbances is discussed at greater length in the Section III below.

Without loss of generality, the underlying disturbances are taken to be serially uncorrelated. The Wold Representation Theorem implies that, under weak regularity conditions, a stationary process can be represented as an invertible distributed lag of serially uncorrelated disturbances. In order to identify the underlying disturbances it is assumed that they are linear combinations of the Wold innovations. If this assumption does not hold the 'correct' disturbances cannot be recovered.[6]

With the above as background, let Y and π denote (the logarithm of) output and measured inflation; and the two disturbances η_1 and η_2. We assume that Y and π have stochastic trends but are not cointegrated. (Preliminary data analysis suggests that this is an accurate characterisation of their time series properties.) Using the notion $\boldsymbol{X} = (\Delta Y, \Delta\pi)'$ and $\boldsymbol{\eta} = (\eta_1, \eta_2)'$ write $\boldsymbol{X}$ as the following:

$$\begin{aligned} \boldsymbol{X}(t) &= \boldsymbol{D}(0)\,\boldsymbol{\eta}(t) + \boldsymbol{D}(1)\,\boldsymbol{\eta}(t-1) + \dots \qquad (1) \\ &= \sum_{j=0}^{\infty} \boldsymbol{D}(j)\,\boldsymbol{\eta}(t-j). \qquad \mathrm{Var}(\boldsymbol{\eta}) = \boldsymbol{I}. \end{aligned}$$

This equation expresses ΔY and $\Delta\pi$ as distributed lags of the two disturbances η_1 and η_2. These disturbances are assumed to be pairwise orthogonal and the diagonal variance–covariance matrix is normalised to the identity.[7]

The long-run output-neutrality condition is that $\Sigma_{j=0}^{\infty} d_{11}(j) = 0$: the upper left-hand entries of the sequence of matrices $\boldsymbol{D}$ sum to zero. To see this, note

[6] For further details on this nonfundamentalness problem see the papers by Quah (1990), Hansen and Sargent (1991), Lippi and Reichlin (1993), and Blanchard and Quah (1993).

[7] The economic interpretation behind the orthogonality condition is discussed in Section III.

that $d_{11}(j)$ is the effect of the first disturbance on ΔY after j periods, and thus $\Sigma_{j=0}^{k} d_{11}(j)$ is the effect on Y after k periods.

Such a sequence $\boldsymbol{D}$ then implies a decomposition of inflation as follows:

$$\Delta\pi(t) = \sum_j d_{21}(j)\,\eta_1(t-j) + \sum_j d_{22}(j)\,\eta_2(t-j). \tag{2}$$

The process $\Sigma_j d_{21}(j)\,\eta_1(t-j)$ is our candidate for changes in underlying inflation.

This representation is recovered from data in the following manner. First, a VAR is estimated and inverted to obtain the following Wold moving average representation:

$$\begin{aligned} \boldsymbol{X}(t) &= \boldsymbol{e}(t) + \boldsymbol{C}(1)\,\boldsymbol{e}(t-1) + \dots \\ &= \sum_{j=0}^{\infty} \boldsymbol{C}(j)\,\boldsymbol{e}(t-j). \qquad \mathrm{Var}(\boldsymbol{e}) = \boldsymbol{\Omega}. \end{aligned} \tag{3}$$

We know, from the (proof of the) Wold Theorem, that this representation is unique. Given our identifying condition that the disturbances of interest, $(\eta_1, \eta_2)'$, are linear combinations of the Wold innovations, $(e_1, e_2)'$, we can therefore uniquely recover η_1 – the disturbance driving core inflation. From equations (1) and (3) it can be seen that the following two conditions hold:

$$\boldsymbol{e} = \boldsymbol{D}(0)\,\boldsymbol{\eta}, \tag{4}$$

$$\boldsymbol{D}(j) = \boldsymbol{C}(j)\,\boldsymbol{D}(0). \tag{5}$$

These expressions relating the disturbances to the Wold innovations allow the recovery of $\boldsymbol{\eta}$ if $\boldsymbol{D}(0)$ is unique. Three restrictions on this 2×2 matrix are imposed by $\boldsymbol{D}(0)\,\boldsymbol{D}(0)' = \boldsymbol{\Omega}$; the neutrality condition imposes a fourth. More formally, let $\boldsymbol{S}$ denote the unique lower triangular Choleski factor of $\boldsymbol{\Omega}$. The matrix $\boldsymbol{D}(0)$ is an orthonormal transformation of $\boldsymbol{S}$; the neutrality condition is an orthogonality condition that uniquely determines the orthonormal transformation.

Using this procedure we construct the first column of the matrix $\boldsymbol{D}(0)$, and then the corresponding elements of $\boldsymbol{D}(j)$ and $\boldsymbol{\eta}$ from equations (4) and (5). An estimate of underlying inflation, depending on the disturbance that is output-neutral in the long run, is then straightforwardly derived.

To identify core inflation as corresponding to disturbances that have minimal impact on output after (say) N periods, we solve:

$$\min_{S} \sum_{j>N} d_{11}(j)^2, \tag{6}$$

$$\Leftrightarrow \min_{S} \sum_{j>N} ([\boldsymbol{C}(j)]_1\,[\boldsymbol{S}]_1')^2, \tag{7}$$

$$\Leftrightarrow \min_{S} [\boldsymbol{S}]_1' \,(\sum_{j>N} [\boldsymbol{C}(j)]_1'\,[\boldsymbol{C}(j)]_1)\,[\boldsymbol{S}]_1, \tag{8}$$

where $[\cdot]_1$ denotes the first row of a matrix. Hence, $[\boldsymbol{S}]_1$ is the eigenvector of $\Sigma_{j>N}[\boldsymbol{C}(j)]_1'\,[\boldsymbol{C}(j)]_1$ corresponding to the smallest eigenvalue, μ – which is the value of expression (8). Then, the size of μ allows an assessment of the neutrality of core inflationary shocks. Note that, as N tends to infinity, this condition becomes our long-run restriction.

We now turn to the economic interpretation of this method of measuring core inflation.

III. INTERPRETATION

Our definition of core inflation – 'that component of measured inflation that has no medium- to long-run impact on output' – captures the commonly held notion that movements in core inflation are benign for the real economy once financial and wave contracts have been written taking them into account.

Models ranging from Lucas (1972, 1973) to Fischer (1977) and Taylor (1980) predict this property, manifest as a vertical long-run Phillips curve. Due to the (relative) consensus among economists on this characteristic of inflation, the Phillips curve relation – in different guises – is a staple of introductory macroeconomics courses. The only controversial issue is how quickly economic agents adjust to core inflation. The traditional Keynesian view is that because of nominal rigidities adjustment will be slow, thereby giving a short-run trade-off between inflation and output. The traditional equilibrium view is that a short-run trade-off could be present only due to expectations errors – those errors might be persistent, or they might not. If not – the rational expectations hypothesis – then there is no short-run trade-off between inflation and output. In either case, those expectations errors cannot be relied on as a means of conducting policy.

Our definition of core inflation is implemented as an identifying condition. Hence, our interpretation of the disturbance which satisfies this condition (η_1) as corresponding to core inflation is merely a restatement of the identifying restriction.

Note that we do not restrict how quickly core-inflationary disturbances become output-neutral. Our identification procedure involves the restriction that core inflationary shocks are output-neutral at medium to long horizons, but the impact at shorter horizons is unspecified – we allow the data to reveal whether or not the economy adjusts quickly to core inflationary disturbances. This feature permits assessment of the validity of our identification procedure; if the real economy fails to adjust to core disturbances in the medium to long run, this would raise doubts about the identification of core inflation as being output-neutral in the very long run.

Nor do we impose as an identifying condition the property that non-core inflationary shocks have no permanent impact on the measured rate of inflation. This allows a further assessment of the validity of our approach. If the data do not support the hypothesis that non-core disturbances have little sustained impact on measured inflation then our identification procedure is dubious. (Our interpretation of the non-core disturbance is deliberately vague – reflecting our weak priors about the type of disturbance that potentially influences inflation in the short run.)

Now consider the assumption that the two disturbances are uncorrelated at all leads and lags. The second disturbance which, by definition, may have a permanent impact on real output may, at certain junctures, be interpreted as the result of policy changes by the government (such as the changing of tax rates), or some manifestation of hysteresis. The model allows for the possibility that such effects can be directly caused by changes in core inflation but does not allow for correlation. We believe that the orthogonality condition is approximately correct in that, if it breaks down, it does so only at specific points in time.

This raises the issue of whether there are only two types of disturbance that affect measured inflation and output. It is more likely that there are many sources of disturbances, each with different effects on the economy. The assumption that the concept of core inflation is meaningful at all is an assumption that there is a unique core inflationary process in a macroeconomy – across all sectors and all regions. While this might, at first, seem improbable, that a common monetary base exists provides some basis for such an assumption. That the various other shocks to the economy can be represented by one type of disturbances is, probably, a greater leap of faith. The hope is that this other type of shock represents an average of the dynamic effects of the (potentially many) underlying shocks.

IV. ESTIMATION

A VAR system in the growth of real industrial output (ΔY) and the 1 month change in the (log of) RPI ($\Delta\pi$) is estimated over the peirod of 1969:3 to 1994:3. Industrial output is used in preference to GDP as it is available monthly rather than quarterly. The system also includes 12 lags, a constant, a time trend and seasonal dummies. The choice of lags is consistent with the test of lag lengths due to Sims (1980). Estimation with nine lags, and/or omitting the trend and seasonal dummies, produced similar results to the ones reported below. The standard tests confirm that measured inflation and output can be treated as I(1) but are not cointegrated.

The properties of the VAR representation shed no light on the core inflationary process so we proceed directly to the impulse responses and the derived estimate of core inflation. Since restricting the time horizon over which core disturbances became output-neutral had little impact, we report only the results for the infinite horizon case.

V. RESULTS

The dynamic effects of the two disturbances on measured inflation and output are reported in Figs. 1 and 2 respectively. The vertical axes refer to the logs of the variables in question. The horizontal axes denote time in months. Figs. 3–6 provide standard deviation bands around the point estimates.[8]

V.1 *Measured Inflation Impulse Responses*

The two disturbances have distinct dynamic effects on measured inflation.

A core inflationary disturbance has a permanent effect. The impulse

[8] These are obtained by using 10,000 bootstrap replications.

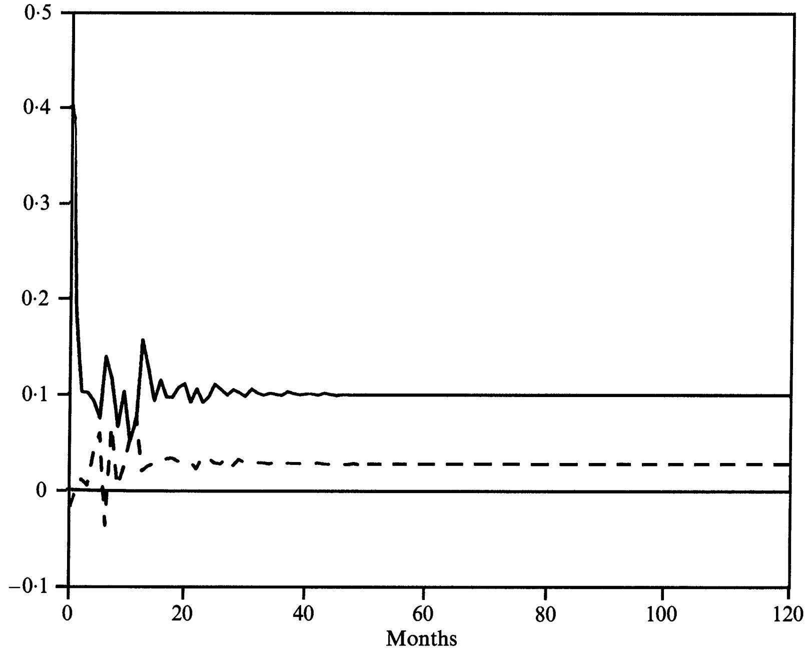

Fig. 1. Measured inflation impulse responses. ——, Core; – – –, non-core.

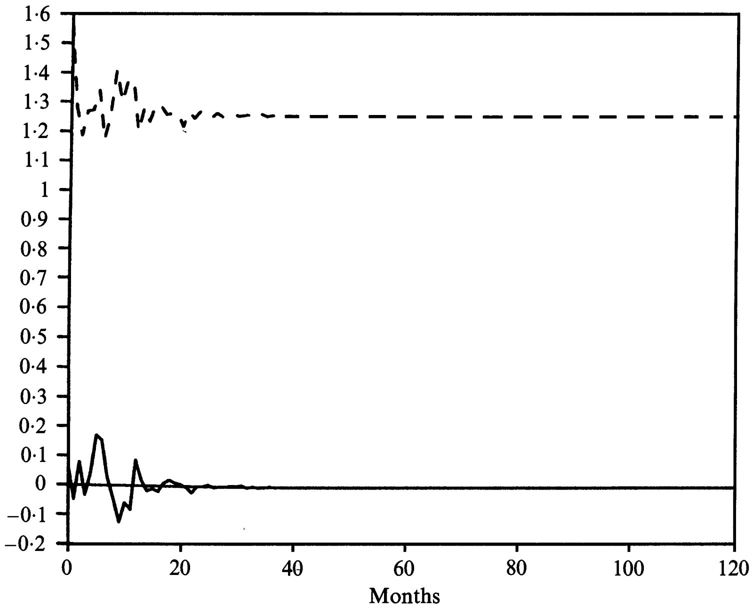

Fig. 2. Output impulse responses. ——, Core; – – –, non-core.

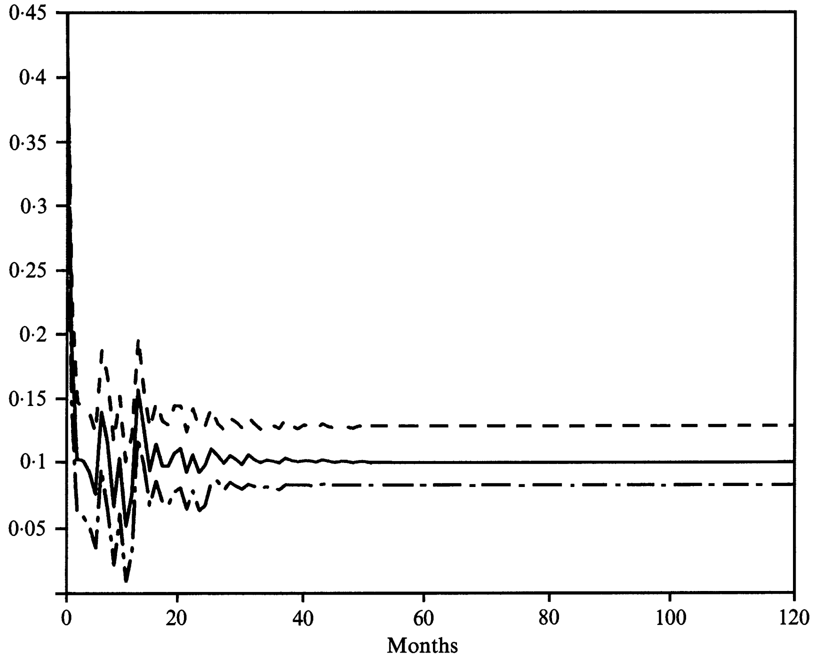

Fig. 3. Measured inflation impulse response. ——, Core; ---, +S.D.; —·—·—, −S.D.

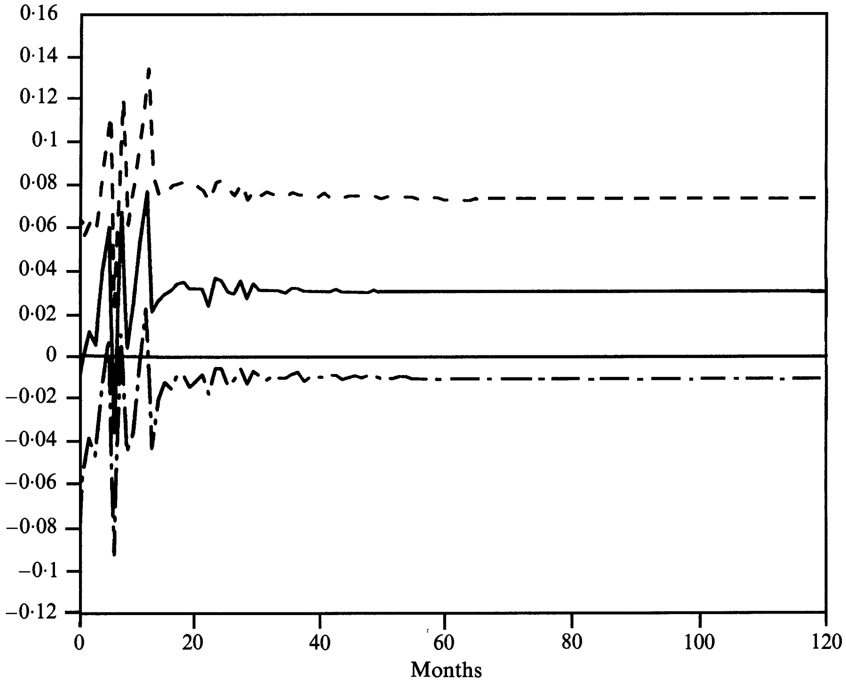

Fig. 4. Measured inflation impulse response. ——, Non-core; ---, +S.D.; —·—·—, −S.D.

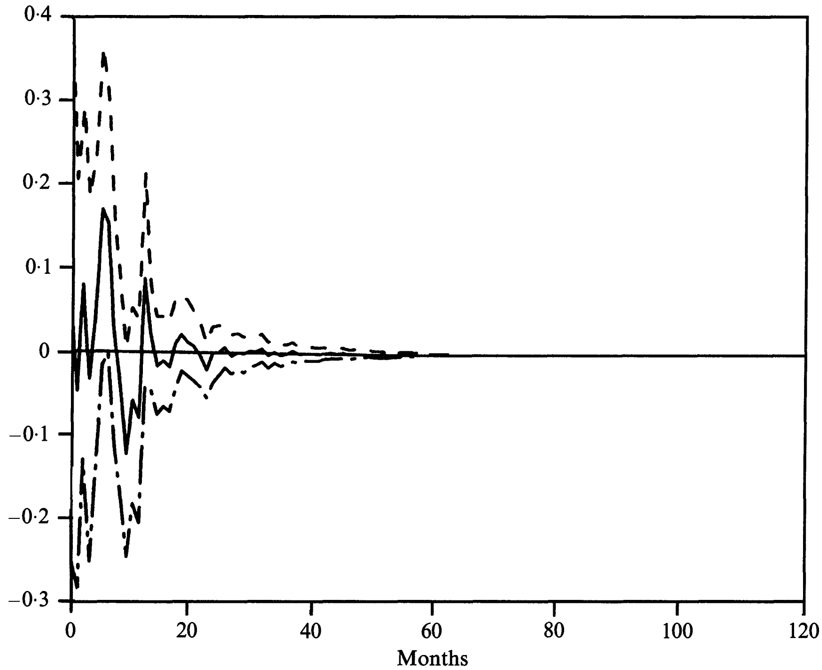

Fig. 5. Output impulse response. ——, Core; – – –, +S.D.; —·—·—, −S.D.

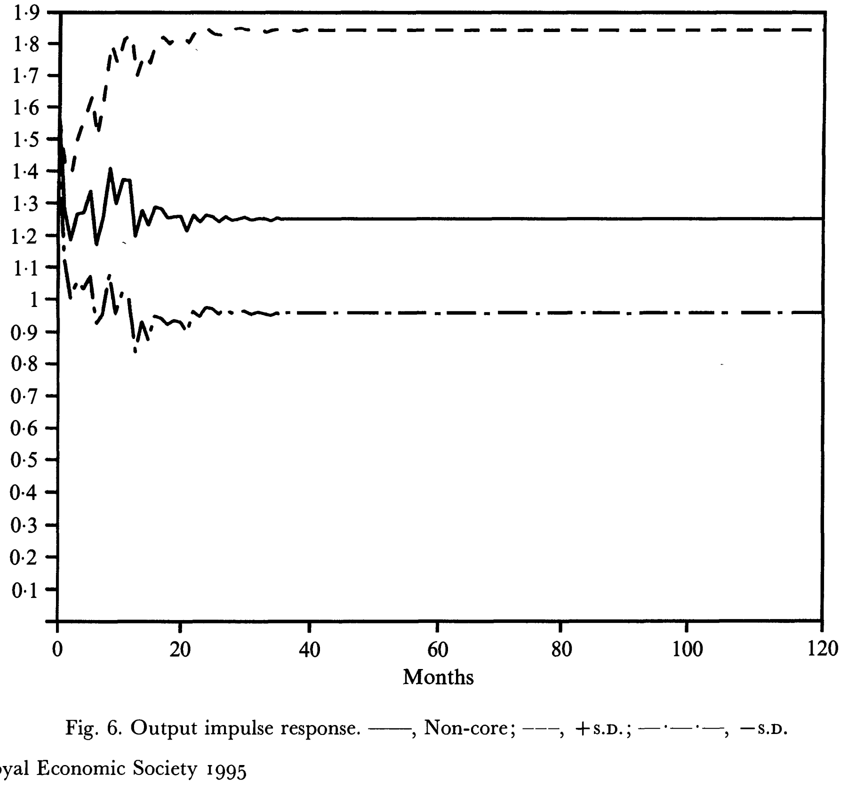

Fig. 6. Output impulse response. ——, Non-core; – – –, +S.D.; —·—·—, −S.D.

response takes approximately 24 months to settle down to its long-run level.[9] The persistence embodied in the response function provides some foundation for inflation's reputation as a stubborn phenomenon.

The effects of a non-core shock on measured inflation are initially very mild and stabilise, at around 17 months. The hypothesis that the long-run impact is approximately zero cannot be rejected. This supports our hypothesis that non-core shocks are exactly that – disturbances that add noise to measured inflation but are not part of the underlying process. In so far as non-core shocks have a transitory impact on measured inflation, in the long run the measured rate is driven primarily by the core.

V.2 *Output Impulse Responses*

The core inflationary shocks initially mildly stimulate and then dampen output. The impulse responses are, however, extremely weak – within 15 months the impact is negligible. Adjustment to core inflation by the real economy is swift with little real effects. We interpret the speed of adjustment as evidence supporting our identification procedure. Had the economy taken longer to adjust, the output-neutrality proposition would have seemed a less valid identifying condition. The lack of output effects can be interpreted as evidence that (for core inflation) the short-run Phillips curve is near vertical.

A positive non-core shock has a much stronger stimulating impact on output. The effect stabilises, again in just over a year, to its permanent value. We interpret this lack of decay as evidence that these disturbances are not fundamental to the inflationary process. The alternative hypothesis – that agents systematically fail to allow for inflation in writing their contracts – seems implausible. Unfortunately, the impulse response is imprecisely estimated.

V.3 *Variance Decomposition*

Table 1 gives the variance decompositions. It has the following interpretation. Define the k month-ahead forecast error in measured inflation as the difference between measured inflation and its forecast k months earlier (from equation (3)). This error is the result of both unanticipated core and non-core disturbances over the k periods. For both measured inflation and output, the figure given at the various horizons gives the percentage of the variance in the k-step ahead forecast error due to core disturbances. The contribution attributable to non-core disturbances is given by 100 minus that number (not reported). The one standard deviation bands are given in parentheses.

Our identification procedure imposes only the restriction that the contribution of non-core disturbances to the variance of output is equal to 100% in the long run. Otherwise, the variance decompositions are unconstrained.

The contribution of core disturbances to movements in output is small, even in the very short run – non-core disturbances explain almost all of the

[9] The inclusion of the seasonal dummies in the VAR representation smoothes the impulse response and causes it to stabilise somewhat quicker.

Table 1

Variance Decomposition of Measured Inflation and Output. Percentage of Variance Due to Core

Horizon (months)	Measured inflation	Output
1	99·8	0·1
	(93·0, 100·0)	(0·0, 6·0)
3	99·8	0·2
	(92·0, 100·0)	(0·0, 5·0)
12	94·1	0·5
	(81·0, 96·0)	(0·0, 3·0)
24	93·4	0·3
	(76·0, 97·0)	(0·0, 2·0)
48	92·7	0·1
	(71·0, 97·0)	(0·0, 1·0)
120	92·0	0·1
	(66·0, 98·0)	(0·0, 1·0)

variation. Core disturbances explain a large proportion of the variation in measured inflation – non-core disturbances are much less important.

However, the standard error bands on both core and non-core disturbances are quite large; the relative impact of the two disturbances on the variance of measured inflation is imprecisely estimated.

V.4 *Estimated Core Inflation*

As noted in Section II, the estimate of the core component of inflation can be constructed as the time path of inflation that would have obtained in the absence of non-core disturbances. In Figs. 7 and 8, the estimate of the 12 month change in core inflation is presented together with the analogous 'headline' and RPIX based figures.

There are a number of striking features about the core series.

First, the peaks and troughs of the core match well with the 'headline' rate – the series appears to perform well in its role as a prime mover of movements in measured inflation.

Second, both the 'headline' and the RPIX measure have, in the past, masked significant movements in the underlying inflation process. In the early 1980s, for example, the inflation process was stronger than either conventional measure would have us believe. This is consistent with the view that non-core (perhaps, productivity) disturbances stimulated the supply side of the economy, temporarily improving the United Kingdom's inflation performance. In particular, there were strong inflationary pressures within the economy during 1985 (when sterling was weak) that were not picked up by our usual measures.

In contrast, in the late 1980s the inflationary process has tended to be somewhat weaker than indicated by 'headline' or RPIX inflation – non-core disturbances appear to have had an adverse impact on output, forcing measured inflation above the core. More recently (from early 1992), the RPI

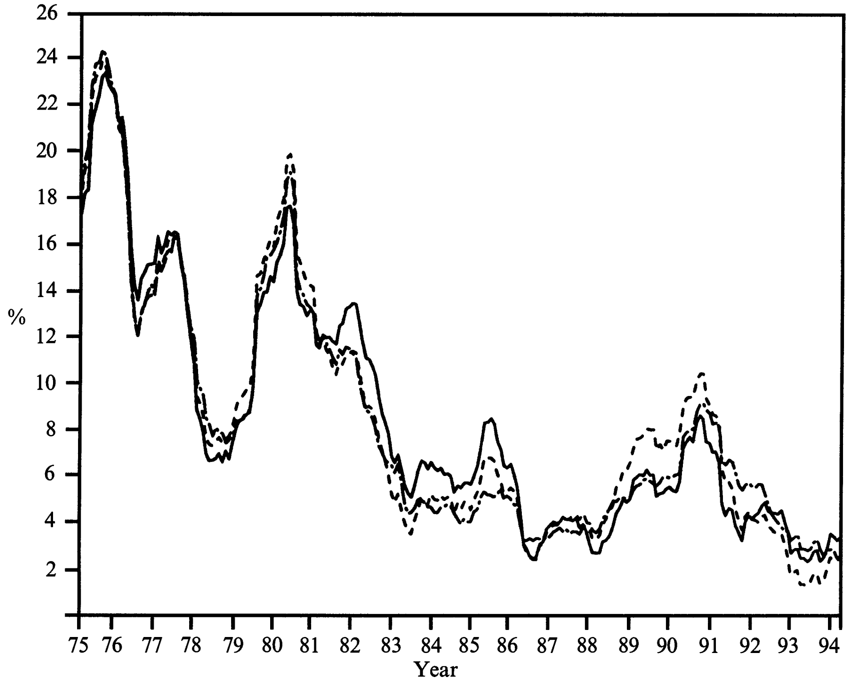

Fig. 7. Measured and core inflation. ——, Core; ---, RPI; —·—·—, RPIX.

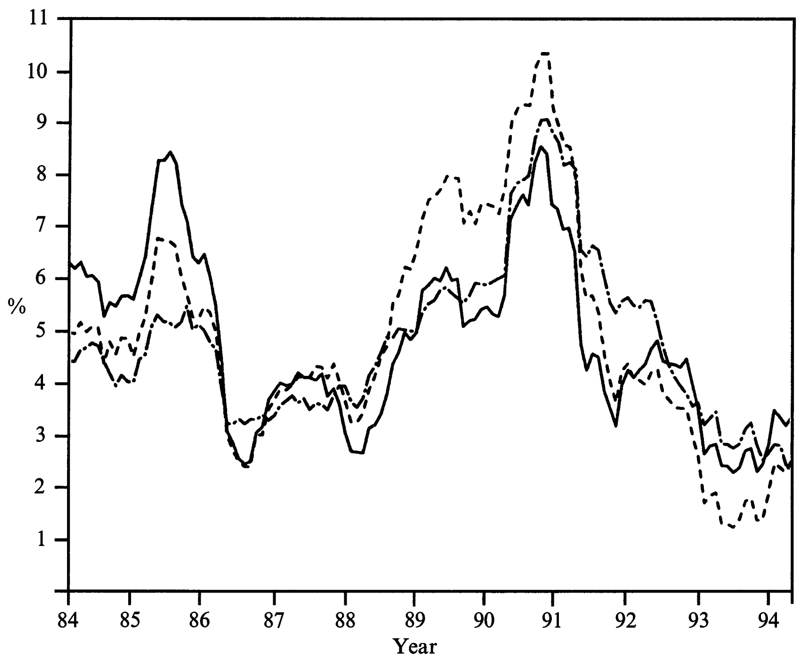

Fig. 8. Measured and core inflation. ——, Core; ---, RPI; —·—·—, RPIX.

has understated core inflation. At the end of 1992, our measure of core inflation levels out at just over 2% – in response to the falls in sterling – and picks up towards the end of 1993. In contrast, the RPIX measure continued to fall over this period.

VI. CONCLUSIONS

We have proposed a technique to deal with the conceptual mismatch between the phenomenon known as inflation and its measure. We have argued that the standard approaches in the literature have little economic interpretation, and have proposed an alternative measure of core inflation – defined as that component of measured inflation that has no impact on real output in the medium to long run – consistent with a vertical long-run Phillips curve. Our estimate of core inflation has been obtained from a VAR system under the assumption that observed changes in the measure of inflation are affected by two types of disturbance. The first type (core inflationary disturbances) has no impact on real output in the medium to long run, whilst the second may have. We conclude that core inflationary disturbances are quickly adjusted to by the real economy but are persistent influences on the measured rate. It turns out that both the 'headline' rate and the RPIX measures of inflation masked the underlying rate considerably throughout the 1980s.

This work has yielded considerable insight into the inflationary process. The conceptual mismatch has been approached in a unique manner – that is compatible with the current understanding of the comovements in macro variables. However, we feel further work is needed. In particular, it would be informative to allow for more variables in the VAR system. Those presently under consideration include monetary and labour cost variables – allowing an assessment of the sources of underlying inflationary pressures.

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