Operational Independence, Inflation Targeting and UK Monetary Policy

Alexander Mihailov
University of Essex

January 2006

Abstract: This paper recovers empirically and evaluates the feedback and stance of monetary policy in the United Kingdom throughout the inflation targeting period, implemented since October 1992. Its principal contribution is in comparing two subsamples, before the Bank of England was granted operational independence in May 1997 and after that. Our econometric approach is theoretically motivated by the New Keynesian model and relies on estimating forward-looking Taylor rules via the Generalized Method of Moments from quarterly data. Both final and real-time data, with alternative variable proxies and regression specifications, were used, to find that Taylor rules based on real-time data provide a more reasonable description of British monetary policy. Interestingly, the operational independence subperiod has differed from the pre-independence one – according to our real-time data set – in terms of a weaker response of the Bank of England to inflation but stronger sensitivity to the output gap and a less restrictive stance of monetary policy. Such a reaction would, first of all, characterize the Bank as a flexible inflation targeter, as should be expected by its legal mandate, and not a strict one; secondly, the asymmetry in the feedback function appears justified once the stage in the business cycle is also taken into consideration.

JEL classification codes: E52, E58, F41.

Key words and phrases: monetary policy feedback and stance, forward-looking Taylor rules, real-time vs final data, flexible vs strict inflation targeting, (central bank) operational independence, United Kingdom.

This is a (slightly) revised version of Discussion Paper No. 602 (October 2005) of the Department of Economics of the University of Essex and of a paper (July 2005) prepared for an invited session on *Monetary Policy* at the 2nd International Conference on *Developments in Economic Theory and Policy*, Bilbao, 7-8 July 2005. A shorter article is forthcoming in the *Journal of Post Keynesian Economics*, Volume 28, Issue 3, Spring 2006, pp. 393-419. I am indebted to the conference organizers, the Department of Applied Economics V of the University of the Basque Country and the Centre for Economic and Public Policy of the University of Cambridge, for their invitation and travel support. I would also like to thank Philip Arestis, Georgios Chortareas and Kumarjit Mandal for useful feedback on earlier drafts as well as conference participants, in particular, the Editor, Paul Davidson, James Galbraith and Edwin Le Heron, for stimulating comments. The usual disclaimer applies.
Department of Economics, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, United Kingdom; +44 (0)1206 87 3351 (phone); +44 (0)1206 87 2724 (fax); mihailov@essex.ac.uk; http://www.essex.ac.uk/economics/people/staff/mihailov.shtm.

Contents

Appendix: Tables and Figures

List of Tables

List of Figures

1. Introduction

For thirteen years, monetary policy in the United Kingdom (UK) has been operating in a regime of *inflation targeting*, from which the last eight years and a half also under *operational independence* of the central bank. To be more precise, the UK monetary authorities moved to inflation(-forecast) targeting[1] in October 1992, and in May 1997 the Bank of England (BoE) was formally granted operational independence[2] from Her Majesty's (HM) Treasury. With a sufficient amount of data for the latter period having accumulated, the contribution of the present paper is to attempt an objective, *econometric* evaluation of British monetary policy under inflation targeting and, in particular, operational independence. For this purpose, we first introduce the recent institutional framework for the conduct of monetary policy in the UK as well as our methodology and then focus on comparing the policy *feedback* and *stance* recovered from our sample *before* and *after* operational independence. Other types of assessment could, of course, be complementary, yet our idea here is to let the data speak as much as they can. To do so, we rely on a recent approach in empirical monetary policy popularized by Clarida, Galí and Gertler (1998, 2000),[3] and having solid grounding in New Keynesian macro theory. It involves estimation of forward-looking Taylor rules incorporating interest rate smoothing via the Generalized Method of Moments (GMM) proposed by Hansen (1982).

We are aware of certain shortcomings in the use of such feedback rules to characterize monetary policy.[4] Yet their simplicity and reliance on statistical facts rather than ('eloquent') ex ante intentions or ex post explanations make them a desirable, impartial and easily interpretable tool for a straightforward analysis of central banks' policy stance and reaction functions. We believe that some insightful – and sufficiently robust – conclusions we were able to extract from the UK data by recurring to forward-looking Taylor rules have largely justified the employed methodology.

Our main findings are summarized next in a preview. First of all, our empirical study has confirmed that simple forward-looking Taylor rules based on *real-time* rather than *final* data perform quite reasonably as a condensed description of monetary policy in the UK under inflation targeting. This is particularly noteworthy, insofar the Bank of England operates de jure in a *targeting* rule regime whereas the Taylor rule is an *instrument* rule. Furthermore, our preferred reaction function specifications identify a differing policy stance, with one episode of monetary tightening and one episode of monetary easing in the pre-independence period and two episodes of monetary easing in the post-independence period, which makes good sense within the British macroeconomic context. Finally, inflation targeting coupled with operational independence does not necessarily mean:

1) a *deflationary bias*: in fact, the interest rate in the UK was lower, on average, after the move to operational independence;

2) *strict* inflation targeting, i.e., that the central bank would not react to the output gap: in fact, the Bank of England has responded to the output gap before as well as after receiving operational independence;

3) that the central bank would react in a *stronger* way to inflation: it may well react in a weaker way, depending on the stage of the business cycle and on whether inflation has been stabilized around target or not;

4) that the central bank would react in a *weaker* way to the output gap: in fact, the Bank of England has reacted more aggressively (and, in this sense, asymmetrically) to the output gap after receiving operational independence.

All these conclusions can basically be explained, as we argue in the paper, by a unique underlying cause: one just needs to also take into consideration the relevant phase of the business cycle, in particular the dominant (or average) output gap before and after operational independence. We thus present evidence that even a greater degree of central bank independence in addition to a well-established inflation targeting strategy would not imply a 'benign neglect' to the business cycle. Such a result appears consistent with New Keynesian theory, and the policy of the Bank of England throughout the inflation targeting period – optimally chosen to balance between 'rule' and 'discretion' – deserves credit.

The paper is further down structured as follows. In the next section we summarize the major institutional developments in the British framework for monetary policy making during the 1990s. We then briefly discuss, in section 3, optimal monetary policy and the evolution of feedback rules, while section 4 describes our data and some preliminary tests. Section 5 sketches the theory behind the econometric approach we apply, and section 6 interprets the key lessons to be learnt from our preferred specifications of estimated forward-looking Taylor rules. Section 7 concludes and the Appendix documents the most important features of our data and regression results in a few tables and figures.

2. The Institutional Framework for UK Monetary Policy since the Early 1990s

It is widely acknowledged that all significant institutional developments in UK monetary policy throughout the 1990s and until now have been implemented following *official public announcements*. As discussed by Nelson (2003), among others, these changes in regime could thus be considered *exogenous* to the economic environment and used for a corresponding 'periodization' of monetary policy in the UK. We summarize below the principal monetary events since the early 1990s and the current policy framework within which the Bank of England operates, as an institutional background for our study.

2.1 Recent History

The late 1980s were marked by an implicit convergence of the British sterling to the Deutsche mark, which ended up in an explicit pegging. Since October 1990 the British sterling became an official member of the *Exchange-Rate Mechanism* (ERM) of the European Community. This experience, however, proved brief and disappointing. An aggravating sterling crisis during the summer of 1992 was followed by a suspension of the ERM in the UK in September 1992. A way out of the exchange rate crisis and restoration of central bank credibility was most immediately seen in the innovative strategy of *inflation targeting*. In October 1992 the United Kingdom adopted it, following the example of countries such as New Zealand and Canada. In June 1995 the target inflation was reformulated from the initial target *band* (or *range*) of 1% to 4% (implying a *mid*-point of 2.5% p.a.) to an explicit medium-term *point* target of 2.5% p.a. – as reported in Haldane (1995) – but remained defined in an *asymmetrical* way. In May 1997 the Bank of England was granted *operational independence* from HM Treasury, and in June 1997 the 2.5% point target was announced to become *symmetrical*: i.e., to give *equal* weight to circumstances in which inflation was higher or lower than the target rate. In December 2003 the target inflation was *lowered* from 2.5% p.a. to 2% p.a. and *expressed* as from January 2004 in terms of the Harmonized Index of Consumer Prices (HICP), renamed (again in December 2003) to simply the Consumer Price Index (CPI), instead of in terms of the Retail Price Index *eXcluding* the mortgage rate (RPIX).[5] The RPIX was the officially announced measure of UK inflation and guide for UK monetary policy during the 1992-2003 period, and the Retail Price Index (RPI), *including* the mortgage rate, had performed that same role before 1992. In fact, the change from RPIX to HICP (or, which is the same, CPI) was preannounced half a year in advance:

> "On 9 June 2003, the Chancellor announced that he planned to change the inflation target to one based on the Harmonized Index of Consumer Prices – HICP – instead of the RPIX. This would be the first major change to the monetary framework introduced since 1997.", Bank of England's website.

The second sentence in the above quotation is important for our purposes here. It basically confirms that there has been no considerable change in UK monetary policy since the point when we break our sample, namely the *second quarter of 1997* (itself *excluded* from our estimation by subsample), when the Bank of England was granted *operational independence*. Moreover, we would argue that the only other major change of a similar magnitude is the break point, namely the *third quarter of 1992* (also *excluded* from our estimation), after which our sample starts with the introduction of *inflation targeting*. This narrative account of the changes in UK monetary policy, reported by a competent and credible primary source of information such as the Bank of England, essentially justifies from an institutional and policy perspective our sample split in two subsamples as well as the respective estimates and comparisons we undertake in the present study.

2.2 Current Goal and Instrument

The current monetary policy framework in the United Kingdom targets inflation but does not ignore, or rather aims to indirectly enhance, other ultimate goals such as economic growth and employment:

> "The Bank's monetary policy objective is to deliver price stability – low inflation – and, subject to that, to support the Government's economic objectives including those for growth and employment. Price stability is defined by the Government's inflation target of 2%. The remit recognises the role of price stability in achieving economic stability more generally, and in providing the right conditions for sustainable growth in output and employment. The Government's inflation target is announced each year by the Chancellor of the Exchequer in the annual Budget statement.", Bank of England's website.

But to achieve the inflation target, the Bank acts on the short-term interest rate, which is thus its operating instrument:

> "When the Bank of England changes the official interest rate it is attempting to influence the overall level of expenditure in the economy. When the amount of money spent grows more quickly than the volume of output produced, inflation is the result. In this way, changes in interest rates are used to control inflation. … The Bank supplies the cash which the banking system as a whole needs to achieve balance by the end of each settlement day. Because the Bank is the final provider of cash to the system it can choose the interest rate at which it will provide these funds each day. The interest rate at which the Bank

> supplies these funds is quickly passed throughout the financial system, influencing interest rates for the whole economy.", Bank of England's website.

In this sense, interest rate management preserves crucial importance in an inflation targeting regime as well. This is a good reason to expect that empirical studies based on Taylor rules, such as ours, may characterize UK monetary policy reasonably well.

3. Theoretical and Empirical Background on Monetary Policy Rules

There has been a long debate in the theory and practice of central banking as to what is optimal monetary policy: in essence, is it a rule or discretion? Recent trends in the debate on policy optimality have converged to what Woodford (2003), p. 2, calls "a new consensus in favor of a monetary policy that is disciplined by clear rules intended to ensure a stable standard of value, rather than one that is determined on a purely discretionary basis to serve whatever ends may seem most pressing at any given time". One should also be, however, careful to distinguish these new policy rules from their rigid predecessors such as the gold standard or the fixed money supply growth, for instance. The new rules are better characterized as *systematic monetary policy*, of which the most well known example today is inflation targeting. Rule-based policymaking of that kind is a combination of a preannounced public commitment to an explicit target with a simultaneous communication and explanation of the policy actions to achieve the target to the society at large.

3.1 Taylor(-Type) Instrument Rules

Woodford (2003), chapter 1, traces the intellectual origins of policy reaction functions back to the works of Wicksell (1898, 1907). Wicksell advocated not only a fiat money regime for the world as a whole (in place of the then existing gold standard) but also price-level targeting as a preferable monetary strategy: more precisely, the *target* nominal interest rate (NIR) should be adjusted by the central bank in response to the *price level*. The principal benefit from such a rule is that, as Woodford (2003) argues in chapter 2 of his book, it is able to stabilize the price index around a constant level. Goodhart (1992) has suggested a similar interest rate rule, but in it the NIR target responds instead to *inflation*. The Taylor (1993) rule is an extended interest rate rule that includes also an explicit *output gap* term, in addition to an inflation (and *not* price level) term. Taylor (1993) has insisted and Woodford (2003), p. 39, has stressed that such a feedback rule can be regarded both as a rough *positive description* of the way monetary policy had actually been made and as a straightforward *normative prescription* of how monetary policy should optimally be conducted.[6]

In the original notation, the monetary policy rule Taylor (1993) proposed was:

$$r = p + 0.5y + 0.5(p - 2) + 2,$$

where r is the federal funds rate,[7] p is the rate of inflation over the previous four quarters and y is the percent deviation of real GDP from a target, approximated by a (linear-)*trend* real GDP, the latter growing by 2.2% per year for the Taylor (1993) sample, 1984:1 through 1992:2. The first constant 2 (in parentheses) stands for the inflation target of the monetary authority and was assumed to be, in the US case for the sample period, 2% p.a.; the second constant 2 (the last term in the equation above) is the ‘equilibrium’ *real* interest rate (RIR), itself chosen so as to be close to the assumed *steady-state* growth rate of the economy of 2.2% (that is, as measured by the linear-trend real GDP growth).

The interpretation Taylor (1993), p. 202, suggested to his rule above was the following:

> "The policy rule ... has the feature that the federal funds rate rises if inflation increases above a target of 2 percent or if real GDP rises above trend GDP. If both the inflation rate and real GDP are on target, then the federal funds rate would equal 4 percent, or 2 percent in real terms."

Taylor (1993) did not estimate the policy response coefficients in the rule he proposed. He simply simulated this reaction function and drew attention to the very good fit it produced with respect to the actual federal funds rate (over a period of 24 quarters, 1987:1-1992:4). The subsequent empirical literature, which mostly attempted econometric estimation, has criticized the original Taylor rule. The principal problems it identified were the serial correlation usually found in the error term and the potential endogeneity arising from the contemporaneous regressors, the latter also posing unrealistic informational requirements to the monetary authority. Feedback functions of the type Taylor (1993) suggested have therefore been augmented in a number of ways.

Allowing for a richer dynamics has led to *backward-looking* reaction functions, with the dynamic structure truncated at some relevant lag length. However, estimation of all sorts of backward-looking Taylor rules is nowadays oversimplistic, given that rational agents, including the central bank, anticipate and forecast the variables of key interest to them.

In accordance with considerations of rationality in economic behavior, the literature on policy reaction functions has complemented backward-looking specifications with *forward-looking* ones. Such versions of the Taylor rule are believed to be more realistic. Moreover, forward-looking central bank feedback functions have recently been grounded in microfounded macroeconomic theory, and thus have a deep theoretical justification.

In fact, *optimal* policy rules, i.e., feedback rules derived from explicit models, such as the New Keynesian model of monetary policy (without and with microfoundations) will *not* be *purely* forward-looking, as Woodford (2003), p. 57 (and chapter 7, in detail) has argued. They will usually be *both* expectations- and history-dependent, as is inflation targeting, and the lead and lag horizons in them will not be too long. We make use of such Taylor rule specifications in the empirical part: they are forward-looking in inflation and the output gap and backward-looking in the interest rate (a feature known as interest rate smoothing, as will be explained later).

Taylor rules have sometimes also explicitly included one or more (contemporaneous and lagged) exchange rate terms, which appears logical, especially in the case of a small open economy as the UK. Yet Taylor (2000) argues that there is no need to do so, because exchange rate dynamics will anyway be reflected in the dynamics of the price level – that is, in inflation as well. So, once an inflation term is included in the Taylor rule, the exchange rate is always implicit in the equation, via its pass-through onto consumer prices. Many sorts of other extensions to the standard Taylor rule have recently been proposed, but the 'mainstream' Clarida-Galí-Gertler (1998, 2000) empirical approach usually sticks to conventional specifications, which we also do below.

3.2 Instrument Rules vs Targeting Rules

Svensson (1999, 2003) proposed to distinguish *targeting* rules from *interest rate* rules of the kind described in the preceding subsection. The best-known example of a targeting rule is the inflation-forecast targeting rule commonly used – e.g., in Vickers (1998) – to explain the monetary policy framework implemented since 1992 by the Bank of England we sketched earlier. Woodford (2003), p. 43, characterizes it in a succinct manner:

> "According to the formula, the Bank should be willing to adopt a given operating target i_t for the overnight interest rate at date *t* if and only if the Bank's forecast of the evolution of inflation over the next 2 years, conditional upon the interest rate remaining at the level i_t, implies an inflation rate of 2.5 percent per annum (the Bank's current inflation target) 2 years after date *t*."

The essence of the inflation-forecast targeting procedure consists in the fact that there is no formula prescribed for setting the central bank *interest rate operating target*. Instead, the BoE is free to set this target at whatever level is consistent with its inflation forecast (or projection) in order to meet a certain *target criterion*. The latter criterion may well resemble the right-hand side of a forward-looking Taylor rule (without an interest rate smoothing term), as argued by Svensson (1999).

Given such similarity, we have not discarded the Taylor rule as a potential description of actually materialized monetary policy only because, on a normative basis, the Bank of England does not explicitly follow an instrument rule but a targeting rule. Moreover, Woodford (2003), chapter 8, has shown that although not *optimal*, Taylor rules are often suboptimal (or second-best) reaction functions, next to much more informationally requiring procedures and are, in such a sense, a feasible and transparent approximation. In selecting the forward-looking Taylor rules to estimate, we focused on simple(r) specifications that are justified from both theoretical (economic) and empirical (econometric) point of view. We believe that our results support, to a large extent, the usefulness of Taylor rules in deriving certain lessons on the outcomes of central bank actions, even in the UK under inflation targeting. In particular, our empirical analysis confirms that the Bank of England has been, *de facto*, a *flexible* inflation targeter, i.e., one also paying attention to the output gap. This is in line with the current broader objectives of UK monetary policy, including (indirectly) growth and employment, as exposed in the beginning.

4. Data and Preliminary Tests

In our Taylor rule estimation we employ standard time series that are common in similar studies. However, we also make use of a few *alternative proxies* for the explanatory variables, which are of particular relevance for the UK.

4.1 Data

Sources and Frequency

All time series were downloaded from the statistical pages on the websites of the UK Office of National Statistics (ONS) and the Bank of England (BoE). As mentioned, we work here with *quarterly* data, mostly because GDP-related data, used to measure the output gap in Taylor rules, are much more precise at a quarterly frequency, although also available at a monthly frequency. This certainly makes our subsamples smaller than if we had recurred to monthly time series. Yet our quarterly estimates turned out most of the time to be both significant in econometric terms and interpretable in economic terms. This is in part because, as Clarida-Galí-Gertler (1998, 2000) and Nelson (2003) have pointed out with respect to their earlier and similar empirical work, the variability of the data involved proves sufficient to produce reasonable results even in relatively small samples.

Variable Proxies

Nominal Short-Term Interest Rate

Following previous Taylor rule papers on the UK, in particular, Nelson (2003) and Martin and Milas (2004), we assume here that the short-term interest rate supposed to be the operating instrument of the Bank of England is best proxied by the *3-month Treasury bill rate*. This is not quite precise, because since operational independence the Bank has been using the *2-week repo rate* as its policy instrument. Yet the latter rate has been relatively recently introduced, i.e., in May 1997. As Nelson (2003) points out, the advantage of the 3-month Treasury bill rate is that, being very close to the various different rates – four in total since the early 1970s – that have played the role of operating instrument,[8] it can be used, for greater comparability and with not much loss of precision, to approximate all of them when longer periods are of interest.

Inflation

Inflation is proxied in our study by two alternative indexes that are usual choices when working with UK data:

- the RPI, as in Martin and Milas (2004) and Kesriyeli, Osborn and Sensier (2004), among others; and
- the RPIX, as, for instance, in Nelson (2003).

As for the consumer price index (CPI), which is the standard measure of inflation in most other economies, including for the purposes of monetary policy, we already noted that it has become the official index accounting for the evolution of the UK general price level only since 2004, and has in this way precluded any possibility to use it in our study.

Output Gap

Our measure for the output gap is, alternatively, constructed out of two available time series:

- the *final* (or *revised*) data for GDP, as in the majority of studies on Taylor rules; and

- the *real-time* (or *initially released*) data for the same variable, GDP, which were available to policy makers ‘in real time’, that is, at the time of making decisions on monetary policy: more precisely, we use the series constructed by Nelson and Nikolov (2001) and accessible on the Bank of England’s website. Orphanides (2001, 2003) first argued that real-time data, in addition to being more realistic, might overturn some conclusions about feedback rules based on final data, a point for which we found empirical support here.

Moreover, each of these two types of real GDP series has been filtered by two now standard (although not perfect) procedures to obtain a measure for the output gap, namely:

- by fitting a *quadratic* trend, as in Clarida, Galí and Gertler (1998, 2000) and Nelson (2003), among others; and

- by a *Hodrick-Prescott* detrending (with a smoothing parameter of 1600, recommended for quarterly data), as in Martin and Milas (2004) and Kesriyeli, Osborn and Sensier (2004), among others.

Each of these methods has its advantages and shortcomings. For this reason, and also to arrive at results that are not necessarily sensitive to the detrending employed, we have preferred to work with both filtering procedures, as duly reported further down.

4.2 Preliminary Tests

Seasonality Tests

Information contained in the files downloaded from the sources of our data, the ONS and the BoE, indicated certain inconsistency of the time series we wished to employ in the Taylor rule estimations with respect to their seasonal adjustment. More precisely, nominal GDP data and the GDP deflator – hence, real GDP, by construction – were provided at their source as *seasonally adjusted* (sa), whereas both price levels, the RPI and the RPIX, as well as the 3-month Treasury bill rate were *not seasonally adjusted* (nsa).

We thus performed Census X12 seasonality tests[9] and, consequently, two versions of our Taylor rule regressions:

- with the *raw* data, as they were from their sources, i.e., with no seasonal adjustment to the RPI, the RPIX and the 3-month Treasury bill rate; and
- with *seasonally adjusted* – by the Census X12 procedure – respective price levels and interest rate.

We did so because of certain criticisms in the literature in the sense that deseasonalization techniques may diminish or eliminate important features of the raw time series and thus give rise to findings that do not necessarily reflect genuine correlations across the data. On the other hand, it seemed to us somewhat inconsistent not to employ seasonally adjusted prices and interest rates side by side with (final) GDP data that were anyway seasonally adjusted at the source. We later on duly report both types of results, nsa and sa.

Stationarity Tests

A typical preliminary procedure in time series analysis, to avoid spurious regressions, is to test for (non)stationarity of the included variables. In the particular case of Taylor rule estimation, however, this has not been systematically done in most of the previous literature. To address the issue, we employed augmented Dickey-Fuller (ADF) unit root tests based on autoregressive models in parallel with kernel-based Phillips-Perron (PP) unit root tests, with the null for both tests being that of a unit root (i.e., nonstationarity) present. These two tests were further supplemented by a test constructed on the *opposite* null, of stationarity, namely the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and both autoregressive and kernel-based specifications of it were used.[10]

We generally found that the price levels, RPI and RPIX, could be either I(1) or I(2). Hence, inflation could be either stationary or not, depending on the chosen proxy and test. The 3-month Treasury bill rate and the real GDP gap obtained from quadratic-trend fitting could not be treated with certainty neither as stationary nor as I(1) variables either, because of mixed findings from the alternative unit root tests and specifications within each test we resorted to. Only the real GDP gap obtained from Hodrick-Prescott detrending appeared to be most likely I(0). Bearing in mind the notorious low power of unit root tests, in particular, in short samples such as ours, we, after all, followed the New Keynesian theory of monetary policy and effected Taylor rule estimation in the standard way, as also argued and done by Clarida, Galí and

Gertler (1998, 2000). These authors defend the key assumptions in their work – stationarity of inflation and the nominal interest rate, as we shall also assume here – by stressing that they are both empirically and theoretically plausible.

5. The NNS-GMM Approach to Estimating Forward-Looking Taylor Rules

Our empirical strategy was to apply a common and theoretically consistent method to estimate forward-looking Taylor rules, namely the Generalized Method of Moments (GMM), as in Clarida, Galí and Gertler (1998, 2000).[11]

5.1 Sketch of the Microfoundations: NNS

It is nowadays standard to think of monetary policy reaction functions in general, and of Taylor rules in particular, as if derived from an underlying model of the economy. This model is usually the baseline New Keynesian model described in King and Woolman (1996) and Yun (1996), among others, and also called – first by Goodfriend and King (1997) and in a broader context – the New Neoclassical Synthesis (NNS) model. It is not necessary for our purposes here to write down this model completely, because such sticky-price analytical frameworks have been well explored – see, for instance, Clarida, Galí and Gertler (1999), Walsh (2003) and Woodford (2003). We would rather sketch its relevance to our estimation below, by simply stating its ‘core’ equations and then relating them to the forward-looking feedback rules we estimated.

After log-linearization around a zero inflation steady state, the equilibrium conditions of the baseline New Keynesian (or NNS) model are embodied in four equations, which – following Clarida, Galí and Gertler (2000) in ignoring certain constant terms, but using a more explicit for our purposes notation – can be written as:

(1) $$\pi_t = \delta E[\pi_{t+1}|I_t] + \lambda(y_t - \xi_t),$$

(2) $$y_t = E[y_{t+1}|I_t] - \frac{1}{\sigma}(i_t - E[\pi_{t+1}|I_t]) + \zeta_t,$$

(3) $$i_t^T = \beta_{\pi,+1} E[\pi_{t+1}|I_t] + \beta_{x,0} x_t,$$

(4) $$i_t = \beta_{i,-1} i_{t-1} + (1 - \beta_{i,-1}) i_t^T.$$

Equation (1) is a (New Keynesian) forward-looking Phillips curve, or also alternatively termed a (New Keynesian) forward-looking aggregate supply (AS) curve. π_t is the rate of inflation. I_t is the information set available at time t. δ is the discount factor and λ the output elasticity of inflation. $y_t \equiv \ln Y_t$ is the current-period level of output and ξ_t is the natural rate of output, defined as the level of output that would obtain under fully flexible prices and assumed to follow an AR(1) process. This AS curve can be derived by aggregation of optimal price-setting decisions by monopolistically competitive firms under Calvo (1983) individual price adjustment.

(2) is a (New Keynesian) forward-looking IS curve, and is derived as a combination of a standard consumption Euler equation and a market clearing condition. σ denotes the coefficient of relative risk aversion (CRRA) embedded in the utility function. ζ_t is in this context interpreted as an exogenous demand shock: like ξ_t in the aggregate supply curve (1), it is assumed to follow an AR(1) process.

Equation (3) is a (New Keynesian) forward-looking monetary policy rule of the usual Taylor type, with i_t^T denoting the NIR *target* of the central bank and x_t some measure of the output gap at t.

(4), finally, is a (New Keynesian) interest rate smoothing equation, where i_t is the *actual* NIR.

In our notation, all *policy* parameters are easily recognized by the letter β: each subscript to it consists of a pair of symbols, the first being the respective letter designating the variable to which the β-coefficient relates and the second being a positive or negative integer denoting the respective lead (+) or lag (–), with 0 standing for the current period. We use this notation further down in the text and tables for a clearer reference.

Following the above New Keynesian approach, one can summarize the policy of the central bank by a linear instrument rule of the Taylor type involving forward-looking formation of rational expectations:

$$(5) \qquad i_t^T = i^T + \beta_{\pi,+k}\left(E\left[\pi_{t+k} \middle| I_t\right] - \pi^T\right) + \beta_{x,+q} E\left[x_{t+q} \middle| I_t\right].$$

By construction, i^T is the desired (constant) nominal interest rate when inflation is at its target level and output is at potential. (5) is the empirical counterpart of (3) above. Clarida, Galí and Gertler (1998, 2000) claim that such a monetary policy reaction function has some appeal on both theoretical and empirical grounds. Theoretically, approximate forms of rules like (3) are optimal if the monetary authority has as objective a quadratic loss function in deviations of inflation and output from their respective targets in the context of the New Keynesian macromodel we have just outlined. Empirically, rules like (5) usually provide a reasonably good summary of most central banks' behavior in recent years.

Incorporating interest rate *smoothing*, widely supported by the practice of central banks as well as from a theoretical perspective, and allowing for exogenous interest rate (i.e., here also monetary policy) shocks, requires an extension of the interest rate *target* (5) by also specifying a model for the *actual* interest rate:

$$(6) \qquad i_t = \beta_i(L)i_{t-1} + (1-\beta_{i,-1})i_t^T + \nu_t ,$$

where L denotes the lag operator and $\beta_i(L) \equiv \beta_{i,-1}L^0 + \beta_{i,-2}L^1 + ... + \beta_{i,-n}L^{n-1}$, with $\beta_{i,-1} \in [0,1)$. In (6), $\beta_i(L)$ measures the *degree* of smoothing of interest rate changes and ν_t is a zero mean exogenous interest rate shock. Equation (6) is, in turn, the empirical counterpart of (4) above.

Plugging the Taylor rule target (5) into the partial adjustment model (6),

$$(7) \qquad i_t = \beta_i(L)i_{t-1} + (1-\beta_{i,-1})\{i^T + \beta_{\pi,+k}(E[\pi_{t+k}|I_t] - \pi^T) + \beta_{x,+q}E[x_{t+q}|I_t]\} + \nu_t ,$$

representing the expected values, $E[\pi_{t+k}|I_t]$ and $E[x_{t+q}|I_t]$, as realized values minus forecast errors, $\pi_{t+k} - (\pi_{t+k} - E[\pi_{t+k}|I_t])$ and $x_{t+q} - (x_{t+q} - E[x_{t+q}|I_t])$, respectively,

$$i_t = \beta_i(L)i_{t-1} +$$

$$+(1-\beta_{i,-1})\{i^T + \beta_{\pi,+k}([\pi_{t+k} - (\pi_{t+k} - E[\pi_{t+k}|I_t])] - \pi^T) + \beta_{x,+q}[x_{t+q} - (x_{t+q} - E[x_{t+q}|I_t])]\} + \nu_t$$

and rearranging, yields

$$i_t = (1-\beta_{i,-1})[r^* - (\beta_{\pi,+k} - 1)\pi^T] + (1-\beta_{i,-1})\beta_{\pi,+k}\pi_{t+k} + (1-\beta_{i,-1})\beta_{x,+q}x_{t+q} + \beta_i(L)i_{t-1} + \varepsilon_t$$

or

$$(8) \qquad i_t = (1-\beta_{i,-1})\beta_{0,+k} + (1-\beta_{i,-1})\beta_{\pi,+k}\pi_{t+k} + (1-\beta_{i,-1})\beta_{x,+q}x_{t+q} + \beta_{i,-1}i_{t-1} + \varepsilon_t$$

with $\beta_i(L) \equiv \beta_{i,-1}$, $\beta_{0,+k} \equiv i^T - \beta_{\pi,+k}\pi^T \equiv i^T - \pi^T - \beta_{\pi,+k}\pi^T + \pi^T \equiv r^* - (\beta_{\pi,+k} - 1)\pi^T$,

where $r^* \equiv i^T - \pi^T$ is the 'equilibrium' real interest rate and

(9) $$\varepsilon_t \equiv -(1-\beta_{i,-1})\{\beta_{\pi,+k}(\pi_{t+k} - E[\pi_{t+k}|I_t]) + \beta_{x,+q}(x_{t+q} - E[x_{t+q}|I_t])\} + \nu_t .$$

It can be seen in (9) that the error term ε_t is a linear combination of *forecast errors* of inflation and the output gap (in curly brackets) and the exogenous disturbance to the interest rate ν_t. It is thus orthogonal to any variable in the information set I_t available at time *t*.

5.2 Sketch of the Econometrics: GMM

Now let $\mathbf{z}_t$ denote a vector of variables within the central bank's information set at the time when the decision on the interest rate is made – that is, $\mathbf{z}_t \in I_t$. As Clarida-Galí-Gertler (1998), p. 1039, suggest, possible elements of $\mathbf{z}_t$ (and, thus, instruments in the econometric sense) include any lagged variables that help forecast inflation and output, as well as any contemporaneous variables that are uncorrelated with the current-period interest rate shock ν_t. Since $E[\varepsilon_t|\mathbf{z}_t] = 0$, (8) then implies the set of *orthogonality* conditions

(10) $$E[\{i_t - (1-\beta_{i,-1})(\beta_{0,+k} + \beta_{\pi,+k}\pi_{t+k} + \beta_{x,+k}x_{t+k}) - \beta_{i,-1}i_{t-1}\}\mathbf{z}_t] = 0 .$$

These orthogonality conditions provide the basis for the estimation of the parameters of interest, collected in the vector $\boldsymbol{\beta} \equiv (\beta_{0,+k}\ \beta_{\pi,+k}\ \beta_{x,+q}\ \beta_{i,-1})'$, applying the Generalized Method of Moments (GMM) due to Hansen (1982). Clarida, Galí and Gertler (1998, 2000) note that, by construction, the first component of $\{\varepsilon_t\}$ follows an MA(a) process, with $a = max\ \{k,q\} - 1$ and will thus be serially correlated unless $k = q = 1$.

For that reason, the GMM estimation should be carried out with a weighting matrix that is robust to autocorrelation, as we also do. Moreover, to the extent that the dimension of vector $\mathbf{z_t}$ is *higher* than the number of parameters to estimate, (10) implies some *over*identifying restrictions that can be tested in order to assess the validity of the specification estimated as well as the set of instruments used. We present such test statistics in Table 2 in the Appendix and discuss them further down. The test rests on the logic exposed in Clarida, Galí and Gertler (1998), pp. 1040-1041.

Finally, (8) can be written as

(11) $$i_t = b_{0,+k} + b_{\pi,+k}\pi_{t+k} + b_{x,+q}x_{t+q} + b_{i,-1}i_{t-1} + \varepsilon_t ,$$

with

(12) $$b_{i,-1} \equiv \beta_{i,-1};$$

(13) $$b_{0,+k} \equiv (1-\beta_{i,-1})\beta_{0,+k} \text{, hence } \beta_{0,+k} \equiv \frac{b_{0,+k}}{1-b_{i,-1}};$$

(14) $$b_{\pi,+k} \equiv (1-\beta_{i,-1})\beta_{\pi,+k} \text{, hence } \beta_{\pi,+k} \equiv \frac{b_{\pi,+k}}{1-b_{i,-1}};$$

(15) $$b_{x,+q} \equiv (1-\beta_{i,-1})\beta_{x,+q} \text{, hence } \beta_{x,+q} \equiv \frac{b_{x,+q}}{1-b_{i,-1}}.$$

We estimated directly via GMM equation (11) and then recovered the *structural*-form parameters (the β's) from the *reduced*-form parameters (the *b*'s) using the correspondence in the definitions (12) through (15). Standard errors for the policy responses of interest (the β's), reported in Table 2, were consequently computed by an application of the delta method.[12]

6. Key Results

Let us now look in more detail at our key results. Table 1 in the Appendix presents descriptive statistics for the data in our two subsamples, *before* (Panel A) and *after* (Panel B) operational independence. Figure 1 provides, in turn, an overall impression for the evolution of the 3-month Treasury bill rate in the UK throughout the inflation targeting period, as well as by subsample. We estimated via GMM the *forward*-looking Taylor rule specification in equation (11) with the *lead* for inflation varying from 1 to 8 quarters ahead, $k = 1,...,8$, and that for the output gap from 0 to 4, $q = 0,...,4$. We then selected our 'best' regressions obtained from *real-time* (and nsa) vs *final* (and sa) data, as defined below and highlighted in Table 2 and figures 2-5 in the Appendix.

We analyze and interpret our principal findings along two dimensions. We start by some comments on the parameters of the central bank's reaction function extracted from the UK data, essentially comparing their magnitudes before and after operational independence. We then move to a more general discussion of the stance of Bank of England's monetary policy. In both dimensions of the analysis, we would emphasize our quantitative results obtained from *real-time* (and nsa) data, and not *final* (and sa) data, for reasons that are made clear further down.

6.1 Bank of England's Policy Reaction Function under Inflation Targeting

Table 2 reports the policy response coefficients from an identical forward-looking Taylor rule, equation (11) above, estimated over the *pre*-independence subsample (Panel A) and over the *post*-independence subsample (Panel B). In it, the leads of $k = 2$ for inflation and of $q = 0$ for the output gap were retained as the preferred ones across all attempted specifications, from the viewpoint of both econometrics and economics.

To judge about the magnitude of the parameters in the Bank of England's policy reaction function, we had to also make a choice concerning the appropriate variable proxies. Otherwise the results vary, sometimes considerably in quantitative terms, although rather weakly in a qualitative sense. We present two types of estimates, based on two particular sets of underlying quarterly data, namely, what can be called 'real-time' data and 'final' data. Thus, the first two columns in Table 2 (in panels A and B) report our estimates based on 'real-time' data, that is, the RPIX (nsa) to calculate inflation, the 3-month Treasury bill (nsa) to define the short-term interest rate and *real-time* GDP data to approximate the output gap; in the latter case, results from both Hodrick-Prescott and quadratic detrending are given. The last two columns in Table 2 (in panels A and B) compare, instead, the respective coefficients obtained from 'final' data, that is, when the RPI (sa) – and not the RPIX (sa)[13] – defines inflation, the 3-month Treasury bill (sa) serves as the short-term interest rate and *final* real GDP data approximate the output gap; again, estimates for both Hodrick-Prescott and quadratic detrending are reported. As can be verified in the last row of both panels A and B in Table 2, the *validity* of our overidentifying restrictions and of the set of our instruments cannot be rejected for all eight reported regressions.

The *combination* of the annual change in the RPIX (nsa) as an inflation proxy and real-time GDP data as a basis to approximate the output gap (reflected in the first, 'real-time' pair of columns in Table 2) was the policy relevant and only available set of information to the Bank of England at the time of actual monetary policy making. Moreover, this particular choice of variable proxies was also much better supported by our econometric results, relative to the *combination* of RPI (sa) and final GDP data (underlying the results highlighted in the last, ‘final’ pair of columns in Table 2). For example, the *goodness of fit* in Panel B for the final set of data appears unreasonably high; together with the very high lagged dependent variable coefficients, this is problematic and may be a sign of misspecification. Furthermore, the *statistical significance* of some of the coefficients of interest in the last two columns of Table 2 is not assured either.

Our findings confirm, first of all, the point made by Orphanides (2001, 2003): in all four specifications based on ‘real-time’ data the *goodness of fit* is high enough, but without being suspiciously high; then, all coefficients except one (15 out of 16) are *statistically significant* at all conventional levels; moreover, the positive expected *signs* of the response to both inflation and the output gap and the bounds well away from the extremes of 0 and 1 of the smoothing parameter are always satisfied. This is a second reason, in addition to realism (or relevance), to place greater weight and confidence on our estimates from the ‘real-time’ data set relative to the corresponding ‘final’ set.

We next look at the *magnitude* of the Bank of England’s reaction function coefficients, in particular before and after operational independence. As explained, we would mostly emphasize the *quantitative* dimension of our results obtained from the ‘real-time’ data.

Reaction to Inflation

What appeared to us unexpected, at least at an initial glance, was that the (positive) magnitude of the coefficient to inflation had *declined* in the post-independence subsample relative to the pre-independence subsample. More precisely, this decline –

captured by our ‘real-time’ (but not ‘final’) data – is rather moderate: the quadratic specification registers a drop of $\beta_{\pi,+2}$ from 0.67 to 0.50 and the Hodrick-Prescott one from 0.81 to 0.50 (with that latter coefficient only marginally insignificant at the 10% level). Interestingly, both estimated versions (quadratic and Hodrick-Prescott) agree exactly on the response to inflation after operational independence, which is quantified at 0.50. This particular magnitude as well as the higher values extracted from the ‘real-time’ data for the pre-independence period are furthermore smaller than unity, so that the policy response during the inflation targeting period has been rather mitigated (or inelastic). Most of our alternative specifications with various underlying proxies seem overall to confirm that the reaction to inflation has been somewhat weakened in the post-independence relative to the pre-independence sample (although an exception can be seen in the ‘final’ data columns of Table 2).

A likely reason for the weaker policy response to inflation can, of course, be the decline in the rate of inflation itself, observed since the mid-1990s not only in Britain but in most developed countries. This trend to lower inflation is partly due to more prudent and technocratic policy making in these countries, but also partly a consequence of a favorable economic environment both globally and nationally, as we shall see below for the UK. Hence, any precise quantification of the contribution of inflation targeting and operational independence to a lower inflation rate in Britain, as well as across the industrialized world, remains an issue for further study. Yet it would be difficult to deny the success of inflation targeting in anchoring inflation expectations, and here the UK case is particularly illustrative. Moreover, low and stable inflation would further contribute to growth, by stabilizing at a low level the real rate of interest. In this sense, exploring the implications of the assumption for a constant 'equilibrium' RIR, inherent in the Clarida-Galí-Gertler (1998, 2000) GMM approach we utilized, offers another avenue for future research.

Interest Rate Smoothing

According to our 'real-time' set of UK data, the degree of interest rate smoothing appears to have declined considerably in the post-independence period, of the order of two to three times. The corresponding 'final' data numbers in Table 2, however, suggest a slight increase. Therefore this matter is likewise left for additional investigation.

Reaction to the Output Gap

As far as the policy response to the output gap is concerned, our overall econometric results from both employed data sets were largely supportive – in qualitative and, to a substantial extent, also quantitative terms – to what Table 2 selectively reports in its first pair of columns. Most of our specifications that make good sense both economically and econometrically have produced *statistically significant* and *positive* estimates for the coefficient to the contemporaneous output gap, $\beta_{x,0}$. Moreover, they indicate almost unanimously (although an exception can be seen in the 'final' data Hodrick-Prescott column of Table 2) a *considerable rise* in the magnitude of this parameter in the *post*-independence period: of the order of two times and a half, according to the 'real-time' data set. This quite robust finding at first appeared puzzling. In trying to understand it, we had to relate it to the stage of the business cycle, in particular, before and after operational independence.

Let us compare the (dominant) phase of the UK business cycle by looking again at the descriptive statistics in Table 1 (panels A vs B). The mean output gap in 1992:4-

1997:1 has been of the order of -0.38% of potential output (Hodrick-Prescott measure) to -1.24% (quadratic measure) if *final* GDP data are used and of the order of -0.34% (Hodrick-Prescott measure) to -0.97% (quadratic measure) with *real-time* GDP data instead; the same statistic for the period of operational independence, 1997:3-2004:4 (or 2001:4 for *real-time* GDP data), is of the order of 0.07% (Hodrick-Prescott measure) to 0.16% (quadratic measure) if *final* GDP data are used and of the order of 0.11% (Hodrick-Prescott measure) to -0.05% (quadratic measure) with *real-time* GDP data. This dimension of our analysis makes clearly the point that the Bank of England has reacted in a much stronger way to the output gap when aggregate demand has, on average, been close(r) to potential, thus creating inflationary pressures, i.e., (mostly) during the post-independence period. Such evidence is consistent with New Keynesian theory, in particular under inflation targeting when the primary (if not the only) concern of the central bank is to keep low and stable inflation. The monetary authority should react more aggressively to the output gap (for theoretical reasons), and did seem to act so (in our empirical results), in a stage of the business cycle *above* or *close to* potential output when inflationary pressures increase and put at risk the credibly stabilized inflation at target.

6.2 Bank of England's Monetary Policy Stance under Inflation Targeting

To discuss now the *stance* of British monetary policy in the spirit of Taylor (1993), we re-estimated equation (11) with $k = 2$ and $q = 0$ over the *whole* inflation targeting period (and using both our final and real-time data sets). We begin by noting the following facts. First, the 3-month Treasury bill rate has been mostly trending up before operational independence and down after that; second, its average level has also been lower in the post-independence subsample (see Figure 1 and, for numerical values, Table 1). Insofar as Bank of England's monetary management has affected this short-term reference rate, an evident lesson from the UK experience is that inflation targeting coupled with operational independence does not necessarily imply an upward pressure on interest rates, as supporters of a more 'activist' monetary policy might claim.

Again, we have to distinguish our results from the 'real-time' vs 'final' data sets, placing more weight on the former – for economic and econometric reasons as we argued.

Final Data Taylor Rules: Good Overall Fit for the UK with a 'Neutral' Stance

Similarly to the original article by Taylor (1993) on US data, figures 2 (with Hodrick-Prescott detrending to obtain the output gap) and 3 (with quadratic detrending) – both based on our 'final' data set – convince in the very good visual fit *ex post* in the UK case under inflation targeting as well: the Taylor-rule implied interest rate and the actual one move quite close to one another. The Hodrick-Prescott version, in Figure 2, performs marginally better in that sense.

Both figures also agree in hardly identifying evident episodes of any *persistent* stance – either expansionary or contractionary – of Bank of England's monetary policy. This can be verified by noting that the peaks and troughs of the residual in the two figures rarely go out of the band of plus/minus one standard deviation; and when they do so, it lasts for only one quarter. More importantly, judging by these figures it turns out (ex post) that UK monetary policy has been overall just right, or 'neutral', throughout the inflation targeting period.

Real-Time Data Taylor Rules: Monetary Tightening and Easing in the UK

Looking at the same pair of graphs but now computed from our ‘real-time’ data, in figures 4 and 5, the picture is different. There are much clearer indications for a ‘non-neutral’ stance of monetary policy during certain periods within and across the two subsamples, again roughly coinciding regardless the detrending method applied to measure the output gap. These findings, being based on ‘real-time’ data, are more relevant in describing what kind of monetary policy the Bank of England *had wished* to conduct *ex ante*.

We can easily identify as periods of an *expansionary* stance the first half of 1996 (2 consecutive quarters), the second half of 1998 and the first half of 1999 (4 consecutive quarters), and the whole of 2001 (roughly, 4 consecutive quarters). At the same time, our preferred forward-looking Taylor rule specifications uncover only one important episode of a *contractionary* stance, the entire year of 1993 (roughly, 4 consecutive quarters). This latter episode of monetary tightening is obviously a consequence of the developments in the British economy and in the institutional framework for monetary policy during the previous year – namely, the ERM crisis of the summer of 1992 and the shift to inflation targeting in the autumn of 1992. More precisely, having moved to a new monetary regime after suffering an exchange rate panic, the Bank of England had to restore stability of the sterling as well as its own credibility. The brief episode of monetary easing in early 1996, on the other hand, could be attributed to an attempt for a slight boost to the economy, meanwhile recovering from the recession of 1992-1993; by that time, the sterling had largely restored its value and the Bank of England had considerably improved its credibility. As for the longer episodes of an expansionary stance, in 1998-1999 and again throughout 2001, these may have finally been due to the Bank trying to counterweigh some recessionary trends and related fears, mostly originating in the neighboring European economies but also in the US, given that by the late 1990s inflation expectations in the UK had already been firmly anchored at the target inflation of 2.5% p.a.

7. Concluding Comments

This paper recovered and evaluated empirically the reaction function and the stance of UK monetary policy under inflation targeting, in effect since October 1992. Our key contribution was to compare two major subsamples, before the Bank of England was granted operational independence from HM Treasury in May 1997 and after that. The econometric approach we employed, theoretically grounded within the New Keynesian model of monetary policy, relied on estimating forward-looking Taylor rules via GMM from quarterly data. Our main conclusions are as follows.

The use of *real-time* vs *final* data matters – mostly in a quantitative sense and less so in a qualitative sense – when describing by forward-looking Taylor rules the policy stance and the reaction function of the Bank of England throughout the inflation targeting period. As also claimed in the related literature, the feedback rules based on real-time data provide a more reasonable description, in both an econometric and economic context, of recent UK monetary policy relative to the same equations based on final data.

Our estimates from real-time data, which are the relevant information set for policy making in 'real time', indicate that the dominant *stance* of UK monetary policy has been different in the pre- and post-independence subsamples. It is characterized by one contractionary episode and one expansionary episode before the Bank of England was granted operational independence and two longer expansionary episodes after that. These findings appear consistent with the UK economic and institutional environment of the time.

Our forward-looking Taylor rules based on real-time data also uncover an asymmetric monetary policy *reaction function* of the Bank of England, in the sense that its response to the output gap was considerably stronger in the post-independence subsample and to inflation somewhat weaker. We have argued that this result seems in line with New Keynesian theory of monetary policy once the stage of the UK business cycle is taken into account. Such a behavior may therefore characterize British inflation targeting under operational independence as less rigid than the recently criticized rather 'monetarist' strategy of the European Central Bank but also less 'Keynesian' than the monetary policy of the Federal Reserve, legally granted – and apparently often recurring to – more discretion in accommodating shocks.

Overall, we have thus presented evidence that helps overcome several potential prejudices against inflation targeting, the more so when implemented under a greater central bank autonomy, as a too mechanistic 'rule' that leaves no room for 'discretion'. In particular, for the United Kingdom, we find that inflation targeting coupled with operational independence does not necessarily generate a deflationary bias in monetary policy, neither a 'benign neglect' to the evolution of the business cycle. In fact, the operational independence subperiod has been different from the pre-independence one in terms of lower interest rates, inflation stabilized very close to target, less restrictive stance of monetary policy, and stronger sensitivity of the Bank of England to the output gap. Such a reaction would, first of all, characterize the Bank as a *flexible* inflation targeter, as should be expected given the broader objectives of UK monetary policy. Second, the asymmetry in the feedback function appears justified and deserves credit: the Bank of England has optimally been balancing between the ‘rule’ (inflation targeting) and ‘discretion’ (operational independence), given the delegated institutional objective (the inflation target) and the constraint of the evolving economic environment (the business cycle).

Endnotes

1. No matter the slight conceptual difference, *inflation targeting* is, in practice, rather *inflation-forecast targeting*. We shall further down simply refer to inflation targeting, formally meaning in the UK context inflation-forecast targeting.

2. The narrower term of *operational independence (of the central bank)*, and not the more general notion of *central bank independence*, is the appropriate one for the UK case. The move to operational independence essentially allowed the Bank of England to set interest rates, earlier the task of HM Treasury.

3. A companion paper, Mihailov (2005), addresses a related question: whether, and how, increased independence has affected the behavior of the Bank of England within the inflation targeting period. It goes beyond the GMM technique applied to forward-looking Taylor rules and the final vs real-time data opposition to offer a unifying interpretation of the Bank's reaction function in terms of a few general findings that survive across alternative estimation methods and data availability timing.

4. For a concise summary of the general criticisms of interest rate rules, see Woodford (2003), chapter 1, section 4.2, pp. 44-49.

5. The main reason for this exclusion has been claimed to be that the mortgage rate tends to move closely with Bank of England's operating instrument.

6. The normative implication has emerged from stochastic simulation of a number of econometric models Taylor (1993) and Henderson and McKibbin (1993) undertook and published at nearly the same time.

7. Which is the short-term interest rate target for monetary policy in the US context.

8. Including also – in addition to the currently used *repo rate* – the *bank rate* (through September 1972), the *minimum lending rate* (October 1972 – July 1981) and the *minimum band 1 dealing rate* (August 1981 – April 1997), as can be learnt from the BoE website.

9. Detailed results from our *seasonality* tests are available upon request.

10. Detailed results from our *stationarity* tests are available upon request.

11. Another recent estimation technique, which we do not pursue here, was implemented by Muscatelli, Tirelli and Trecroci (2000). They apply the structural time series (STS) approach proposed by Harvey (1989) to *generate* series of the *expected* inflation rate and output gap. By contrast, the Clarida-Galí-Gertler (1998, 2000) GMM approach essentially consists in using the *errors-in-variables* method to *model* rational expectations: in it, instead of forecasting inflation and output (e.g., by Kalman filter methods, as in Muscatelli-Tirelli-Trecroci (2000)), future *actual* values replace as regressors *expected* values, as we explain in detail further down in the main text.

12. A technical appendix in Mihailov (2005) describes in detail the derivation of the formulas used for computation in the programs.

13. Our results when combining the RPIX (sa) with *final* data for real GDP – and with the 3-month Treasury bill (sa) – are quite unsatisfactory in econometric terms and, moreover, cannot be interpreted in a reasonable economic way. For this reason, we do not report such estimates here.

References

[1] Bank of England, website: http://www.bankofengland.co.uk/index.htm.

[2] Calvo, G. “Staggered prices in a utility-maximizing framework”, *Journal of Monetary Economics* 12 (3, September), 1983, 383-398.

[3] Clarida, R., Galí, J., and Gertler, M. “Monetary policy rules in practice: some international evidence”, *European Economic Review* 42 (6, June), 1998, 1033-1067.

[4] Clarida, R., Galí, J., and Gertler, M. “The science of monetary policy: a New Keynesian perspective”, *Journal of Economic Literature* 37 (4, December), 1999, 1661-1707.

[5] Clarida, R., Galí, J., and Gertler, M. “Monetary policy rules and macroeconomic stability: evidence and some theory”, *Quarterly Journal of Economics* 115 (1, February), 2000, 147-180.

[6] Goodfriend, M., and King, R. “The New Neoclassical Synthesis and the role of monetary policy”, *NBER Macroeconomics Annual* 12 (December), 1997, 231-283.

[7] Goodhart, C. “The objectives for, and conduct of, monetary policy in the 1990s”, in Blundell-Wignall, A. (ed.), *Inflation, Disinflation, and Monetary Policy*, Sydney: Ambassador Press, 1992, 315-344.

[8] Haldane, A. “Inflation Targets”, *Bank of England Quarterly Bulletin* 35 (3, August), 1995, 250-259.

[9] Hansen, L. “Large sample properties of generalized method of moments estimators", *Econometrica* 50 (4, July), 1982, 1029-1054.

[10] Harvey, A. C. *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge: Cambridge University Press, 1989.

[11] Henderson, D., and McKibbin, W. "A comparison of some basic monetary policy regimes for open economies: implications of different degrees of instrument adjustment and wage persistence", *Carnegie-Rochester Conference Series on Public Policy* 39 (December), 1993, 221-318.

[12] Kesriyeli, M., Osborn, D., and Sensier, M. "Nonlinearity and structural change in interest rate reaction functions for the US, UK and Germany", University of Manchester, *Centre for Growth & Business Cycle Research* Discussion Paper 044 (October), 2004.

[13] King, R., and Woolman, A. "Inflation targeting in a St. Louis model of the 21st century", *Federal Reserve Bank of St. Louis Bulletin* 78 (3, May/June), 1996, 83-107.

[14] Martin, C., and Milas, C. "Modelling monetary policy: inflation targeting in practice", *Economica* 71 (282, May), 2004, 209-221.

[15] Mihailov, A. "Has more independence affected Bank of England's reaction function under inflation targeting? Lessons from Taylor rule empirics", University of Essex, Department of Economics, Discussion Paper 601 (October), 2005.

[16] Muscatelli, A., Tirelli, P., and Trecroci, C. "Does institutional change really matter? Inflation targets, central bank reform and interest rate policy in the OECD countries", University of Munich, *CESifo* Working Paper 278 (April), 2000.

[17] Nelson, E. "UK monetary policy 1972-97: a guide using Taylor rules", in Mizen, P. (ed.), *Central Banking, Monetary Theory and Practice: Essays in Honour of*

Charles Goodhart, Vol. 1, Cheltenham and Northampton, MA: Edward Elgar, 2003, 195-216.

[18] Nelson, E., and Nikolov, K. “UK inflation in the 1970s and 1980s: the role of output gap mismeasurement”, *Centre for Economic Policy Research* Discussion Paper 2999 (October), London, 2001.

[19] Office of the National Statistics (ONS), United Kingdom, website: http://www.statistics.gov.uk/.

[20] Orphanides, A. “Monetary policy rules based on real-time data”, *American Economic Review* 91 (4, September), 2001, 964-985.

[21] Orphanides, A. “The quest for prosperity without inflation”, *Journal of Monetary Economics* 50 (3, April), 2003, 633-663.

[22] Svensson, L., “Inflation targeting as a monetary policy rule”, *Journal of Monetary Economics* 43 (3, June), 1999, 607-654.

[23] Svensson, L. “What is wrong with Taylor rules? Using judgment in monetary policy through targeting rules”, *Journal of Economic Literature* 41 (2, June), 2003, 426-477.

[24] Taylor, J. “Discretion versus policy rules in practice”, *Carnegie-Rochester Conference Series on Public Policy* 39 (December), 1993, 195-214.

[25] Taylor, J. “The role of the exchange rate in monetary policy rules”, Stanford University, mimeo, 2000.

[26] Vickers, J. "Inflation targeting in practice: the UK experience", *Bank of England Quarterly Bulletin* 38 (4, November), 1998, 368-375.

[27] Walsh, C. *Monetary Theory and Policy*, Cambridge, MA: MIT Press, 2003 (2nd ed.).

[28] Wicksell, K. *Geldzins und Güterpreise*, Jena: Gustav Fischer, 1898. *Interest and Prices*, English translation by Kahn, R., London: Macmillan, for the Royal Economic Society, 1936. Reprinted New York: Augustus M. Kelley, 1962.

[29] Wicksell, K. "The influence of the rate of interest on prices", *Economic Journal* 17 (66, June), 1907, 213-220.

[30] Woodford, M. *Interest Rates and Prices*, Princeton and Oxford: Princeton University Press, 2003.

[31] Yun, T. "Nominal price rigidity, money supply endogeneity, and business cycles", *Journal of Monetary Economics* 37 (2, April), 1996, 345-370.

Appendix: Tables and Figures

1992:4 – 1997:1									
	Inflation, % pa		RGDP growth, % pa		3m TB, % pa	RGDP gap, % of potential			
	RPI	RPIX	Fin	RT		HP Fin	Q Fin	HP RT	Q RT
Mean	2.48	2.80	2.92	2.98	5.79	-0.38	-1.24	-0.34	-0.97
Median	2.54	2.81	2.84	2.77	5.76	0.04	-0.73	0.02	-0.49
Max	3.60	3.62	4.68	4.97	6.73	0.65	-0.11	0.95	0.20
Min	1.29	2.17	0.99	0.87	4.95	-2.15	-3.09	-2.35	-2.38
SD	0.65	0.35	1.03	1.13	0.58	0.97	1.04	1.06	1.10
J-B p-v	0.79	0.81	0.94	0.82	0.57	0.23	0.26	0.35	0.29
# obs	18	18	18	18	18	18	18	18	18

Panel A: *Pre*-Independence Subsample

1997:3 – 2004:4 (or 2001:4 for real-time GDP data)									
	Inflation, % pa		RGDP growth, % pa		3m TB, % pa	RGDP gap, % of potential			
	RPI	RPIX	Fin	RT		HP Fin	Q Fin	HP RT	Q RT
Mean	2.50	2.34	2.74	2.71	5.09	0.07	0.16	0.11	-0.05
Median	2.66	2.27	2.73	2.82	4.85	0.10	0.24	0.15	-0.05
Max	3.94	2.90	4.33	3.55	7.50	0.90	1.60	0.61	0.64
Min	1.04	1.85	1.52	1.63	3.50	-0.85	-1.25	-0.68	-1.35
SD	0.83	0.31	0.71	0.59	1.20	0.46	0.87	0.37	0.50
J-B p-v	0.36	0.40	0.69	0.57	0.35	0.70	0.43	0.50	0.35
# obs	30	30	30	30	30	30	30	18	18

Panel B: *Post*-Independence Subsample

Table 1: Descriptive Statistics of the Data for the UK under Inflation Targeting

Note to Table 1 (panels A and B): RGDP = Real GDP; 3m TB = 3-month Treasury bill rate; RT = real-time (data); Fin = final (data); HP = Hodrick-Prescott (detrending); Q = quadratic (detrending); SD = standard deviation; J-B p-v = Jarque-Bera statistic probability value (for testing the null of normality of regression residuals); # obs = number of observations.

Data:	'Real-time' ≡ RPIX (nsa) and real-time GDP, 1992:4–1997:1 (18 observations)		'Final' ≡ RPI (sa) and final GDP, 1992:4–1997:1 (18 observations)	
GDP filter:	Quadratic	Hodrick-Prescott	Quadratic	Hodrick-Prescott
$\beta_{0,+2}$	4.58***(0.38)	3.49***(0.47)	6.73***(1.46)	3.46***(0.34)
$\beta_{\pi,+2}$	0.67***(0.19)	0.81***(0.14)	0.27 (0.30)	0.83***(0.07)
$\beta_{x,0}$	0.63***(0.05)	0.97***(0.04)	0.60***(0.18)	0.57***(0.07)
$\beta_{i,-1}$	0.56***(0.03)	0.60***(0.02)	0.70***(0.04)	0.65***(0.02)
Adj R^2	0.66	0.68	0.64	0.78
OvId p-v	0.81	0.82	0.89	0.82

Panel A: *Pre*-Independence Subsample

Data:	'Real-time' ≡ RPIX (nsa) and real-time GDP, 1997:3–2001:4 (18 observations)		'Final' ≡ RPI (sa) and final GDP,1997:3–2004:4 (28 observations, 2 degrees of freedom lost)	
GDP filter:	Quadratic	Hodrick-Prescott	Quadratic	Hodrick-Prescott
$\beta_{0,+2}$	4.75***(0.27)	4.52***(0.26)	0.61 (0.56)	-1.96 (2.18)
$\beta_{\pi,+2}$	0.50***(0.16)	0.50 (0.29)	1.70***(0.11)	3.52***(0.42)
$\beta_{x,0}$	1.79***(0.06)	2.50***(0.10)	0.74***(0.16)	-2.01* (1.15)
$\beta_{i,-1}$	0.37***(0.02)	0.17***(0.08)	0.72***(0.03)	0.93***(0.02)
Adj R^2	0.86	0.75	0.93	0.91
OvId p-v	0.79	0.74	0.64	0.78

Panel B: *Post*-Independence Subsample

Table 2: Forward-Looking Taylor Rule Estimates for the UK under Inflation Targeting

Note to Table 2 (panels A and B): Estimation by GMM using a Newey-West weighting matrix robust to error autocorrelation and heteroskedasticity of unknown form; the instrument set includes 4 lags of all (3) variables in the estimated equation, (11), with $k = 2$ and $q = 0$, and a constant; standard errors in parentheses for the indirectly estimated (structural-form) coefficients (the β's) are computed via the delta method; ***, **, * = statistical significance at 1, 5, 10% level, respectively, for the corresponding directly estimated (reduced-form) coefficients (the b's); Adj R^2 = adjusted R^2; OvId p-v = probability value of the Hansen test of (9 = 13 instruments – 4 parameters to estimate) overidentifying restrictions.

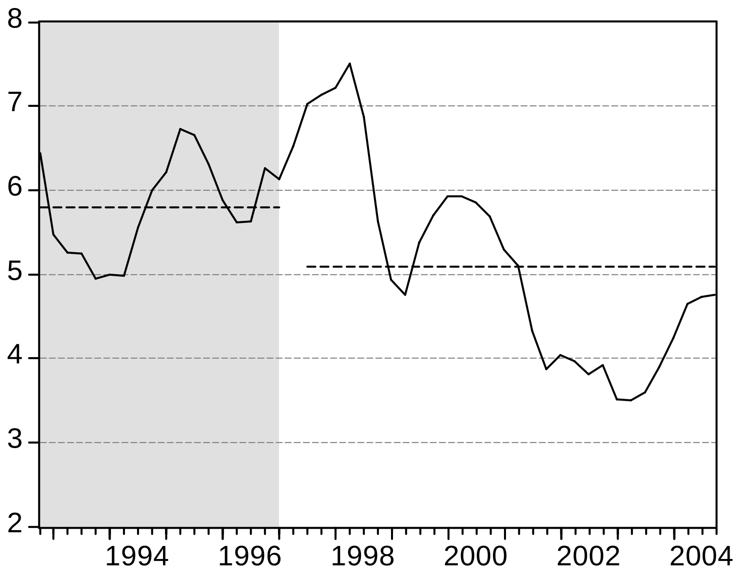

Figure 1:
Actual 3-Month Treasury Bill Rate, UK, 1992:4 – 2004:4 (49 observations), % p.a., dashed lines indicate average level by subsample, shaded area denotes pre-independence period.

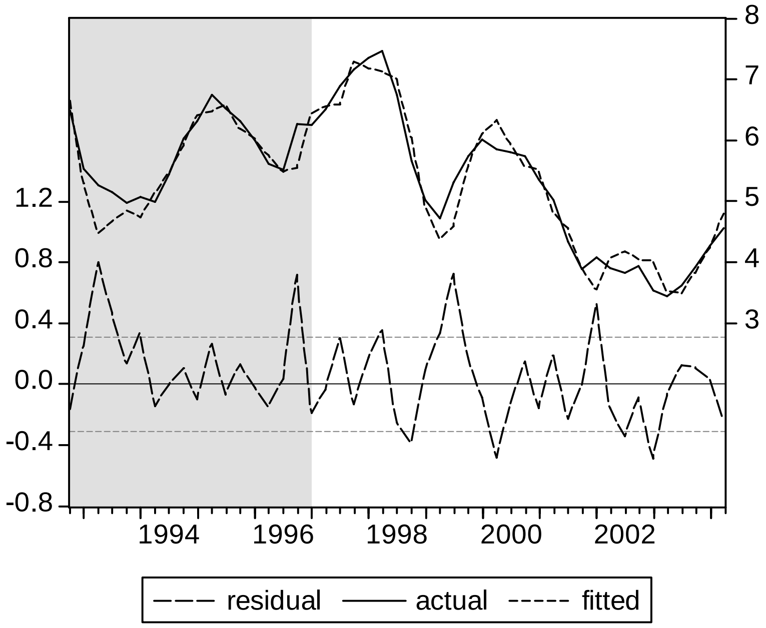

Figure 2:
Actual and Taylor-Rule Fitted 3-Month Treasury Bill Rates, UK, 1992:4 – 2004:2 (47 observations), % p.a., 'final' (and sa) data, Hodrick-Prescott trend to obtain real GDP gap, shaded area denotes pre-independence period; fitted values obtained after estimating equation (11) via GMM, as explained in the Note to Table 2, over the whole sample.

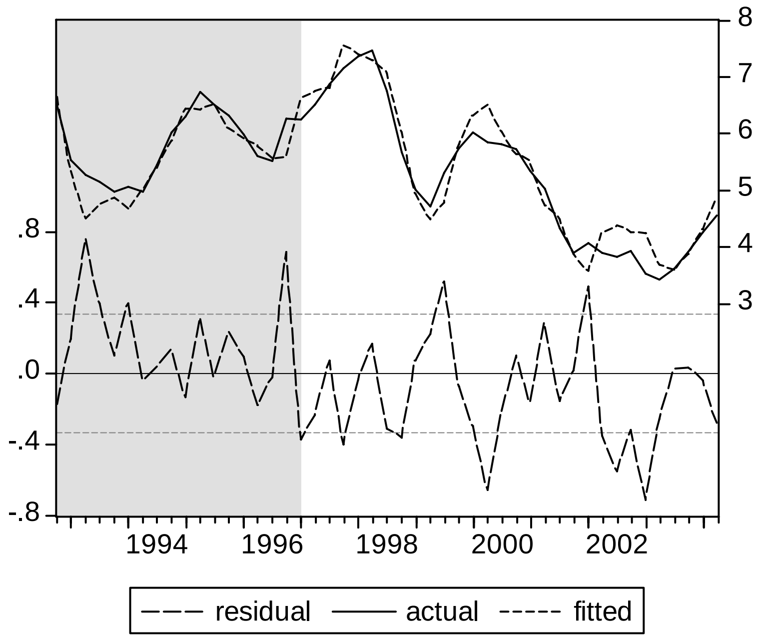

Figure 3:
Actual and Taylor-Rule Fitted 3-Month Treasury Bill Rates, UK, 1992:4 – 2004:2 (47 observations), % p.a., 'final' (and sa) data, quadratic trend to obtain real GDP gap, shaded area denotes pre-independence period; fitted values obtained after estimating equation (11) via GMM, as explained in the Note to Table 2, over the whole sample.

Figure 4:
Actual and Taylor-Rule Fitted 3-Month Treasury Bill Rates, UK, 1992:4 – 2001:4 (37 observations), % p.a., 'real-time' (and nsa) data, Hodrick-Prescott trend to obtain real GDP gap, shaded area denotes pre-independence period; fitted values obtained after estimating equation (11) via GMM, as explained in the Note to Table 2, over the whole sample.

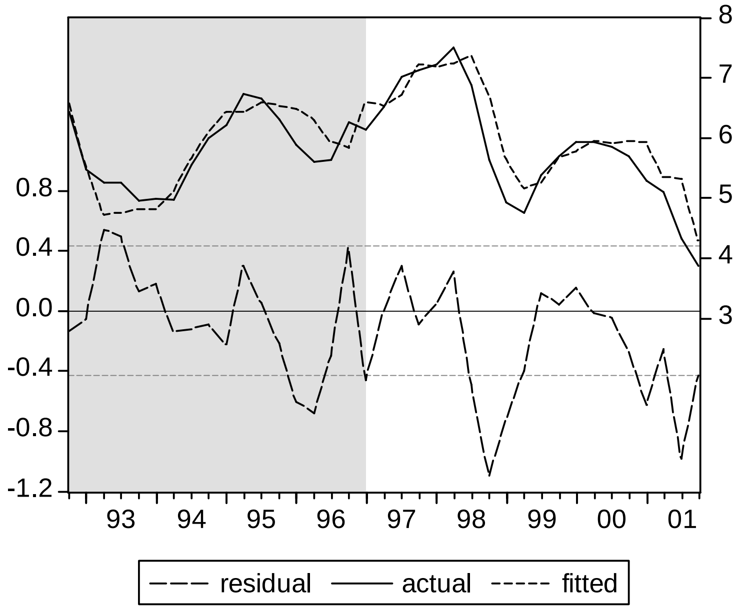

Figure 5:
Actual and Taylor-Rule Fitted 3-Month Treasury Bill Rates, UK, 1992:4 – 2001:4 (37 observations), % p.a., 'real-time' (and nsa) data, quadratic trend to obtain real GDP gap, shaded area denotes pre-independence period; fitted values obtained after estimating equation (11) via GMM, as explained in the Note to Table 2, over the whole sample.