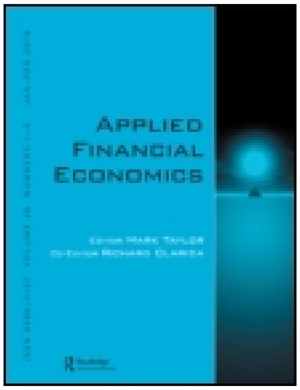

Applied Financial Economics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rafe20

The British opt-out from the European Monetary Union: empirical evidence from monetary policy rules

Stefano d'Addona[a] & Ilaria Musumeci[b]
[a] Department of Political Science, University of Rome 3, I-00145 Rome, Italy
[b] University of Rome 3, Rome, Italy

Applied Financial Economics, 2013
Vol. 23, No. 23, 1783–1795, http://dx.doi.org/10.1080/09603107.2013.851768

The British opt-out from the European Monetary Union: empirical evidence from monetary policy rules

Stefano d'Addona[a,*] and Ilaria Musumeci[b]

[a]*Department of Political Science, University of Rome 3, I-00145 Rome, Italy*
[b]*University of Rome 3, Rome, Italy*

We analyse the current state of monetary integration in Europe, focusing on the United Kingdom's position regarding the European Monetary Union (EMU). The interest rate decisions of the European Central Bank and the Bank of England are compared through different specifications of the Taylor rule. Comparison of the monetary conduct of these two institutions provides useful guidance in identifying the differences that the British Government claims motivating its refusal to join the EMU. Testing for forward-looking behaviour and possible asymmetries in policy responses, we show evidence supporting the opt-out decision taken by the British Government.

Keywords: Taylor rule; European monetary integration; regime switching models; interest rate smoothing

JEL Classification: E32; E52; E44

I. Introduction

In 1992, the UK opted out of the third stage of the European economic and monetary union as a condition for its adoption of the Maastricht Treaty. Under the provisions of the opt-out, the UK follows an independent monetary policy and maintains the pound sterling, under a floating exchange rate regime against the Euro. Since the opt-out, participation by the UK in the European Monetary Union (EMU) has remained an open question, and the related debate is quite active[1] (see Artis, 2000; Buiter, 2000; Minford, 2002; Minford *et al.*, 2004; Buiter, 2008; among others).

In this article, we compare ECB and BoE monetary policies to test the lack of monetary convergence claimed by the British Government as the motivation behind its refusal to join the EMU. In so doing, we use a Taylor rule approach.

Introduced by Taylor (1993), the 'rule' is defined in terms of the conduct of monetary policy; interest rates are systematically set in response to upward or downward

*Corresponding author. E-mail: daddona@uniroma3.it

[1] To assess whether the adoption of a single currency under the sovereignty of the European Central Bank (ECB) was in the UK's economic interest in 1997, the British Government set out five economic tests concerning the status of the convergence between the economic systems of the UK and the Eurozone. The last assessment of the five tests, performed in 2003, gave a negative outcome, which confirms the 1992 decision to opt out (see Potton and Mellows-Facer, 2003). The potential benefits of a monetary union were indeed acknowledged (cf. Brown, 2003), however, the lack of cyclical convergence still stands as one of the UK's principal concerns because of a potentially higher likelihood of asymmetric shocks occurring within the Eurozone.

deviation in the inflation rate from its target, and to shortfall in output from its potential level. A vast empirical literature which followed the introduction of the Taylor rule (for a comprehensive review see Sauer and Sturm, 2003) and several theoretical modifications were proposed. In particular, Clarida *et al.* (1998) introduce expectations in the model, while Sack and Wieland (2000) discuss the role of interest rate smoothing.

The empirical literature in this field covers both BoE and ECB monetary policy actions. A comprehensive study of BoE monetary choices is set forth in Nelson (2000), who estimates the Taylor rule for different subsamples based on relevant monetary changes between 1972 and 1997. Nelson (2000) finds that the response to inflation and the output gap varies within the chosen subsamples, showing that the *policy* priorities changed over time. In particular, this author argues that the commitment to price stability was not significant between 1987 and 1990 and that it became relevant only after 1992. McCallum (2000) compares the classic Taylor rule with an alternative policy where the monetary base is targeted by the BoE. This author's estimation shows that while both rules are able to catch the inflationary pressures of the 1970s, the monetary base instrument rule implies that policy was too loose during the middle and late '80s, whereas the Taylor rules does not.

As soon as the ECB officially began operations in 1998, many studies proposed an *ex ante* approach to future policy conduct in the Eurozone and compared this approach to monetary policy rules. By simulating an open economy model, Taylor (1999) argues that a simple benchmark rule like the Taylor rule is a good candidate, in terms of efficiency and robustness, to serve as a guideline for ECB monetary policy. In a similar setup, Peersman and Smets (1999) compare several monetary rules, simulating a closed-economy model based on five European countries. The authors show that the original Taylor rule does a good job in stabilizing inflation and output with no need for additional instrumental variables in the model. In an empirical contribution, Gerlach and Schnabel (2000) test the Taylor rule using a proxy of EMU monetary conduct by weighting economic data from 11 countries between 1990 and 1997. These authors find that the original Taylor rule performs well, with estimates of the coefficients close to those of Taylor (1993). They also test a forward-looking specification augmented with several economic variables as controls, yielding similar results. As a first test of the Taylor rule based on the EMU data, Sauer and Sturm (2003) compare the monetary conduct of the ECB and the Bundesbank. Testing both a classic Taylor rule and a forward-looking one, these authors argue that the ECB inherited the *conservative* approach of the Bundesbank.

Building on this literature, we test the Taylor rule in its basic form and relevant extensions for both the ECB and the BoE. The robustness of results is checked through introducing both forward-looking expectations (see Clarida *et al.*, 1998) and interest rate smoothing (see Sack and Wieland, 2000) in our estimation. Following Gerlach and Schnabel (2000), we introduce additional instrumental variables to control the role of exchange rates and monetary markets.

Finally, we complete our analysis by comparing central banks behaviour in different phases of the business cycle. In its basic formulation, the Taylor rule implies a symmetric behaviour by central banks in setting interest rates. This implicit hypothesis was recently challenged in the literature both empirically and theoretically. On the empirical side, recent contributions show evidence of nonlinearities for three European countries (Germany, France and Spain) and the US monetary policies (see Dolado *et al.*, 2004, 2005). Taylor and Davradakis (2006) detect an empirical asymmetry in the BoE's response to the fluctuations of the inflation rate around its target; Surico (2007b) investigates the presence of nonlinearities in the European Central Bank monetary policy. On the theoretical side, nonlinearities in policy response are explained via: (i) nonlinearities in the underlying aggregate supply schedule (see Nobay and Peel, 2000); (ii) nonlinear preferences on the part of policymakers (e.g., Surico, 2007a; Cuckierman and Muscatelli, 2008) and (iii) uncertainty in economic fundamentals (see Meyer *et al.*, 2001).

To test the potential nonlinearities in the ECB and BoE reaction functions we compare their monetary policy responses among different states of the economy. Following this purpose, we introduce a Markov Regime Switching framework. Markov Regime Switching allows for discrete regime changes which are governed by an exogenous and unobservable transition process.[2] This exercise enables to account for shifts in monetary policy due to exogenous economic downturns. Among the empirical contributions on this field, Markov (2010) compares actual and perceived regime-dependent Taylor rules for the ECB. Altavilla and Landolfo (2005) compare the ECB and the BoE monetary policies through a Markov-Switching Vector Autoregressive (MS-VAR) Model. In their study, the coefficients of the Taylor Rule are derived from the estimation of a regime-dependent VAR. The variables structuring this model follow a recursive order and all the parameters governing their generating process depend on a

[2] As an alternative approach, Smooth Transition Regression (STR) models assume a regime shifting process that is related to high and low inflation thresholds or to the gradual transition of target variables. See Martin and Milas (2005) for an empirical application of this gradual regime switching approach to the BoE inflation targeting commitment; see Gerlach and Lewis (2010) for a focus on the ECB monetary policy. See Castro (2008) for a comparison between the two.

latent state variable which follows a two-regime Markov Chain. In this setting, the Taylor Rule is nested inside the VAR model as a regime-dependent interest rate equation and, given this setup, it is backward-looking.

Our investigation follows a quite different approach. First, we model an economy that switches between two unobservable states. We assume that an agent (i.e., the central banker) interprets an external signal (namely, GDP growth) and infers the probabilities of moving from one regime. Second, these *state beliefs*, then, are used as weights to adjust the Taylor Rule as the central banker reaction function dependent on the state of the economy. Different from the MS-VAR methodology, this procedure allows us to rely on both a contemporary and a forward-looking specification of the Taylor Rule. Therefore, although the regime shifts are governed by an exogenous and unobservable process, we can still provide an insight of the nonlinearities in ECB and the BoE's strategies over the business cycle.

This article proceeds as follows: Section II introduces the theoretical framework behind the monetary rules. In Section III, we describe the data and explain in details our empirical strategy. Section IV presents our results and Section V sets forth our conclusions.

II. Methodology

The baseline monetary policy reaction function used in our empirical exercise is a classic Taylor rule, specified as

$$i_t = i^* + \beta(\pi_t - \pi^*) + \gamma(y_t - y^*) \tag{1}$$

where i^* is the steady-state value of the nominal interest rate, π_t is the current inflation rate, π^* is the inflation target set by the central bank, y_t is the real output of the economy and y^* is potential level of output.

We estimate this equation's empirical counterpart as

$$i_t = \alpha + \beta\pi_t + \gamma g_t + \upsilon_t \tag{2}$$

where $\alpha = i^* - \beta\pi^*$ defines the real interest rate, $g_t = (y_t - y^*)$ is the output gap and υ_t is an independent and identically distributed (i.i.d.) normal error term.

As a second step, we investigate whether central bankers respond to anticipated inflation rather than realized inflation. To do this, we follow Clarida *et al.* (1998) in specifying the monetary policy reaction function as

$$\hat{i}_t = i^* + \beta(\mathrm{E}_t[\pi_{t+n}] - \pi^*) + \gamma(y_t - y^*) \tag{3}$$

where the actual rate is partially adjusted to the specified target $(\hat{i}_t)$ to account for smoothing behaviour by central bankers (see Goodfriend, 1991; Sack and Wieland, 2000, among others)

$$i_t = (1-\rho)\hat{i}_t + \rho i_{t-1} + \varpi_t \tag{4}$$

where i_{t-1} is the lagged interest rate, ρ is the coefficient capturing the degree of smoothing of the interest rate and ϖ_t is a standard i.i.d. error term. By combining Equation 3 and 4, we obtain the estimable equation

$$i_t = \alpha^* + \beta^*\mathrm{E}_t[\pi_{t+n}] + \gamma^* g_t + \rho i_{t-1} + \varpi_t \tag{5}$$

where $\alpha^* = \alpha(1-\rho)$, $\beta^* = \beta(1-\rho)$ and $\gamma^* = \gamma(1-\rho)$

Regime switching model

To investigate whether central bankers respond asymmetrically to business cycles, we can specify the monetary reaction functions introduced above (Equations 2 and 5) in a regime switching economy. We model an economy where output switches between (unobservable) states, and an agent (i.e., a central banker) infers the probabilities of being in a particular state from the output realizations. The inferred probabilities are then used in the monetary policy decisions.

Specifically, we consider the economy in a regime switching model, where its latent state is indicated by s_t. We assume that s_t follows a hidden Markov chain with transition probabilities matrix P (see Hamilton, 1989).

The two reaction functions (2) and (5) are then specified as regime dependent policy rules, as follows:

$$i_t = \alpha(s_t) + \beta(s_t)\pi_t + \gamma(s_t)g_t + \upsilon_t \tag{6}$$

$$i_t = \alpha^*(s_t) + \beta^*(s_t)\mathrm{E}_t[\pi_{t+n}] + \gamma^*(s_t)g_t + \rho^*(s_t)i_{t-1} + \varpi_t \tag{7}$$

Agents cannot directly observe the state of the economy, s_t, and they must rely on interpreting external signals. In our specification, we use as a signal of the state of the economy, the output growth rate ($\Delta \log y_t$), which is supposed to follow a state-dependent process in its mean (μ), with i.i.d. normal innovations with volatility (σ). Thus, the agents update their belief according to the posterior probabilities, computed as

$$\hat{\xi}_{t|t} = \frac{\hat{\xi}_{t|t-1} \odot \zeta_t}{\mathbf{1}'\left(\hat{\xi}_{t|t-1} \odot \zeta_t\right)} \tag{8}$$

where $\odot$ denotes the Hadamard product, and ζ_t is a vector that stacks the conditional densities of the output growth rates, as follows:

$$\zeta_t = \begin{bmatrix} f(\Delta \log y_t | s_t = 1, \Omega_{t-1}) \\ \vdots \\ f(\Delta \log y_t | s_t = n, \Omega_{t-1}) \end{bmatrix} \tag{9}$$

with the density of $\Delta \log y_t$ conditional on state s_t, defined as

$$f(\Delta \log y_t | s_t = i, \Omega_{t-1}) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left\{ -\frac{(\Delta \log y_t - \mu(s_t))^2}{2\sigma^2} \right\} \tag{10}$$

where Ω denotes the information set.

III. Estimation and Data

Estimation procedure

Turning to the empirical method, we carefully address possible econometric biases that can arise when estimating the two response functions. In the baseline linear model, we account for possible serial correlation in the residuals by estimating Equation 2 with a Prais and Winsten (1954) procedure, correcting its SEs for heteroscedasticity.

The same baseline reaction function under the regime switching hypothesis requires a three-step procedure. First, we estimate the regime switching model using a Markov Chain Monte Carlo (MCMC) procedure on the output series. Here, we closely follow the algorithm described in Section 9.1 of Kim and Nelson (1999), obtaining the estimated state beliefs ($\hat{\xi}_{t|t}$).

Second, to account for possible serial correlation, we 'pre-whiten' the data and the regressors using the estimated serial correlation of residuals obtained from a standard OLS regression. In particular, we estimate the autocorrelation as

$$\hat{\delta} = \frac{\sum_{t=2}^{n} (e_t e_{t-1})}{\sum_{t=1}^{n} e_t^2}$$

where e are the residuals obtained by regressing the nominal interest rate on a constant, the inflation rate and the output gap. Then, we adjust both the regressors and the dependent variable according to

$$\tilde{Y}_{t+1} = Y_{t+1} + \hat{\delta} Y_t$$
$$\tilde{X}_{t+1} = X_{t+1} + \hat{\delta} X_t$$

where Y is the vector that stores the time series of the nominal interest rate and X is the matrix containing the inflation rate and the output gap.

Third, we estimate the policy function (6) by maximum likelihood using the state beliefs obtained from the MCMC estimation as weights for the monetary responses for each state of the economy. That is, we maximize[3]

$$\mathcal{L} = log(L)$$

with

$$L = \prod_t^T \hat{\xi}_{t|t}^i \left[\frac{1}{\sqrt{\pi\sigma_i^2}} exp\left(\left(\tilde{Y}_t - \hat{B}^i \tilde{X}_t \right) \left(\tilde{Y}_t - \hat{B}^i \tilde{X}_t \right)' / 2\sigma_i^2 \right) \right]$$

where ($i = 1, 2$) indicates the state of the economy, and $\hat{B}$ is the vector of coefficients to be estimated.

In the forward-looking extension of the model, we estimate the Equation 5 using the Generalized Method of Moments (GMM). The expected inflation is instrumented by the core harmonized inflation rate in order to control the role of 'underlying' price developments in the formation of inflation expectations.[4] Moreover, we employ the deviation of the monetary aggregate M3 from its target as an additional instrumental variable for the expected inflation in the EMU.[5]

Besides, as a robustness check, we follow Clarida *et al.* (1998) and estimate the equation

$$i_t = \alpha^* + \beta^* \pi_{t+n} + \gamma^* g_t + \theta z_t + \rho i_{t-1} + \varpi_t \tag{11}$$

where, consistently with Gerlach and Schnabel (2000), z_t indicates an additional control variable that accounts for the role of monetary and foreign exchange market. Specifically, we alternately use the money growth rate, the federal funds rate, the dollar/sterling and the euro/sterling real exchange rates.

Turning to the regime switching specification, we adopt a methodology similar to the three-steps procedure described for the baseline model to estimate Equation 7. After estimating the state beliefs ($\hat{\xi}_{t|t}$) with the MCMC

[3] See Lütkepohl (2007), Chapter 17.
[4] As the ECB states (ECB, 2001), core HICP is less volatile than the overall HICP for it excludes food and energy prices and filters out temporary pressures on the price level. Accordingly, core inflation conveys information about the forces that drive persistent price dynamics and expected inflation in the long-run. For this reason, the ECB employs core inflation as a key indicator for the comprehensive analysis of price stability on longer horizons. On the same pace, HM Treasury relies on core inflation as a supplementary variable for the regular assessment of expected inflationary pressures (See HM Treasury, 2013).
[5] The ECB assigns a considerable role to monetary aggregates within its 'two pillar strategy'. The link between M3 and inflation in the Eurozone is robust in the long run so that shifts in the trend of money growth tend to influence the future path of the inflation rate. Accordingly, the ECB regularly monitors the deviations of M3 growth from its reference value in order to anchor inflation expectations. In line with this approach, we include the deviations of the money growth from its trend among our instruments.

algorithm, we instrument the expected inflation rate using the same instruments as in the linear case. Finally, we estimate the policy function (7) again by maximum likelihood using the state beliefs obtained from the MCMC algorithm as weights for the monetary responses for each state of the economy.

Data

For our empirical tests we use quarterly data focusing, given availability, on the time period 1987–2012.[6] Data are taken mainly from the Area Wide Model (AWM) Database, constructed by Fagan *et al.* (2005), and from the OECD Main Economic Indicators database. Data from Eurostat, after being re-based to the same base year as the AWM data (1996), are used to complete the AWM series, which ends in the fourth quarter of 2009.

As a measure for short-term nominal interest rate of the Eurozone, we use the 3-month Euro Interbank Offered Rate (EURIBOR) while, for the UK we use the 3-month London Interbank Offered Rate (LIBOR).[7]

Inflation rates are computed as the percentage change in the price index for each quarter as compared with the same quarter in the preceding year. For the Eurozone, we use the Harmonized Index of Consumer Prices (HICP).

To estimate the UK inflation rate, we use a joint measure instead. Until 2003, UK inflation was officially measured by the Retail Price Index (RPIX). Since December 2003, HICP has been used. Accordingly, from 1987 to 2003 we measure inflation using the RPIX; then, from 2004 to 2010 the Core HICP (excluding energy and unprocessed food) is employed.[8]

As is standard practice in the literature, output gaps are identified by analysing data decomposed via a frequency filter. Our measure of cyclical output is obtained after applying the Hodrick and Prescott (1997) filter to the real industrial production series. The output gap is then measured as the percentage deviation of the index from its potential level.[9]

To estimate the regime switching model, we employ the quarterly real GDP growth rate for both the UK and the Eurozone over the time period 1987–2010.

Finally, the additional variables used to estimate the Equations 5 and 11 are constructed according to the following procedures:

- *Money Growth rate* is calculated as the percentage annual variation of the overall index of the monetary aggregate M3 provided by the OECD Statistics Portal.
- *Federal Funds Rates* are quarterly averages of monthly figures provided by the Federal Reserve Bank of New York.
- *Dollar/Sterling real exchange rate* is measured as the nominal Dollar per Sterling rate multiplied by a price deflator. The price deflator is constructed as the ratio of UK consumer price index and the US consumer price index for all urban consumers published by the Bureau of Labor Statistics. The nominal exchange rate is provided by the Federal Reserve Bank of New York.
- *Euro/Sterling real exchange rate* is calculated as a crossed rate between the Dollar/Sterling real exchange rate and the Dollar/Euro real exchange rate provided by The AWM Database, as set forth in Fagan *et al.* (2005).

IV. Results

The MCMC procedure outlined in Section ‘Regime switching model’ gives reassuring results when applied to the UK economy. The estimated probabilities of switching from the two states are 3.88% and 18.16%, respectively. This implies an average duration of 6 years for the state of high GDP growth rate, and slightly more than one year for the state of low GDP growth rate.

Figure 1 confirms that the model is able to detect the historical business cycles of the UK economy over the sample period. The model plots the estimated posterior probability of being in the low mean state, showing how the Markov switching model is able to capture UK recessions fairly well, as chronicled by official BoE business cycle dates[10] (gray areas in the graph).

Turning to the EMU economy, the MCMC estimates provide a probability of switching of 3.63% for the high mean state, and 17.60% for the low mean state. This implies an average duration of more than six years for the state of high GDP growth rate, and slightly more than one year for the state of low GDP growth rate.

The ability to detect the EMU business cycle is overall satisfactory. Figure 2 shows how the Markov switching

[6] According to Nelson (2000), in 1987 the UK engaged an informal linkage to the Deutsche Mark, and soon after that, before joining the Exchange Rate Mechanism in 1990, the BoE followed Bundesbank’s interest rate decisions as a nominal reference. Thus, it seems reasonable to begin the empirical analysis in 1987 in order to capture the monetary convergence/divergence between the BoE and the ECB, which inherited the Bundesbank’s policy approach.

[7] Previous contributions (see, e.g., Sauer and Sturm, 2003) are uncertain whether EURIBOR or EONIA (Euro Overnight Index Average) should be favoured as the reference interest rate for the Eurozone. As a robustness check, we also employ the latter in our estimates, finding very similar results.

[8] HICP data are provided by Eurostat; the RPIX index is extracted from The Office for National Statistics Database.

[9] As suggested by Hodrick and Prescott (1997), we use $\lambda = 1600$ for our quarterly database.

[10] see Thomas *et al.* (2010).

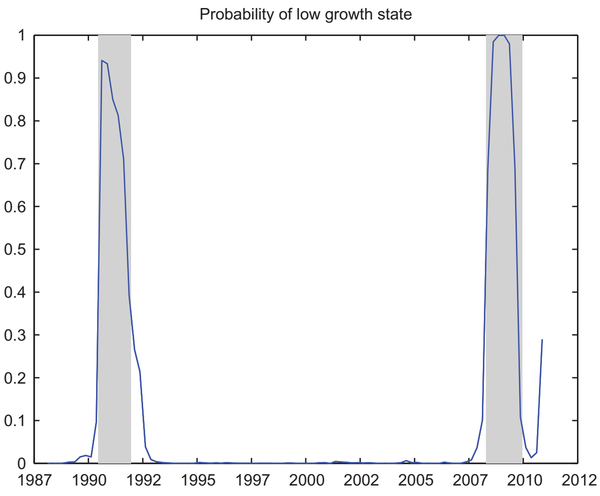

Fig. 1. Posterior probabilities of low growth rate in the UK
Notes: This figure shows the estimated posterior probabilities of being in a recession, coupled with the official BoE recession dates (shadow area). Data employed in the estimation are quarterly starting from 1987.

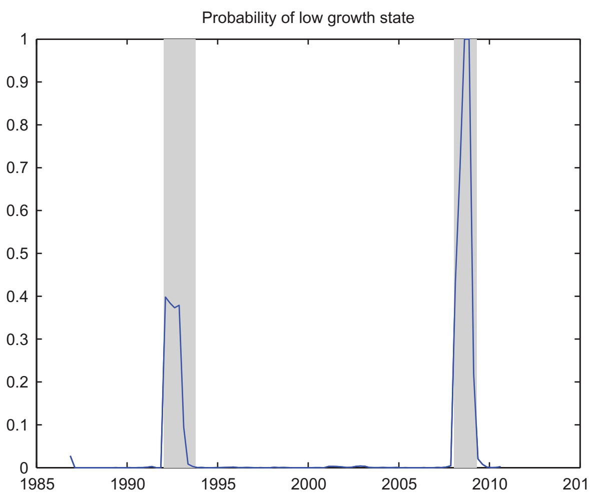

Fig. 2. Posterior probabilities of low growth rate in the EMU
Notes: This figure shows the estimated posterior probabilities of being in a recession, coupled with the official Centre for Economic Policy Research (CEPR) recession dates (shadow area). Data employed in the estimation are quarterly starting from 1987.

model is able to detect the 2008–2009 recession with a probability of almost 100%. Instead, the 1992–1993 recession is detected with a probability of about 40%.[11] This can be due to several reasons. Among these, it may be of interest to recall that the CEPR dating committee claims that the EMU 'experienced a prolonged pause in the growth of economic activity' during the period 2001–2003 without

Table 1. Simple Taylor rule

	European Monetary Union	
	1987q1–2012q4	1999q1–2012q4
Infl. (β)	0.338*	0.151
Out. gap (γ*)	0.13**	0.142**
dummy1992	1.19*	
Cons	4.07***	1.85
δ	0.934	0.980
Adj. R^2	0.42	0.52
Obs.	104	56
F	13.938	7.613
p-value	0.000	0.000
	United Kingdom	
	1987q1–2012q4	1999q1–2012q4
Infl. (β)	0.453***	0.115
Out. gap (γ*)	0.198*	0.25*
dummy1992	0.314*	
Cons	4.6***	3.42***
δ	0.921	0.891
Adj. R^2	0.41	0.45
Obs.	104	56
F	13.497	15.513
p-value	0.000	0.000

Notes: This table reports estimates of the baseline Taylor rule introduced in Equation 2. The dependent variable is short-term nominal interest rates.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

ending up in a recession in the first two quarters of 2003. This period can mislead the MCMC algorithm in detecting the different states of the series.

The classical Taylor rule

As a first test of the two monetary policies, we estimate a standard Taylor Rule as the one reported in Equation 2. Generally speaking, results obtained for both the UK and the Eurozone and reported in Table 1, show evidence of first-order autocorrelation of the error terms, supporting our choice of the estimation procedure.

Turning to the interpretation of the results, the Taylor Rule provides a straight empirical insight into the salient features of the ECB and BoE monetary policies. As is common caution in literature, it is not claimed that the baseline model nor its following extensions bear full resemblance to the complex policy-making process adopted by the two central banks. Nonetheless, the Taylor Rule coefficients capture the conditional response of monetary policy instruments to the prevailing economic conditions; therefore, they

[11] Recessions are chronicled by the Centre for Economic Policy (CEPR) business cycle dates (gray areas in the graph). http://www.cepr.org/data/dating/

give us useful information about the two central banks' behaviour towards the trade-off between output and price stability. In particular, given the set of monetary policy objectives declared by the ECB and the BoE, we expect (i) a stabilizing commitment to price stability by both the ECB and the BoE (specifically, with adherence to the Taylor Principle which implies an inflation coefficient greater than 1); (ii) the slopes on output gap fluctuations to diverge across policy reaction functions with a stronger involvement of the BoE rather than the ECB to output fluctuations.

When the whole sample is used (see column 1 in Table 1, upper panel), estimates for the Eurozone do not support a stabilizing policy towards both the nominal and the business cycle indicator. In fact, the inflation coefficient is indeed significant but lower than the value predicted by the Taylor Principle which states that the coefficient on inflation should be larger than 1. Also, the coefficient on the output gap is well below 0.5 originally predicted by Taylor (1993) as a benchmark value for stabilizing output response, based on the example of Federal Reserve's monetary policy.[12] The inflation coefficient is estimated as three times greater than the one on the output gap. So, even if the ECB seems to place greater weight on the nominal indicator, it seems not to comply with the Taylor principle. Interestingly, if we focus on a subsample starting when the ECB officially took control over monetary policy (January 1999), the inflation coefficient turns out to be not significant. As explained in Section 'Testing for partial adjustment of the interest rates', these results can be due to the strong auto-correlation detected in the dependent variable.

Similarly, the Bank of England seems to follow an accommodative policy, as well. In fact, when the Taylor rule is assessed on the whole sample, the resulting inflation coefficient is significant but well below unity (0.453). Interestingly, the coefficient of the output gap, even if significant, is estimated to be only 0.198. Thus, when the classic Taylor rule is the benchmark, the BoE seems to place greater weight on the inflation indicator.[13] We also provide estimates on UK monetary policy during the same subsample period as the EMU ones. When the decade 1999–2010 is considered (see second column of Table 1, UK panel) the estimates fail to confirm the classic Taylor rule, as we find a coefficient for inflation not significantly different from zero.

Testing for partial adjustment of the interest rates

The scarce adherence of the ECB and BoE inflation coefficients to the Taylor principle is attributable to several causes. On the one hand, both central banks have progressively introduced nonconventional monetary policy measures to address the overcoming financial turmoil. Since 2009, the Asset Purchase Facility tool adopted by the BoE and the set of Outright Monetary Transactions introduced by the ECB provided strong liquidity injections aimed at fostering the recovering of the economic system despite interest rates maintained steady at their lower zero bound. The temporary disentanglement between monetary policy decisions and interest rate movements could indeed have an influence on estimates including last decade of data.

A second reason can be found in light of English *et al.* (2003). These authors show how partial adjustment of interest rates may play a role even when serial correlation of errors is accounted for. In particular, they consider two concurrent policy specifications, the first being a partial adjustment specification

$$\widehat{i_t} = \alpha + \beta\pi_t + \gamma g_t$$
$$i_t = (1-\rho)\widehat{i_t} + \rho i_{t-1} + \varpi_t$$

while the second is a policy rule with serially correlated errors

$$\widehat{i_t} = \alpha + \beta\pi_t + \gamma g_t$$
$$i_t = \widehat{i_t} + \upsilon_t$$
$$\upsilon_t = \delta\upsilon_{t-1} + \varpi_t$$

By rewriting the two equations above, respectively, as

$$\Delta i_t = (1-\rho)\Delta\widehat{i_t} + (1-\rho)(\widehat{i_{t-1}} - i_{t-1}) + \varpi_t \qquad (12)$$

$$\Delta i_t = \Delta\widehat{i_t} + (1-\delta)(\widehat{i_{t-1}} - i_{t-1}) + \varpi_t \qquad (13)$$

we can test the two policy specifications with a test of the coefficient on $\Delta\widehat{i_t}$. Results are reported in Table 2.[14] In both the Eurozone and the UK, the coefficient on $\Delta\widehat{i}$ is statistically different from 1, supporting the presence of partial adjustment in monetary policy.

As a second robustness check, English *et al.* (2003) show that, when both partial adjustment and serial correlation are considered in a single monetary policy rule, Equations 12 and 13 combine in the following testable equation:

$$\Delta i_t = (1-\rho)\Delta\widehat{i_t} + (1-\rho)(1-\delta)(\widehat{i_{t-1}} - i_{t-1}) + \rho\delta\Delta i_{t-1} + \varpi_t \qquad (14)$$

[12] To control exchange market pressures in the beginning of the 1990s we use the 'dummy1992' indicator variable for the period 1992q3–1993q3.

[13] We also added the 'dummy1992' in the UK regression. The indicator variable turns out to be significant, but the coefficient estimates are nonsensitive to this inclusion.

[14] Details on the estimation procedure can be found in English *et al.* (2003).

Table 2. Test between partial adjustment and serially correlated errors

	European Monetary Union	United Kingdom
Infl. (β)	2.48***	1.30***
Out. gap (γ*)	−0.08	0.28*
dummy1992	2.72**	3.28***
Cons	−1.12*	1.68***
Coeff. on $\Delta\hat{i}$	0.23***	0.33***
Coeff. on $(\widehat{i_{t-1}} - i_{t-1})$	0.01	0.02
Adj. R^2	0.58	0.56
Obs.	104	104
F	66.45	102.95
p-value	0.000	0.000

Notes: This table reports the estimates of Equations 12 and 13 with no restrictions on the coefficients. Estimations are on the period 1987q1–2012q4.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Again, we can use the significance of the coefficient on Δi_{t-1} as a test of the presence of both partial adjustment of interest rates and serial correlation in the errors.[15] Results for both the UK and the EMU suggest that both partial adjustment and serially correlated errors play an important role in the dynamics of their central banks' policies, as the coefficients on Δi_{t-1} are significant, equal to 0.27 and 0.43, respectively.[16]

The forward looking estimates

Pushing our analysis further, in Table 3 we examine the forward-looking specification where partial adjustment of interest rates is explicitly modelled. Specifically, the first column collects coefficients from Equation 5, where the expected inflation is instrumented by the current core inflation rate and money growth's deviations from trend. Building on this base, remaining columns show results

Table 3. Forward looking Taylor rule

European Monetary Union						
E. infl (β*)	0.396***	0.304***	0.438***	0.451***	0.406***	0.412***
Int. rate (–1) (ρ)	0.91***	0.934***	0.854***	0.881***	0.908***	0.904***
Out. gap (γ*)	0.078***	0.0865***	0.0628***	0.0656***	0.0765***	0.0736***
M3 growth		−0.0213				
Int. rate UK			0.0545*			
Int. rate US				0.0435		
Exch. rate UK EMU					0.0889	
Exch. rate EMU US						0.226
Cons	−0.561**	−0.325*	−0.718***	−0.723***	−0.7	−0.957
Adj. R^2	0.984	0.986	0.984	0.983	0.984	0.983
Obs.	100	100	100	100	100	100
χ^2	5000.412	5596.762	4692.112	5358.117	5041.446	5106.947
p-value	0.000	0.000	0.000	0.000	0.000	0.000
United Kingdom						
E. infl (β*)	0.145*	0.118	0.15*	0.168*	0.263**	0.163*
Int. rate (–1) (ρ)	0.926***	0.948***	0.896***	0.874***	0.883***	0.914***
Out. gap (γ*)	0.158***	0.181***	0.162***	0.108**	0.108*	0.15***
M3 growth		−0.0186				
Int. rate EMU			0.0348			
Int. rate US				0.0895*		
Exch. rate UK EMU					1.5**	
Exch. rate UK US						0.43
Cons	−0.111	0.0266	−0.115	−0.218	−2.34*	−0.829
Adj. R^2	0.977	0.980	0.977	0.978	0.975	0.977
Obs.	100	96	100	100	100	100
F						
p-value	0.000	0.000	0.000	0.000	0.000	0.000

Notes: This table reports estimates of the forward-looking model in Equation 5 (first column), and Equation 11 (columns 2 through 7). Estimations are on the period 1987q1–2012q4.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

[15] The rationale behind this approach is that if either of the two coefficients (ρ or δ) is zero, the coefficient on Δi_{t-1} would be zero as well.
[16] Estimations are obtained using data on the period 1989q1–2012q4 for the EMU and 1987q1–2012q4 for the UK.

from different specifications of the Equation 11 where the control variables listed above are alternately added to the model, namely the growth rate of the monetary aggregate (M3), interest rates of both the UK and the US, real exchange rates between US and EMU and real exchange rates between UK and EMU.

Compared to the simple framework discussed in Section 'The classical Taylor rule', the information provided by this model configuration is far more exhaustive. As explained before, our set of instrumental variables accounts for key data actually employed by the ECB and the BoE to predict future inflation. In addition, the control variables used capture the relative influence of a broader spectrum of monetary and foreign indicators widely involved in the conduct of monetary policy.

The upper panel of Table 3 reports results for the EMU. Estimates are robust across specifications of Equation 11. When core inflation and money growth's deviations from trend are used as instruments, all the coefficients on the expected inflation are strongly significant. Similarly, output gap coefficients are significant whatever control variable is considered in the model.

Both monetary and foreign exchange markets seem to have no direct influence on the ECB monetary conduct, instead. UK money market rates are the only exception as they affect the conditional response of interest rates in the Eurozone with a 5% significance level.

The resulting coefficient on M3 growth is statistically undistinguishable from zero. This outcome is quite surprising, given that the ECB commitment to price stability is driven by the wide agreement that developments in the price level are a monetary matter as a tight link exist between money growth and perspective inflationary pressures. Monetary aggregates are expected to hold a prominent role in monetary policy analysis as key tools to predict the future path of the inflation rate. This vision is indeed robust in the medium and long-run and the ECB regularly monitors deviations in the money aggregate against its 4.5% reference value in order to provide a nominal anchor to expected inflation. However, significant shifts of money growth may arise due to temporary changes in money demand and velocity. These factors do not threaten price stability in the medium-term, but do interfere with the link between money and prices in the short run. For this reason, M3 can no longer be treated as a primary warning indicator within the interest rate setting process.[17]

Estimates in Table 3 can be explained in light of these background details. On the one hand, the regression coefficient on M3 growth confirms that the monetary aggregate cannot be treated as a systematic predictor of short term interest rates. On the other, as outlined above, deviations of money growth from trend successfully contribute to the determination of the expected inflation.

To check for the relative strength of ECB policy responses to inflation as opposed to the business cycle indicator, we first need to recover implied elasticities (β and γ) from the regression coefficients β^* and γ^* adjusting for the interest rate smoothing. Results provide evidence of strong forward-looking preference of price stability in the Eurozone. In fact, implied elasticities on expected inflation range between 3 and 5.6; differently, implied elasticities on the output gap only range between 1.30 and 0.4.

The lower panel of Table 3 reports the same set of regressions applied to the UK economy. As expected, estimates of the output gap coefficients are fairly stable and statistically significant across different specifications of the model. Implied elasticities on the business cycle indicator range from 4.04 to 0.80 and show that the Bank of England is actually committed to intensive output stabilization in a forward-looking perspective. The price stabilizing behaviour of the Bank of England is also confirmed. Nonetheless, BoE's responsiveness to inflation appears overall lower as compared to the ECB's thorough commitment to price stability. The implied elasticities on inflation are comprised between 1.38 and 2.5 in compliance with the Taylor principle but they are well below the level of ECB's inflation response coefficients. Moreover, estimates for the expected inflation are not robust and only turn significant when foreign exchange market indicators and US federal funds rates are introduced in the model.

However, a deeper analysis of the divergence between the ECB and the BoE's elasticities reveals that few of the differences detected by this linear model are statistically significant. We collected the z-statistics values on the standardized differences between the ECB and BoE inflation coefficients and repeated the same exercise on the output gap estimates.[18] In absolute terms, the z-scores on both inflation and output coefficients range between 0.13 and 2.50. In fact, the gap between the responses of the two central banks is not different from zero except when the monetary aggregate and foreign interest rates are employed as control variables.

The quest for nonlinearities

Given the previous results, it seems clear that the linearity of the specifications tested above does not help in capturing whether these two central banks adjust their responses

[17] Because of this informational limit, the ECB claims that it does not mechanically react to all deviations in M3, relying instead on a broader information set given by both monetary and nonmonetary variables. In particular, starting from the end of 2003, the 'economic analysis' pillar, which includes non monetary indicators of real activity and cost factors, gained greater relevance.

[18] The significance test is run under the null hypothesis of equality between, respectively, the inflation and the output gap pairs of coefficients.

based on the business cycle they believe the economy is in. This can be particularly important if we want to assess the different responses to the real economy. Moreover, if the economic regimes are somehow persistent, modeling the business cycles would help in capturing autocorrelation in the data. To address these issues, we employ the estimation based on the regime switching model depicted in Section 'Estimation procedure'.

We test the regime-based, forward-looking model introduced in Equation 7 in order to privilege a comprehensive understanding of monetary policy determinants under changing economic circumstances. Results reported in Tables 4 and 5 confirm the intuition of the model's linear counterpart.

As far as the Eurozone is concerned, the regime-switching reaction function in Equation (7) detects no significant difference in the response of the European Central Bank to the state of the economy. Resulting inflation coefficients confirm that the ECB strictly focuses on stabilizing inflation targeting regardless of the phase of the business cycle. In more detail, implied elasticities associated with expected inflation range between 2.7 and 4.7 during booms and maintain on a 4.6 average during bursts, with a peak of 5.3 when the control variable M3 growth is introduced in the model. Departing from the linear case, quarterly variations in the monetary aggregate seem to convey significant information in the event of downturns, when the coefficient on M3 growth turns strongly significant. Similarly, the ECB accounts for US and UK monetary markets in booms and keeps monitoring the evolution of UK monetary policy during recessions, while enforcing the reaction to price movements (following the introduction of UK interest rates in the Taylor Rule, the implied elasticity on expected inflation jumps from 2.7 in booms to 4.1 during bursts).

Responsiveness to cyclical fluctuations in the output indicator seems not to be affected by the state of the economy, as well. Regression coefficients on the output gap are statistically significant regardless of the instrument used. However, implied elasticities are well below 1 during the high growth phase of the cycle and even slightly decline during low growth states.

Moving to the UK, empirical estimates in Table 5 show that the inflation targeting approach of the Bank of England is overall stabilizing in booms. Although coefficients on inflation are considerably lower than those reported for the Eurozone, corresponding implied elasticities span from 1.8 to 3.37. By contrast, implied inflation βs sharply decline during recession and even fall below the 1 reference value when either the federal funds rate or the Euribor are the employed as controls (the elasticities reduce, respectively, to 0.5 and 0.9). In stark difference from the European Central Bank, the BoE seems to favour a more accommodative monetary policy stance with respect to the nominal indicator in the face of downturns. Rather, a wider range of

Table 4. Forward looking Taylor Rule with regimes – Eurozone

Boom						
E. infl. (β*)	0.343**	0.291***	0.455***	0.416***	0.377***	0.354**
Int. rate (–1) (ρ)	0.923***	0.937***	0.871***	0.843***	0.918***	0.919***
Out. gap (γ*)	0.067***	0.071***	0.058***	0.055***	0.066***	0.064***
M3 Growth		−0.012				
Fed funds			0.055**			
Int. rate UK				0.065***		
Exch. rate UK EMU					0.130	
Exch. EMU US						0.178
Cons. (α*)	−0.481**	−0.351*	−0.734***	−0.675***	−0.724	−0.792
Recession						
E. infl. (β*)	0.746***	0.453***	0.412**	0.633***	0.594***	0.791***
Int. rate (−1) (ρ)	0.842***	0.920***	0.910***	0.846***	0.860***	0.820***
Out. gap (γ*)	0.081***	0.112***	0.091***	0.063***	0.084***	0.069***
M3 Growth		−0.078***				
Fed funds			0.028			
Int. rate UK				0.069*		
Exch. rate UK EMU					0.205	
Exch. EMU US						0.502
Cons. (α*)	−1.054***	−0.198	−0.658**	−1.151***	−1.019	−1.916*
Adj. R^2	0.99	0.99	0.99	0.99	0.99	0.99
Obs.	100	100	100	100	100	100

Notes: This table reports estimates of the regime switching model in Equation 7 for the EMU over the time period 1987q1–2012q4.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5. Forward looking Taylor Rule with regimes – United Kingdom

Boom						
E. infl. (β*)	0.219**	0.192**	0.224**	0.218**	0.306***	0.262**
Int. rate (−1) (ρ)	0.919***	0.943***	0.882***	0.913***	0.882***	0.895***
Out. gap (γ*)	0.114**	0.134***	0.077*	0.116**	0.074	0.093*
M3 Growth		−0.020				
Fed funds			0.067			
Int. rate EMU				0.007		
Exch. rate UK EMU					1.574**	
Exch. UK US						0.948
Cons. (α*)	−0.273	−0.131	−0.334*	−0.269	−2,547**	−1.870*
Recession						
E. infl. (β*)	0.193*	0.161*	0.074	0.277***	0.276**	0.154
Int. rate (−1) (ρ)	0.902***	0.921***	0.837***	0.677***	0.844***	0.919***
Out. gap (γ*)	0.163***	0.215***	0.146***	0.143***	0.122**	0.175***
M3 Growth		−0.078**				
Fed funds			0.193***			
Int. rate EMU				0.246***		
Exch. rate UK EMU					2.418***	
Exch. UK US						−0.032
Cons. (α*)	−0.301	0.482***	−0.122	−0.359*	−3.441***	−0.237
Adj. R^2	0.98	0.98	0.98	0.98	0.98	0.98
Obs.	100	96	100	100	100	100

Notes: This table reports estimates of the regime switching model in Equation 7 for the United Kingdom over the time period 1987q1–2012q4.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

additional economic and financial information is taken into consideration. It is worth noting that when the model switches to a low growth state, the full set of control variables turns strongly significant, whereas the impact of monetary and foreign exchange markets on short term interests rates appears negligible during booms.

As expected, the output becomes more relevant during recessions. In fact, while in boom periods values of model's implied elasticities are between 0.6 to 2.5, all coefficients on the output gap raise during recessions. This confirms that, when the state of the economy is considered, recovery is enhanced by greater attention to the real side of economy.

In summary, our estimates show evidence that the EMU follows a stabilizing policy with respect to the price stability target. This outcome is robust to different extensions of the classic Taylor rule and is confirmed when economic regimes are accounted for. Interestingly, when the real economy indicator is considered, the estimates show low elasticity of response to the output gap.

For the BoE estimates, we find evidence of a stabilizing policy toward the price stability target as well. Moreover, our results support the closer attention paid by the UK monetary authority to the real indicator. The stronger response to the output gap, with respect to ECB conduct, becomes clearer when we adjust our estimate for regime-switching. The analysis of the standardized differences between the inflation and output coefficients confirms this intuition. In particular, the z-scores on inflation coefficients are not distinguishable from zero in booms but do turn strongly significant during recessions, where the absolute z-values range from 2.1 to 3.1. On the same pace, the z-scores collected on output elasticities in the recession state range from 1.97 to 3, suggesting that there exist a notable gap in the sensitivity of the two central banks to pressures facing the real economy over the business cycle.

V. Conclusion

We focus on a comparison between BoE and ECB monetary conduct. The comparative estimates of the Taylor rule proposed in this article add to the literature, as they contextualize the monetary choices of the two authorities within the process of integration in Europe, which is not yet complete. In 1992, by exercising the opt-out clause in the EMU law concerning monetary union, the UK has elected to defer adherence to the EMU. British monetary authorities have raised and still confirm deep concerns about the exhaustiveness of the Maastricht criteria and the economic benefits the UK would enjoy by entering the Eurozone. Our empirical results appear to support the UK's claims: when we take into account interest rate smoothing, the BoE estimates comply with the Taylor principle, showing a stabilizing behaviour with respect to prices and a stronger response to the output cycle. This latter behaviour seems not to be followed by ECB monetary conduct, whose estimates of elasticity with respect to the real indicator show values consistently less than those for the BoE. Interestingly, these results emerge in a regime switching specification, where monetary authorities set their policy responses based on beliefs inferred from being in a particular state of the economy.

Acknowledgements

We thank seminar participants at the 44th annual Money Macro and Finance Conference, and at the XX International Tor Vergata Conference on Money, Banking and Finance.

References

Altavilla, C. and Landolfo, L. (2005) Do central banks act asymmetrically? Empirical evidence from ECB and the Bank of England, *Applied Economics*, **37**, 205–8.

Artis, M. J. (2000) The UK and the EMU. EUI-RSCAS Working Papers 67, EUI-RSCAS, Florence.

Brown, G. (2003) *Statement by Gordon Brown on UK Membership of the Single Currency*, HM Treasury Archive, London.

Buiter, W. H. (2000) Optimal currency areas: why does the exchange rate regime matter?, *Scottish Journal of Political Economy*, **47**, 213–50.

Buiter, W. H. (2008) Why the United Kingdom should join the Eurozone?, *International Finance*, **11**, 269–82.

Castro, V. (2008) Are central banks following a linear or nonlinear (augmented) Taylro Rule?, Economic Research Paper series No. 872, University of Warwick, Coventry.

Clarida, R., Gali, J. and Gertler, M. (1998) Monetary policy rules in practice. Some international evidence, *European Economic Review*, **42**, 1033–67.

Cuckierman, A. and Muscatelli, V. A. (2008) Nonlinear Taylor rules and asymmetric preferences in central banking: evidence from the United Kingdom and the United States, *The B.E. Journal of Macroeconomics*, **8**, Article 7.

Dolado, J. J., Maria-Dolores, R. and Naveira, M. (2005) Are monetary-policy reaction functions asymmetric? The role of nonlinearity in the Phillips curve, *European Economic Review*, **49**, 485–503.

Dolado, J. J., Maria-Dolores, R. and Ruge-Murcia, F. J. (2004) Nonlinear monetary policy rules: some new evidence for the U.S., *Studies in Nonlinear Dynamics and Econometrics*, **8**, 1–34.

ECB (2001) Background studies for the ECB's evaluation of its monetary policy strategy, *European Central Bank*, November 2003.

English, W. B., Nelson, W. R. and Sack, B. P. (2003) Interpreting the significance of the lagged interest rate in estimated monetary policy rules, *Contributions to Macroeconomics*, **3**, Article 5.

Fagan, G., Henry, J. and Mestre, R. (2005) An area-wide model for the Euro Area, *Economic Modelling*, **22**, 39–59.

Gerlach, S. and Lewis, J. (2010) The zero lower bound, ECB interest rate policy and the financial crisis. DNB Working Paper No. 254, Netherlands Central Bank, Amsterdam.

Gerlach, S. and Schnabel, G. (2000) The Taylor rule and interest rates in the EMU area, *Economics Letters*, **67**, 165–71.

Goodfriend, M. (1991) Interest rates and the conduct of monetary policy, *Carnegie-Rochester Conference Series on Public Policy*, **34**, 7–30.

Hamilton, J. D. (1989) A new approach to the economic analysis of nonstationary time series and the business cycle, *Econometrica*, **55**, 357–84.

HM Treasury (2013) *Review of the Monetary Policy Framework*, HM Treasury, London.

Hodrick, R. and Prescott, E. (1997) Post-war US business cycles: an empirical investigation, *Journal of Money, Credit, and Banking*, **29**, 1–16.

Kim, C.-J. and Nelson, C. R. (1999) *State-Space Models with Regime Switching*, MIT Press, Cambridge and London.

Lütkepohl, H. (2007) *New Introduction to Multiple Time Series Analysis*, Springer-Verlag, Berlin.

Markov, N. (2010) A regime-switching model for the European Central Bank, Univerisite de Geneve Working Paper Series, WPS 10091, Université de Genève, Geneva.

Martin, C. and Costas M. (2005) Modelling monetary policy: inflation targeting in practice, *Economica*, **71**, 209–21.

McCallum, B. T. (2000) Alternative monetary policy rules: a comparison with historical settings for the United States, the United Kingdom, and Japan, *Economic Quarterly*, **86**, 49–79.

Meyer, L. H., Swanson, E. T. and Wieland, V. W. (2001) NAIRU uncertainty and nonlinear policy rules, *The American Economic Review*, **91**, 226–31.

Minford, P. (2002) *Should Britain Join the Euro? The Chancellor's Five Tests Examined*, The Institute of Economic Affairs, London.

Minford, P., Meenahg, D. and Webb, B. (2004) Britain and EMU: assessing the costs in macroeconomic variability, *The World Economy*, **27**, 301–58.

Nelson, E. (2000) UK monetary policy 1972–97: a guide using Taylor rules. Bank of England Working papers No. 120, Bank of England, London.

Nobay, A. R. and Peel, D. A. (2000) Optimal monetary policy with a nonlinear Phillips curve, *Economics Letters*, **67**, 159–64.

Peersman, G. and Smets, F. (1999) The Taylor rule, a useful monetary policy benchmark for the Euro Area?, *International Finance*, **2**, 85–116.

Potton, E. and Mellows-Facer, A. (2003) The Euro: background to the five economic tests. House of Commons Library Research Paper 03, 53. House of Commons Library, London.

Prais, G. J. and Winsten, C. B. (1954) Trend estimators and serial correlation. Cowles Commission Discussion Papers 383, Cowles Commission, Chicago, IL.

Sack, B. and Wieland, V. (2000) Interest-rate smoothing and optimal monetary policy: a review of recent empirical evidence, *Journal of Economics and Business*, **52**, 205–8.

Sauer, S. and Sturm, J. E. (2003) ECB monetary policy: how well does the Taylor rule describe it?, University of Munich and CESIfo, unpublished manuscript.

Surico, P. (2007a) The Fed's monetary policy rule and U.S. inflation: the case of asymmetric preferences, *Journal of Economic Dynamics and Control*, **31**, 305–24.

Surico, P. (2007b) The monetary policy of the European Central Bank, *Scandinavian Journal of Economics*, **109**, 115–35.

Taylor, J. (1993) Discretion versus policy rules in practice, *Carnegie-Rochester Conference Series on Public Policy*, **39**, 195–214.

Taylor, J. (1999) Robustness and efficiency of monetary policy rules as guidelines for interest rate setting by the European Central Bank, *Journal of Monetary Economics*, **43**, 655–79.

Taylor, M. and Davradakis, E. (2006) Interest rate setting and inflation targeting: evidence of a nonlinear Taylor rule for the United Kingdom, *Studies in Nonlinear Dynamics and Econometrics*, **10**, Article 1.

Thomas, R., Hills, S. and Dimsdale, N. (2010) The UK recession in context – what do three centuries of data tell us?, *Bank of England Quarterly Bulletin*, **50**, 277–91.