THE TIME-VARYING NATURAL RATE OF UNEMPLOYMENT AND MONETARY POLICY IN THE UK

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Abstract

Since Milton Friedman's 1968 seminal paper on the role of monetary policy, the concept of a time-varying unemployment rate at which inflation remains stable has established itself as one of the most influential in macroeconomics. Yet, although few would dispute its analytical value, empirical estimates of the time-varying natural rate have largely been greeted with skepticism. To a large extent, this is due to the uncertainty that accompanies estimates of unobserved variables as well as the fact that competing methods of estimation have delivered quite dissimilar results. In this context, the paper employs a number of univariate and multivariate methods to estimate the time-varying natural rate of Britain during 1960:1-2003:4 and examines which of these methods delivers estimates with the highest information content for future inflation. It also shows that, in times of structural economic change, one-sided estimates of the natural rate can potentially help reduce perception lags in monetary policy.

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JEL Classification: C22, E24, E31, E52.

1 Introduction

It is widely accepted that, to attain the objective of low and stable inflation, the monetary policy authority should adjust its policy instrument in response to exogenous inflation shocks and to deviations of output and employment from their natural levels. In particular, when aggregate expenditure and employment fall below their natural levels, or when other disinflationary concerns appear, the central bank should consider adjusting interest rates downwards, whereas when aggregate expenditure and employment exceed their natural levels, or when other inflationary concerns emerge, the central bank should consider tightening monetary policy.[1] In this setting, the natural levels of output and employment, and the associated natural rate of unemployment, are levels at which - absent supply shocks - inflation is stable. Should the policy maker have an accurate quantitative estimate of them, macroeconomic stabilization policy would be a more straightforward and predictable exercise.

Yet, in practice, monetary policy making is never as straightforward, partly because decisions are taken under conditions of model uncertainty and partly because of limited information about the nature, size, and persistence of various disturbances as well as about the true state of the economy. In particular, policy makers may be uncertain about the overall features of the model that describes the structural relationships of the economy or they may be uncertain about the quantitative strength of some of those relationships, e.g. the exact value of the model parameters. They may also face uncertainty about the

[1] See, for example, Clarida, Gali and Gertler (1999).

identification and interpretation of economic disturbances, e.g. whether an observed shock realization originates in the demand-side or the supply-side of the economy or whether it is temporary or persistent. Perhaps more importantly, policy makers may face uncertainty about the sign and size of the output and unemployment gaps. Limited information about the latter often stems from imperfections in the quality of economic data and, critically, from uncertainty about the position of the natural level of output or the natural rate of unemployment.[2]

Uncertainty about the natural level of output and the natural rate of unemployment is primarily the result of them being unobservable and time-varying. The natural level of output is driven by slowly evolving technological and demographic factors and changes in the stock of capital, and is perturbed by irregular but frequent productivity shocks. On the other hand, the natural rate of unemployment exhibits significant low frequency variation following changes in labour market institutions, changes in product market competition, or unanticipated changes in trend productivity growth.[3] Failure to observe, and act upon, the variation of the natural level of output and the natural rate of unemployment may lead to misguided monetary policy. Orphanides (1999), for example, shows that behind the surge in US inflation during the 1970s (the so-called Great Inflation), lies the failure of the Federal Reserve to quickly appreciate the slowdown in the trend growth of output and the consequent widening expansionary gap. Of course, the elusive nature of the natural level of output or the natural rate of unemployment is not a new problem and, over time, many economists have been sceptical about natural-rate-based policies. As early as 1968,

[2] For an interesting discussion of the forms of uncertainty facing the monetary policy maker, see Issing, Gaspar, Tristani and Vestin (2005).

[3] For a detailed discussion of the determinants of the natural rate of unemployment see Layard, Nickell, and Jackman (1991).

in his American Economic Association presidential address, Milton Friedman noted: "One problem is that [the policy maker] cannot know what the natural rate is. Unfortunately, we have as yet devised no method to estimate accurately and readily the natural rate of either interest or unemployment. And the natural rate will itself change from time to time."

More recently, the application of statistical methodologies of estimating trends or unobserved time-varying parameters has helped to address some of these earlier concerns. Notwithstanding problems of sampling and model uncertainty, the latter stemming from the policy maker's imperfect knowledge about the true data generating process of the natural level of output or the natural rate of unemployment, the use of alternative methods of trend-cycle decomposition can go some way in identifying the position and direction of change of the output and unemployment gaps. Hence, they can provide a useful input in the policy making process, and help avoid big policy mistakes, especially during periods of structural economic change and changing natural rates.[4] Still, however useful they may be in theory, competing statistical methodologies of trend-cycle decomposition often yield different paths for the natural level of output or the natural rate of unemployment, thus, introducing an additional element of uncertainty into policy making. In view of the significance that modern monetary policy models attach on output and unemployment gaps, discriminating between competing methods and assessing which method delivers natural rates with a higher information content for future inflation, is a significant task.

The goal of the paper is to address this task. Specifically, first, the paper aims to derive alternative historical estimates of the natural rate of unemployment of the UK during the

[4] For a discussion of the problems of sampling and model uncertainty in the estimation of natural rates, see Staiger, Stock and Watson (1997) and Orphanides and Williams (2002).

past forty years, using a range of alternative univariate and multivariate methods. Second, in light of the considerable dispersion of alternative estimates at any point in time, the paper aims to find out which of these statistical methods delivers natural rates that are more appropriate for the purposes of monetary policy. As the natural rate of unemployment is an important force behind inflation dynamics, the paper assesses competing statistical methods on the basis of the power of their natural rate estimates to predict inflation. Third, the paper uses the preferred estimate of the natural rate of unemployment in the context of a natural-rate-based Taylor rule to assess whether imperfect knowledge of the economy's supply potential at the time of decision making may have led the Bank of England to excessively loose or excessively tight monetary policy. The paper finds that, since the adoption of inflation targeting, the Bank of England has tracked the secular changes of the natural rate of unemployment relatively successfully albeit with some lag. In light of the sustained fall of the natural rate during this period, this is a considerable achievement.

The remainder of the paper is organized as follows. Section 2 derives alternative time-varying natural rates of unemployment for the UK during 1960:1-2003:4, using a range of univariate and multivariate methods, and discusses the results. Section 3 discriminates between competing methodologies by assessing the power of the different natural rate estimates to predict inflation. Section 4 examines the effect of natural rate uncertainty on the monetary policy stance of the Bank of England since the adoption of inflation targeting and Section 5 concludes.

2 Historical Estimates of the Natural Rate of Unemployment of the UK

Below I will derive six alternative measures of the natural rate of unemployment of the UK since 1960. These measures correspond to alternative specifications of two basic statistical methodologies that have been employed extensively in the literature, i.e. univariate filters and multivariate unobserved components models. A third way of estimating the time-varying natural rate of unemployment would rely on the estimation of a system of wage-setting and price-setting equations and would require the prior measurement of the factors that determine it, such as the degree of centralization of wage bargaining, the extent of coordination between employers and workers or the degree of mismatch between workers and vacancies. Recent research has suggested that estimates of the natural rate based on such labour market models are sensitive to small changes in the specification and measurement of those variables, hence, they are usually received with scepticism.[5] In light of this, I will not consider this approach here.

2.1 Univariate Filter Estimates of the Natural Rate

The natural rate of unemployment is here defined as the rate of unemployment at which, in the absence of supply shocks, inflation is stable. It is well known that, on the assumption of imperfections of information or in the presence of staggered wage and price setting, demand shocks have real short run effects. More particularly, positive demand shocks may reduce unemployment below the natural rate at the cost of rising inflation whereas negative demand shocks may increase unemployment above the natural rate at the expense of falling inflation. Yet, in the long run, once expectations have fully adjusted to changes in inflation, actual unemployment converges to its time-varying natural rate. It is therefore possible to consider the natural rate of unemployment as a slowly evolving trend from which actual

[5] For an interesting discussion of the drawbacks of the structural approach, see Cassino and Thornton (2002).

unemployment may temporarily deviate, thus, a trend which could be estimated using standard univariate filters. Univariate filters have been widely used in the trend-cycle decomposition of a number of macroeconomic time series and possess the advantage of imposing very little structure on the problem at hand. Below, I will consider two versions of each of the two most popular univariate filters, i.e. the Hodrick-Prescott (1997) filter and the approximation of an ideal low-pass filter as described by Baxter and King (1999).

The Hodrick-Prescott filter views a given time series as the sum of a transitory cyclical component and a trend component which varies smoothly over time. An estimate of the latter is derived by minimizing the variance of the cyclical component subject to a penalty on the variability of the trend component. Naturally, the larger the value of the parameter that penalizes the variability of the trend component, the smoother is the path of this component and the greater is the standard deviation and the degree of persistence of the cyclical component. The value of the penalty (or smoothness) parameter is here given exogenously and Hodrick and Prescott recommend a value of $\lambda = 1,600$ when using data with quarterly frequency. In estimating the natural rate of unemployment of the UK, I will consider two alternative implementations of the filter, one with the smoothness parameter recommended by Hodrick and Prescott and another with a smoothness parameter of $\lambda = 25,600$ which allows for greater persistence of cyclical unemployment and is closer in spirit to the approach advocated by Rotemberg (1999).

Baxter and King's approximation of the ideal low-pass filter is a two-sided moving average that 'passes through' the low frequency trend component of an economic time series while suppressing components whose frequency is associated with cyclical or irregular variation. The application of the low-pass filter requires the specification of a cutoff frequency below which all frequencies are 'passed through'. Following the pioneering work of Burns and Mitchell on the US business cycle, Baxter and King adopt a cutoff frequency of $\pi/16$ but their low-pass filter is flexible enough to allow researchers to set the cutoff frequency they consider appropriate for their specific purpose. We will examine two alternative implementations of the low-pass filter, one with the cutoff frequency favoured by Baxter and King and another with a cutoff frequency of $\pi/30$, employed by Staiger, Stock and Watson (2001), i.e. a low-pass filter which admits time series components with periodicity of 60 quarters or more. The underlying idea here is that, in the presence of unemployment persistence mechanisms, cyclical unemployment is more persistent than output deviations from trend.

2.2 Multivariate Unobserved Components Estimates of the Natural Rate

Unlike univariate methods of trend-cycle decomposition which do not make use of information provided by economic models of the natural rate, the multivariate unobserved components method derives estimates of the natural rate based on the accelerationist Phillips curve. More particularly, the method uses the Kalman filter technique, a recursive procedure which, combined with the maximum likelihood estimation method, estimates the unobserved natural rate of unemployment and the slope coefficients of the accelerationist Phillips curve simultaneously. In this framework, the natural rate is modelled as a stochastic time-varying parameter, with restrictions imposed on its volatility to avoid implausible variation and make the estimated series conform to our understanding of the natural rate as a slowly moving variable. Below, I will obtain estimates of the UK time-varying natural rate of unemployment based on two alternative specifications of this method, a standard specification, i.e. a specification widely used in the estimation of unobserved components, and a hybrid specification introduced by Staiger, Stock and Watson (2001).

2.2.1 The Standard Specification

The key components of the standard specification, from which the behaviour of the unobserved variable is elicited, are a model of inflation dynamics and the stochastic process that generates the unobserved variable. A few comments about these two components are worth making.

The standard model of inflation dynamics suggests that inflation is determined by inflation inertia, the unemployment gap, and temporary supply shocks. Specifically, the model implies that at steady state, i.e. when actual unemployment is on the natural rate and there are no supply shocks, actual inflation is stable, yet, if unemployment deviates from its natural rate or if temporary supply shocks occur, changes in inflation will set in. In particular, if, and for as long as unemployment stays above the natural rate, inflation will be falling whereas if, and for as long as unemployment stays below the natural rate, inflation will be rising. The model can be illustrated as follows:

$$\pi_t = a(L)\pi_{t-1} + b(L)(u_t - u_t^*) + c(L)s_t + e_t \tag{1}$$

where π denotes actual inflation, u denotes the observed unemployment rate, u^* the unobserved time-varying natural unemployment rate, s denotes a vector of temporary supply shock variables, L is a polynomial in the lag operator, and the disturbance e is i.i.d. normal with zero mean and variance σ_e^2.

The inflation inertia term in equation (1) captures the effect of backward looking expectations on current inflation. In principle, this interpretation of inflation inertia is theoretically unappealing and renders the model liable to the Lucas critique. But a good deal of research has shown that, for the period under consideration, the univariate behaviour of inflation is close to a random walk, thus, backward looking expectations are close to an optimal univariate inflation forecast.[6] Alternatively, the inflation inertia term can be thought of as capturing sluggish price adjustment due to costs in obtaining and processing information on the part of price-setters.[7]

The vector of temporary supply shock variables includes those supply shocks that might be reasonably expected to revert to zero over a horizon of one to two years, such as changes in real oil price deflators, real import price deflators or real effective exchange rates. Supply side shocks of a more permanent nature, such as changes in labour market institutions, are thought to affect sustainable employment and hence are captured by variations in the natural rate of unemployment.

The stochastic process that determines how the natural rate varies over time is usually assumed to be a random walk, i.e.:

$$u_t^* = u_{t-1}^* + \nu_t \tag{2}$$

where ν_t is a random error with zero mean and variance σ_ν^2.

Equations (1) and (2) contain all necessary economic information for the estimation of the time-varying natural rate of unemployment. This standard specification of the multivariate unobserved components method has been used by, among others, Gordon (1997, 1998) and Batini and Greenslade (2006) for the estimation of the natural rate of unemploy-

[6] See Ball (2000).
[7] See Mankiw and Reis (2003).

ment of the US and UK respectively.

2.2.2 The Hybrid Specification

The hybrid specification uses a two-step procedure to estimate the time-varying natural rate. First, a univariate trend of unemployment is derived from a low-pass filter and, second, the natural rate of unemployment is estimated using a multivariate model within which the univariate trend of unemployment serves as input. To the extent that a considerable part of the time variation in the natural rate is likely to be reflected in changes in the univariate unemployment trend, the additional information contained in this trend can potentially contribute in delivering more precise estimates of the natural rate of unemployment.

More particularly, the hybrid specification defines the potential deviation of the natural rate from the univariate trend of unemployment as:

$$\xi_t = u_t^* - u_t^N \tag{3}$$

where, as above, u^* denotes the natural rate of unemployment and u^N denotes the univariate trend of unemployment.

Accordingly, the equation of inflation dynamics (1) can be rewritten as:

$$\pi_t = \mu_t + a(L)\pi_{t-1} + b(L)(u_t - u_t^N) + c(L)s_t + e_t \tag{4}$$

where $\mu_t (= -b(L)\xi_t)$ is a time-varying intercept and all other variables are defined as in (1).

If the slope coefficients of equation (4) are stable, the time-varying intercept will simply reflect the departure of the natural rate from the univariate trend of unemployment and can be estimated by using the multivariate unobserved components method. To implement the procedure, the intercept drift is modelled as a stochastic time-varying parameter that follows a random walk, i.e.:

$$\mu_t = \mu_{t-1} + \eta_t \tag{5}$$

where η_t is i.i.d. $N(0, \sigma_\eta^2)$.

Estimates of the time-varying natural rate can thus be obtained by combining the univariate trend and the estimated intercept drift, i.e.:

$$u_t^* = u_t^N - (\hat{\mu}_t/\hat{b}) \tag{6}$$

where $\hat{b}$ is the estimator of b and $\hat{\mu}$ is the estimator of μ.

The hybrid specification has been used by Staiger, Stock and Watson (2001) for the estimation of the time-varying natural rate of unemployment of the US.

2.2.3 Estimation Issues

The standard specification formed by equations (1) and (2) and the hybrid specification formed by equations (4) and (5) can be written in state-space form and estimated by maximum likelihood using the Kalman filter.[8] Yet, before proceeding, some issues pertaining to the estimation of the two multivariate unobserved components models are worth highlighting.

First, to ensure the long-run neutrality of inflation with respect to unemployment, one has to impose on (1) and (4) the restriction that the sum of coefficients on lagged inflation equals unity. Although the estimated sum of coefficients on lagged inflation, over the period under consideration, approaches unity, a meaningful calculation of the natural rate requires that the sum should be constrained to be exactly equal to unity. I impose this restriction by

[8] See Hamilton (1994).

casting and estimating the two models in first differences - rather than levels - of inflation.[9] Second, the vector of supply shock variables includes the change of log real import price and log real oil price deflators, shocks which are expected to have only a transitory effect on domestic inflation. The supply shock variables are standardized to have a zero mean and a standard deviation of one. Third, a number of studies have noted that inflation may be affected by whether unemployment is rising or falling - not just by the level of unemployment relative to the natural rate. To allow for, and measure directly, possible speed limit effects, the unemployment gap variable enters the model in level as well as in difference form. Fourth, during the late sixties and seventies, there have been several attempts to contain inflation by means of incomes policies. To capture their potential effect, a number of intercept dummies are included. In particular, following Henry (1981) and Flanagan, Soskice and Ulman (1983), I include intercept dummies for two instances of statutory incomes policies: the twelve-month freeze on wages and prices of the Wilson administration during 1966:3-1967:2 and the social contract of the Wilson and Callaghan administrations during 1975:3-1977:2. I also include intercept dummies to capture the possibility of "catch up" wage explosions following the relaxation of incomes policies. The periods covered by these latter dummies are of the same length as the periods for which the incomes policies were in operation. A final specification issue concerns the selection of lags in the polynomials $a(L)$, $b(L)$ and $c(L)$. All variables enter initially with eight lags and tested down on the basis of their significance. Given these choices, the standard and hybrid specifications of the unobserved components method are respectively:

$$\Delta\pi_t = a(L)\Delta\pi_{t-1} + b^{'}(L)(u_t - u_t^*) + b^{''}(L)\Delta u_t + c(L)s_t + d_t + e_t \qquad (7)$$

[9] See Staiger, Stock and Watson (1997a).

where $e_t \sim N(0, \sigma_e^2)$,

$$u_t^* = u_{t-1}^* + \nu_t \tag{8}$$

where $\nu_t \sim N(0, \sigma_\nu^2)$, and

$$\Delta\pi_t = \mu_t + a(L)\Delta\pi_{t-1} + b^{'}(L)(u_t - u_t^N) + b^{''}(L)\Delta u_t + c(L)s_t + d_t + e_t \tag{9}$$

where $e_t \sim N(0, \sigma_e^2)$,

$$\mu_t = \mu_{t-1} + \eta_t \tag{10}$$

where $\eta_t \sim N(0, \sigma_\eta^2)$.

Before the Kalman filter procedure starts, the vector of parameters, including the time varying natural rate of unemployment, needs to be initialized. Initial parameter values for the slope coefficients of equations (7) and (9) were obtained from their OLS estimation, in which the time-varying natural rate was proxied by a univariate unemployment trend.[10] The initial conditions of the state variables in the standard and hybrid specifications of the model are respectively set equal to the first observation of the univariate unemployment trend and to zero. It is worth noting that the estimates of the natural unemployment rate are robust to alternative parameter starting values and initial conditions.

Finally, to implement the procedure, one needs to restrict the value of the signal-to-noise ratio. The signal-to-noise ratio is the ratio of the variance of the error term of the stochastic process that drives the natural rate over to the variance of the error term in the inflation dynamics equation and determines the smoothness of the resulting time-varying natural rate series. In particular, a high signal-to noise ratio implies that a large part of the residual variation in the inflation equation is soaked up by the natural rate, hence, the

[10] Low-pass filter with cutoff frequency $\pi/30$.

natural rate series is quite volatile. On the other extreme, a signal-to-noise ratio equal to zero implies a constant natural rate. In principle, the Kalman filter procedure makes it possible to estimate all the parameters of the model - including the signal-to-noise ratio. In practice, however, estimating the natural rate without restricting the ratio leads to a series that is too volatile. It is common therefore to impose a restriction on the value of the ratio. In line with previous studies, I experiment with alternative values of the signal-to-noise ratio, all of which permit the natural rate to move about as much as it likes without though exhibiting high frequency variation.[11]

2.3 Empirical Results

Estimates of the natural rate of unemployment are obtained using UK quarterly data from 1960:1 to 2003:4. Columns three and five of Table 1 report results obtained from the estimation of the standard and hybrid specifications of the unobserved components model respectively. In both cases the signal-to-noise ratio is set to 0.09, an entirely standard value in the estimation of natural unemployment rates, although below I consider the robustness of the estimated natural rates to alternative values of the ratio. The following findings are worth highlighting. First, all regressors are signed as expected with the unemployment gap having a significant negative effect and changes in real import price inflation a significant positive effect on changes in domestic price inflation. The unemployment gap coefficients, in particular, equal -0.17 and -0.30 implying that the impact effect of a one percent fall in the unemployment gap is a rise in annualized inflation of 0.68 and 1.20 percent respectively. In the presence of real import price inflation, real oil price inflation is statistically insignificant

[11] Note the similarity between the signal-to-noise ratio and the smoothness parameter of the Hodrick-Prescott filter.

and therefore not included, a rather expected result given that changes in real import price inflation already capture the effect of oil price shocks on domestic inflation. Furthermore, the speed limit effect is correctly signed but not statistically significant, perhaps suggesting that the unemployment persistence mechanisms are rather weak. The incomes policy dummies are correctly signed but not significant while the "catch-up" wage explosion dummies are wrongly signed and insignificant and therefore are not reported.

TABLE 1

ESTIMATION OF INFLATION DYNAMICS EQUATIONS USING THE KALMAN FILTER
UK 1960:1-2003:4

Dependent variable: $\Delta\pi$					
Regressors	Lags	Standard specification		Hybrid specification	
$\Delta\pi$	*1*	-0.63	(0.07)	-0.65	(0.07)
	2	-0.60	(0.09)	-0.64	(0.09)
	3	-0.58	(0.08)	-0.62	(0.09)
	4	-0.19	(0.11)	-0.25	(0.11)
	5	-0.15	(0.01)	-0.20	(0.11)
Unemployment Gap	*1*	-0.17	(0.08)	-0.30	(0.11)
ΔUnemployment	*1*	-0.34	(0.27)	-0.27	(0.28)
ΔRMP Inflation	*1*	0.08	(0.06)	0.08	(0.06)
	2	0.18	(0.06)	0.17	(0.06)
	3	0.18	(0.07)	0.17	(0.07)
	4	0.19	(0.06)	0.18	(0.06)
	5	0.21	(0.05)	0.21	(0.05)
	6	0.12	(0.06)	0.13	(0.06)
	7	0.15	(0.05)	0.15	(0.05)
	8	0.17	(0.04)	0.17	(0.04)
Incomes Policy 1966/67		-0.31	(0.46)	-0.37	(0.45)
Incomes Policy 1975/77		-0.40	(0.24)	-0.32	(0.24)
Dummy 1		-3.38	(0.44)	-3.37	(0.52)
Dummy 2		1.64	(0.61)	1.67	(0.58)
Log likelihood		606.8		609.1	

Notes: Standard errors in parentheses; Δ is the first difference operator; RMP denotes real import prices; Dummy 1 takes the value of -1 for 1979:3 and 1 for 1980:3, zero otherwise; Dummy 2 takes the value of 1 for 1974:4 and 1975:1, zero otherwise.

Figures 1 and 2 show the time profiles of time-varying natural rates estimated using alternative univariate and multivariate methods.

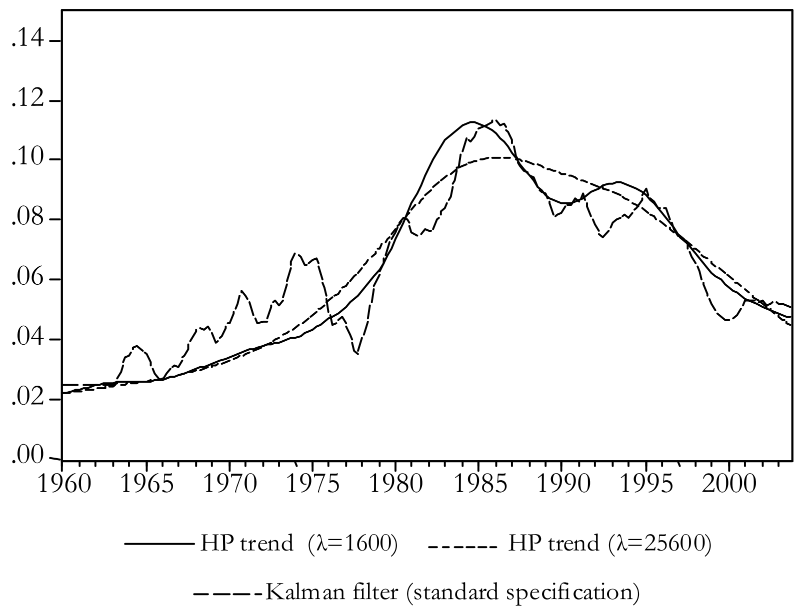

FIG. 1. Historical Estimates of Time-Varying Natural Rates, UK 1960:1-2003:4

Regardless of the method, all measures reveal the same overall pattern: the natural rate of unemployment was low during the first half of the sixties floating around three percent. It drifted upwards from the late sixties to the mid-eighties stabilizing towards the end of the decade around eight per cent. It declined steadily during the second half of the nineties and, at the turn of the century, it was standing close to five percent. The causes of the rise and fall of the natural rate have been discussed extensively elsewhere. The rise of the natural rate is often ascribed to the interaction of adverse macroeconomic shocks and labour market institutions that propagate those shocks over time, such as the sectoral level of wage bargaining, the absence of coordination between employers and trade unions, and the bias of the system of unemployment insurance in favour of passive and against active measures[12]. Likewise, the fall of the natural rate is usually ascribed to the benign macroeconomic environment of the past fifteen years coupled with the implementation of some key labour market reforms[13].

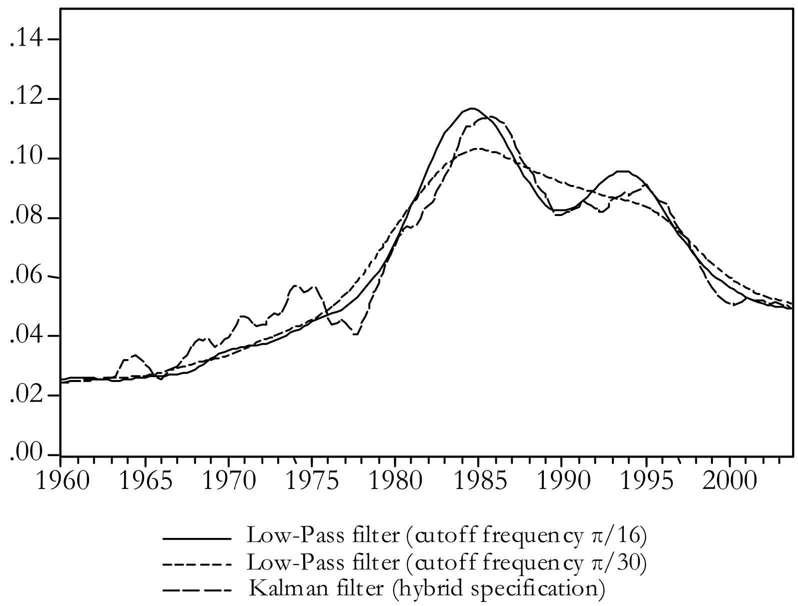

FIG. 2. Historical Estimates of Time-Varying Natural Rates, UK 1960:1-2003:4

The bell-shaped pattern of the natural rate is robust to a number of specification changes, some of which are especially worth reporting. First, I re-estimate the unobserved components model using alternative values of the signal-to-noise ratio. In particular, I set the ratio to 0.04 and 0.16, i.e. I allow the quarterly variation of the time-varying natural rate to equal 20 and 40 percent respectively of the residual variation of the inflation dynamics model. The resulting estimates of the time-varying natural rates, together with the original estimate, are reported in Figure 3(i).

12 See Layard, Nickell and Jackman (2005).
13 For a detailed discussion see Nickell (2001).

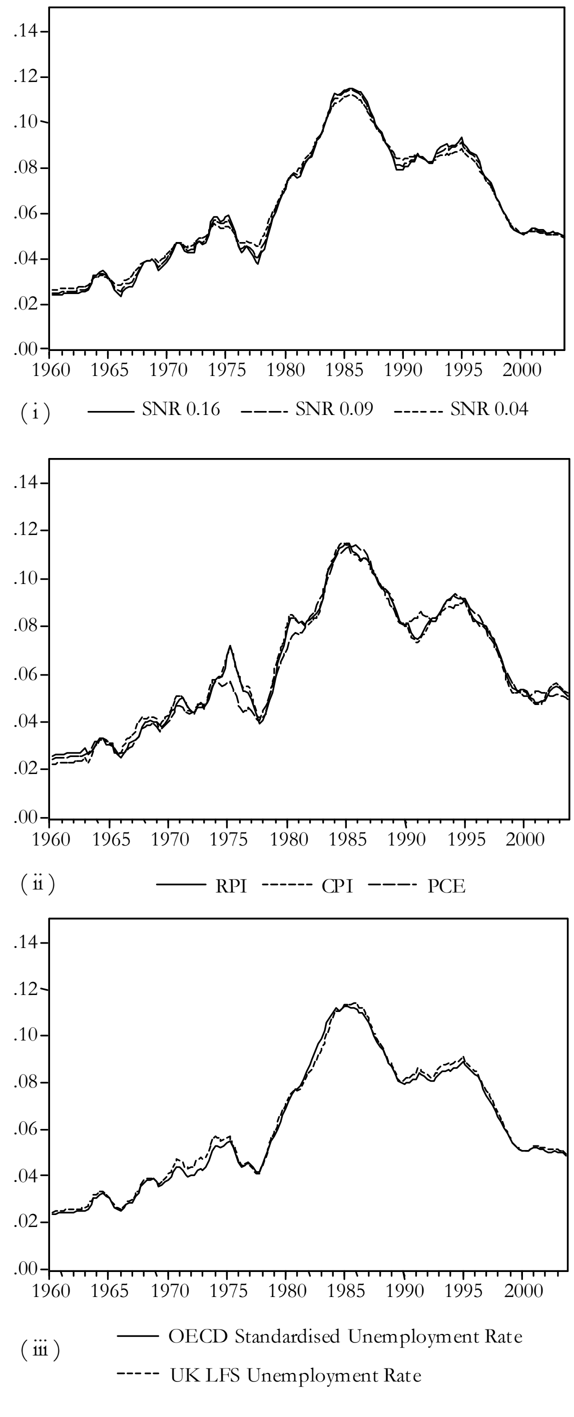

FIG. 3. Sensitivity Analysis, Kalman Filter Estimates of Natural Rates: Hybrid Specification

As expected, the estimated series differ somewhat between themselves - lower signal-to-noise ratios produce relatively flatter estimates - but the differences are very small and the overall pattern does not change. Second, I consider the robustness of the estimated time-varying natural rates to alternative definitions of price inflation. To do so, I re-estimate the unobserved components model using inflation rates based alternatively on the retail price and consumer price indices. The resulting natural rate estimates, shown in Figure 3(ii), are broadly similar to the one derived earlier using the implicit final consumption expenditure deflator. A third specification check is to consider the robustness of the results to alternative measures of unemployment. I do so by replacing the UK LFS unemployment rate with the OECD standardized unemployment rate. Figure 3(iii) shows that the resulting natural rate estimates remain very close to the original one. A fourth sensitivity test is to use an alternative model of how the natural rate evolves over time. In particular, I model the change in the natural unemployment rate as a persistent stationary process whereby, following a shock, the natural rate converges to its new steady state gradually, i.e.:

$$\Delta u_t^* = \phi \Delta u_{t-1}^* + \upsilon_t \tag{11}$$

where $0 \leq \phi < 1$ and υ_t is a random error with zero mean and variance σ_υ^2. I re-estimate the standard specification of the unobserved components model using the above stochastic process as state equation. A Wald test on the ϕ coefficient fails to reject the null hypothesis that the coefficient equals zero, i.e. it fails to reject the null of a random walk process.[14]

Table 2 reports estimates of the natural rate, at various points in time, and shows that differences across methods can be wide, thus, increasing the uncertainty about the true

[14] Wald chi-square statistic: 2.4 (p-value 0.12).

level of the natural rate and the true state of the economy.

TABLE 2

HISTORICAL ESTIMATES OF THE NATURAL UNEMPLOYMENT RATE OF THE UK

Method	1964:1	1974:1	1984:1	1994:1	2000:1
HP trend ($\lambda = 1600$)	2.6	4.1	11.2	9.2	5.7
HP trend ($\lambda = 25600$)	2.5	4.4	9.8	8.6	6.1
Low-Pass filter (cutoff frequency $\pi/16$)	2.5	4.2	11.5	9.5	5.7
Low-Pass filter (cutoff frequency $\pi/30$)	2.6	4.3	10.2	8.5	6
Kalman filter (standard specification)	3.4	6.9	10.3	8.1	4.6
Kalman filter (hybrid specification)	3.2	5.7	10.8	8.8	5.1
Memoranda					
Median of estimates	2.6	4.3	10.5	8.7	5.7
Range of estimates	2.5-3.4	4.1-6.9	9.8-11.5	8.1-9.5	4.6-6.1
Actual unemployment rate	2.9	3.6	11.8	9.9	5.8

Differences across methods are also reflected clearly in the time profile of unemployment gaps. Figures 4 and 5 report unemployment gaps constructed on the basis of the six alternative estimates of the natural rates. In line with one's priors, the unemployment gap series are positive during the early eighties and early nineties, i.e. in the aftermath of negative demand shocks, and negative during the early seventies and late eighties, i.e. during periods of excess demand such as the years of the Barber and Lawson booms.

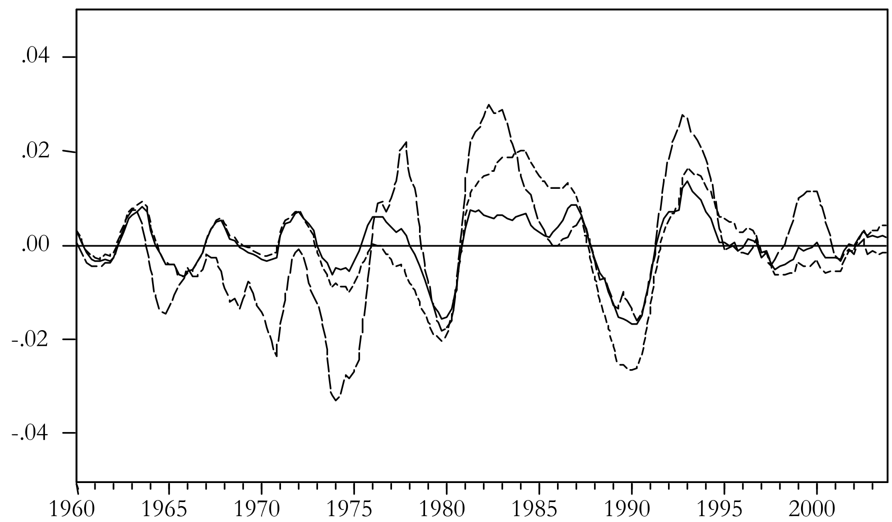

FIG. 4. Unemployment Gaps

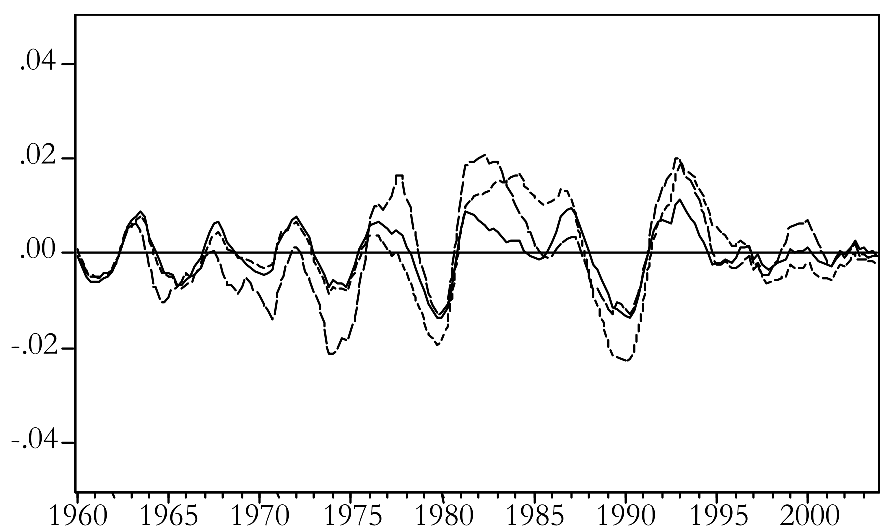

FIG. 5. Unemployment Gaps

Yet, despite similarities in the overall pattern, the differences between the unemployment gap series are considerable and, in the light of the potential importance of the unemployment gap series as a monitoring devise of the state of the economy, this finding is rather disconcerting. In principle, because multivariate methods bring additional information to bear on the decomposition of trend and cycle, one can argue that they provide more accurate estimates of natural rates assuming that the underlying model is correctly specified. Yet, in practice, given uncertainty about model specification, especially uncertainty regarding the proper modelling of the behaviour of the unobserved component, the advantage of multivariate methods may be largely illusory. One way to deal with this uncertainty is to discriminate between the natural unemployment estimates and find out which one is more accurate. It is to this that I now turn.

3 Assessment of Alternative Natural Rate Estimates

The aim of this section is to determine which of the above methods delivers natural rate estimates that may be more appropriate for the purposes of monetary policy. As the natural rate of unemployment, and the associated unemployment gap, is an important input in models of inflation dynamics, a good way to do so is on the basis of the power of alternative natural rate estimates to predict inflation. For this purpose, I generate pseudo out-of-sample forecasts of changes in inflation using alternative natural rate estimates and compare their forecasting performance using their root mean squared forecast error. I also generate pseudo out-of-sample forecasts of changes in inflation from a model of inflation dynamics with a constant natural rate as well as from an autoregressive inflation model, both of which serve as benchmarks.

As observed differences in root mean squared errors across equations are not necessarily statistically significant, it is important to use a formal statistical procedure and test them. I do so using the test of equality of predictive accuracy proposed by Diebold and Mariano (1995). The Diebold-Mariano test procedure is designed to test the null hypothesis of equality of predictive accuracy by considering the mean loss differential that is constructed from the mean squared errors of pairs of competing models. Under the null hypothesis, this mean, suitably normalized, has an asymptotic standard normal distribution. For small sample sizes, Diebold and Mariano recommend the use of finite-sample tests of predictive accuracy to complement theirs. In line with their recommendation, I also use a standard sign test.[15]

Column two of Table 3 reports the root mean squared errors obtained from one-step-ahead pseudo out-of-sample inflation forecasts. The seven first root mean squared errors are based on forecasts of (7) where, each of them, is derived using a different measure of the natural rate of unemployment. The last root mean squared error is based on a forecast using a standard autoregressive model.[16] Prima facie, the results suggest that models based on Kalman filter estimates of the natural rate outperform those based on univariate methods. They also suggest that models based on univariate methods fail to outperform even models with constant natural rates. Columns three and five of Table 3 examine to what extent the

[15] Noting that, for small and moderate-sized samples, the Diebold-Mariano test is over-sized, Harvey, Leybourne, and Newbold (1997) propose a modification in order to improve the test's finite sample performance. The main modification involves using an approximately unbiased estimator of the variance of the mean of the mean squared error differences. Also, they propose comparing their modified Diebold-Mariano statistic with critical values from the Student's t distribution with (n-1) degrees of freedom rather than from the standard normal distribution. The results of the Harvey, Leybourne and Newbold test were only marginally different from those of the Diebold-Mariano test thus I do not report them here. Naturally, they are available upon request.

[16] This is an AR(3) model; the lag selection is based on the AIC.

superior forecasting performance of models based on Kalman filter estimates of the natural rates is statistically relevant. More particularly, column three reports the Diebold-Mariano

Table 3

Forecasting Performance of Alternative Natural Rate Estimates

Method	RMSE	DM Statistic *Benchmark* *hybrid*	DM Statistic *Benchmark* *constant*	Sign Test Statistic *Benchmark* *hybrid*	Sign Test Statistic *Benchmark* *constant*
HP trend ($\lambda = 1600$)	0.294	3.063 (0.002)	-0.188 (0.850)	1.633 (0.102)	-1.225 (0.221)
HP trend ($\lambda = 25600$)	0.294	3.047 (0.002)	-0.201 (0.840)	2.041 (0.041)	-0.816 (0.414)
Low-Pass filter (cutoff frequency $\pi/16$)	0.286	3.195 (0.001)	-0.697 (0.486)	1.633 (0.102)	-1.633 (0.102)
Low-Pass filter (cutoff frequency $\pi/30$)	0.300	3.039 (0.002)	0.524 (0.600)	2.858 (0.004)	0.408 (0.683)
Kalman filter (standard specification)	0.223	-1.117 (0.264)	-3.022 (0.002)	-1.225 (0.221)	-2.449 (0.014)
Kalman filter (hybrid specification)	0.231	- -	-2.906 (0.004)	- -	-2.449 (0.014)
Constant natural rate	0.296	2.906 (0.004)	- -	2.449 (0.014)	- -
Memorandum					
AR(3)	0.211	-0.695 (0.487)	-3.009 (0.003)	-0.408 (0.683)	-2.449 (0.014)

Notes: RMSEs based on one-step-ahead pseudo out-of-sample inflation forecasts; Estimation sample: 1960:1-1997:4; Forecast sample: 1998:1-2003:4; *Benchmark* refers to the model against which all other models are compared; p-values in parentheses.

test statistic and column five the sign test statistic derived from comparisons of all models against the inflation dynamics model whose natural rate is estimated using the hybrid specification of the multivariate method. Overall, the superior performance of the latter against models based on univariate method estimates of the natural rate is highly statistically significant whereas its performance against the model based on natural rate estimates using the standard specification of the multivariate method or against the autoregressive model is insignificant. Thus, the results confirm the superior forecasting performance of the models based on the Kalman filter method. Columns four and six of Table 3 report the Diebold-Mariano and sign test statistics respectively derived from comparisons of all models against the inflation dynamics model with a constant natural rate. The results confirm that the hypothesis of equality of predictive accuracy between models based on univariate estimates of the natural rate and the model with a constant natural rate cannot be rejected.

In a similar exercise, using US data, Orphanides and Williams (2002) failed to detect differences in the forecasting performance across models with different estimates of the natural rate and concluded that "inflation forecasting accuracy is virtually identical across the specifications that include the unemployment gap". The above results suggest that this is not true for the UK. In particular, the results show that one cannot reject the hypothesis that models of inflation dynamics based on multivariate estimates of the time-varying natural rates have superior forecasting performance to those based on univariate estimates of natural rates or those based on constant natural rates. To the extent that the power to predict inflation is considered as one of the key features of the natural rate of unemployment, the multivariate estimates of the natural rate are clearly superior.

4 A Taylor Rule with a Time-Varying Natural Rate

Starting with Taylor (1993) a substantial literature argues that the US monetary policy of the past twenty years can be well explained by a simple interest rate reaction function where interest rates respond to deviations of inflation from its target as well as to aggregate slack. Ball and Tchaidze (2002) and Blinder and Reis (2005), among others, show that a simple Taylor rule based on a time-varying natural rate can track closely the US monetary policy of the nineties, suggesting that the policy makers' "forbearance" in face of falling unemployment and a booming economy reflected simply a real-time awareness of the steady decline of the natural rate of unemployment.[17] To the extent that "forbearance" in face of falling unemployment was a key component of the remarkable economic record of the United States during the nineties, the American Federal Reserve's early recognition of the steady decline of the natural rate should claim part of the credit.[18]

As shown above, the UK economy too witnessed a significant and sustained decline in its natural unemployment rate during the second half of the nineties. Indeed, in retrospect one can say with confidence that towards the end of the decade the UK economy could sustain rates of unemployment not seen since the early seventies. How successful have the UK monetary policy authorities been in recognizing early, as the US Federal Reserve did, the structural changes that led to the steady fall of the natural rate? Or, to put it differently, how different would the interest rate path have been if policy makers had perfect knowledge

[17] The term forbearance was coined by Blinder and Yellen (2001) to describe the patient behaviour of the US monetary policy authorities in front of historically low unemployment rates and fast growth.

[18] Ball and Tchaidze (2002) and Blinder and Reis (2005) argue that the ability of the American Federal Reserve to recognize changes in the natural rate of unemployment was due to an early appreciation of the emerging new economy and the ensuing acceleration of productivity growth.For the potential effect of productivity growth on the natural rate of unemployment see Ball and Moffitt (2001) and Ball and Mankiw (2002).

of the natural rate, i.e. if they knew in real time what we learnt in hindsight?

Recent evidence suggests that, since the adoption of inflation targeting, a simple interest rate reaction function comes close to mimic the behaviour of the Bank. Nelson (2001) estimated interest rate reaction functions for each UK monetary policy regime since 1972 and concluded that monetary policy during inflation targeting is characterized by a reaction function with slope coefficients not dissimilar to those proposed by Taylor. If so, a simple Taylor rule based on historical estimates of the time-varying natural rate could describe how policy makers would have behaved if they had observed in real-time the actual changes in the natural rate. It can thus serve as benchmark against which some preliminary answers to the above questions can be drawn.

One caveat is in order. The actual interest rate might deviate from the one prescribed by the above Taylor rule for reasons other than real-time uncertainty about the true state of the economy, e.g. instability in the slope coefficients of the rule. Any indication therefore of systematic deviations between the two should be interpreted carefully and corroborated by additional evidence. To the extent necessary, I follow the approach of Romer and Romer (1989), and refer to the minutes of the monetary policy committee meetings and speeches of members of the committee. Before proceeding, some issues pertaining to the calibration of the natural-rate-based Taylor rule are discussed.

The interest rate reaction function that I consider is a standard Taylor rule whereby the short-term nominal interest rate responds positively to deviations of actual inflation from target inflation and to changes in the output gap, i.e.:

$$i_t = \pi_t + \omega_1(\pi_t - \pi^*) + \omega_2(y_t - y_t^*) + r_t^* \tag{12}$$

or using the unemployment gap as a measure of economic slack:

$$i_t = \pi_t + \omega_1(\pi_t - \pi^*) - \frac{\omega_2}{\phi}(u_t - u_t^*) + r_t^* \tag{13}$$

where i denotes the short-term nominal interest rate, π^* denotes the inflation target of the Bank, y denotes the log of real output and y^* its potential level, r^*denotes the natural rate of interest, $\omega_1$and ω_2 are slope coefficients and ϕ is the Okun's coefficient.

In effect, the standard Taylor rule postulates that when the economy is at steady state and actual inflation equals target inflation, the real interest rate equals the natural interest rate. The values of the slope coefficients $\omega_1$and ω_2 that Taylor recommends are both equal to 0.5 reflecting the observation that the opportunity cost of more inflation stability increases sharply when the fluctuations in inflation are smaller than those of output and, conversely, the opportunity costs of more output stability increases sharply when the fluctuations in output are smaller than those of inflation.

Before proceeding to derive the interest rate path that is consistent with our preferred estimate of the time-varying natural rate, one has to have an estimate of the Okun's coefficient and an estimate of the natural rate of interest which, like the natural rate of unemployment, is unobservable and time-varying. To estimate the Okun's coefficient, I first derive estimates of potential output by applying a low-pass filter that admits cycles of periodicity of eight years or longer, on the basis of which I calculate the output gap. Figure 6 shows the resulting series. The series behave as one would expect registering a recessionary gap in the first half of the decade and being close to zero thereafter.

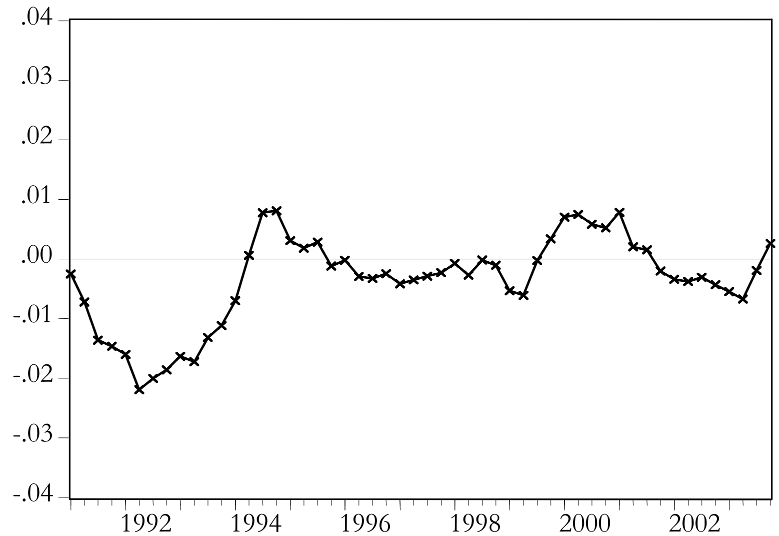

Fig. 6. The UK Output Gap, 1991:1-2003:4

Then I estimate a dynamic version of Okun's equation, as described by Gordon (1984) and Weber (1995). Table 4 reports the results. It is worth noting that the estimate of the long-run Okun's coefficient that I obtain is close to the entirely standard value of −0.5.

Table 4
OLS Estimation of Okun's Equation

Dependent variable: Unemployment Gap			
Regressors	*Lags*		
Unemployment Gap	1-2	0.851	(0.048)
Output Gap	1-2	-0.078	(0.045)
Implied Long-Run Okun's Coefficient		-0.526	(0.214)
R^2		0.95	
SER		0.001	
LM		3.36	(0.50)

Notes: Standard errors in parentheses; Breusch-Godfrey LM statistic for serial correlation up to order 4 (p-value in parenthesis).

Modern New Keynesian models of monetary policy define the natural interest rate as the rate of interest at which the output gap converges to zero. In the spirit of this definition, I estimate the natural interest rate using the following multivariate unobserved components model:

$$q_t = a(L)q_{t-1} + b(L)(r_t - r_t^*) + \varepsilon_t \tag{14}$$

and

$$r_t^* = r_{t-1}^* + \eta_t \tag{15}$$

where q denotes the output gap, r the short-term real interest rate, ε is a random error with zero mean and variance σ_ε^2, and η is a random error with zero mean and variance σ_η^2.

The basic specification and methodology are close to this used by Laubach and Williams (2002) but, unlike them, I assume that the natural rate of interest follows a random walk. To ensure that the estimated natural rate of interest exhibits low frequency variation, I restrict the signal-to-noise ratio $(\sigma_\eta^2/\sigma_\varepsilon^2)$ to 0.01. The estimated natural rate of interest hovers around 3.8 percent for the first three years of the inflation targeting regime but declines gradually thereafter. At the end of 2002, the natural rate of interest stood close to 2.5 percent.

Having retrieved estimates of the Okun's coefficient and the natural rate of interest, I proceed to consider how different the interest rate path would have been if policy makers had perfect knowledge of the natural rate of unemployment in real time. I will do so in the context of the natural-rate-based Taylor rule, where the historical estimate of the time-varying natural rate used is the one derived from the hybrid specification of the unobserved components model. I measure inflation using the retail price index excluding mortgage payments and I set the inflation target to 2.5 percent, respectively, the preferred measure of inflation and the inflation target of the Bank until the end of 2003.

Figure 7 plots the actual interest rate against the interest rate prescribed by the natural-rate-based Taylor rule. Two salient features of the graph are worth noting. First, the two

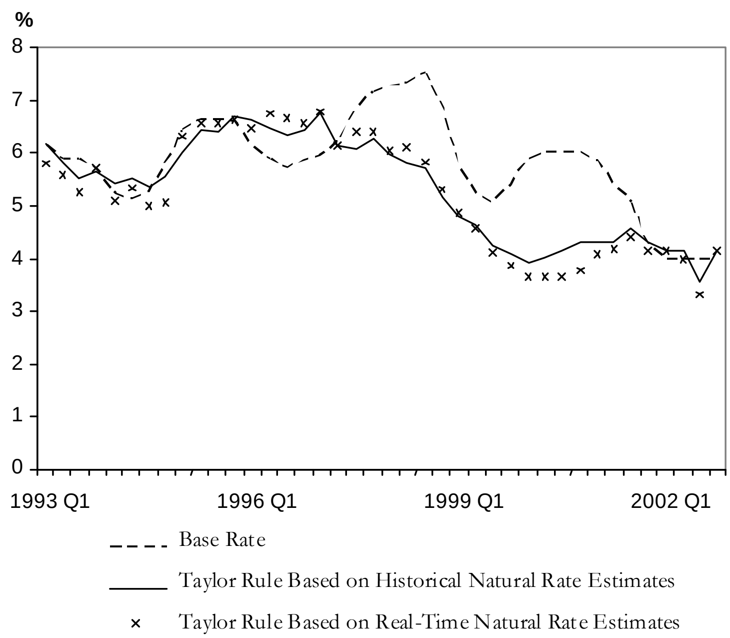

FIG. 7. The Base Rate vs Taylor Rules Based on Time-Varying Natural Rates

series follow broadly the same path. In particular, both series fluctuate around six percent during the first three years of inflation targeting and both decline thereafter, converging to an interest rate of four percent towards the early years of the new century. The behaviour of the actual and calibrated interest rates suggests that, overall, the UK monetary policy authorities have tracked the changes in the natural rate of unemployment reasonably well. Second, the actual and calibrated interest rates move closely together during periods at which the natural rate remains stable whereas they temporarily deviate during periods at which the natural rate declined. In particular, during the first three years of inflation targeting, while the natural rate was roughly constant, the actual and calibrated interest rates move closely together, whereas, during the second half of the nineties, while the natural rate was declining, the two series temporarily deviate. This pattern points towards the presence of perception lags regarding changes in the natural rate, suggesting that in periods of sustained changes of the natural rate it may be taking some time for policy makers to process the new information and update their model parameters accordingly.

To substantiate this hypothesis, I follow the narrative approach advocated by Romer and Romer (1989), and examine the monetary policy debate, as reflected in the minutes of the monetary policy committee meetings and public speeches of the members of the committee. I do so by focusing, in particular, in the periods from 1997:2 to 1998:3 and 1999:3 to 2001:1, both periods during which the actual base rate increased while the interest rate prescribed by the Taylor rule suggested a somewhat looser monetary policy stance.

Early in the first period, the committee identifies an interesting pattern in the data: although quantity indicators of the labour market, such as the unemployment claimant count, vacancies and skilled labour shortages, point consistently towards a tight labour market with considerable upside risks to the domestic component of inflation, earnings growth exhibits remarkable stability, rising on average at an annual rate of 4 to 4.5 percent, a rate consistent with the Bank's inflation target. This "benign conjunction of strong quantities and modest earnings growth" was new and puzzling. In principle, it could either signify that the natural rate of unemployment was lower than thought or that the substantial real appreciation of the sterling since 1996 reduced temporarily the wedge between the real consumption wage and the real product wage. Both explanations would show in the data as reduced pressure on earnings growth for any given level of unemployment, although in the first case this would be a permanent, whereas in the second a temporary effect.[19] In the minutes of the monetary policy committee meeting of July 1997, the committee noted:

"It remained surprising that earnings growth had not increased further during the last few years given the recorded increases in employment and falls in unemployment. It appeared possible that the rate of unemployment compatible with a stable rate of inflation was lower than had earlier been thought. But it was also possible that there could be a sudden sharp increase in earnings growth, as there had been in the late 1980s, when earnings growth had risen after what had seemed at the time a surprisingly long period of stability" (MPC Minutes, July 1997, § 45).

In subsequent meetings, the committee explicitly acknowledged the theoretical possibility that the natural rate of unemployment might have declined but remained uncertain about the likelihood of this outcome and dismissed taking any action upon it. While waiting to see how long-lasting the stability of earnings growth would be, the committee attached much higher weight to the probability that, following the expected reversion of sterling towards its equilibrium value, inflation would reignite. The minutes of the meeting of September 1997 noted:

"The Committee concluded that uncertainties remained about how much further tightening of the labour market could be tolerated without generating upward pressure on wages.

[19] Note that this analysis is consistent with a standard open economy natural rate model. For details, see Layard, Nickell, and Jackman (2005).

It would be unwise in the current state of knowledge to take a strong view about the level of the natural rate of unemployment but it remained essential to monitor closely wage settlements and average earnings" (MPC Minutes, Sept 1997, § 21).

In subsequent meetings, and as the underlying trend in earnings growth remained stable, the possibility of a decline in the natural rate of unemployment came under closer scrutiny. In the minutes of April 1998, and for the first time, the committee discussed extensively the determinants of the natural rate and considered alternative reasons for its possible decline. On balance, the committee acknowledged the presence of a perception lag and invited further scrutiny of the natural rate, while also raising concerns about trends in the labour market quantity indicators. In particular, the minutes noted:

"Taken together, the quantity signals appeared to indicate a tightening of the labour market and some surveys suggested that the tightening would continue. The problem was in judging where the natural rate of unemployment lay. On one view, the subdued behaviour of earnings was encouraging evidence that the natural rate of unemployment might be lower than had previously been thought." (MPC Minutes, April 1998, § 42).

In subsequent meetings, and in particular from mid-2000 onwards, as the expected correction of the real exchange rate did not materialize while the benign combination of falling unemployment with subdued earnings growth continued, the minutes reveal a greater confidence in revising downwards the perceived estimates of the natural rate and gradually coming into terms with a new period of lower sustainable unemployment. The minutes of the meetings of November 2000 noted:

"More generally, it was possible that the sustainable rate of unemployment had, for a variety of reasons, improved by more than the Committee had already allowed for in its recent forecasts. A further adjustment had been made by the Committee in the latest Inflation Report projections." (MPC Minutes, November 2000, § 20).

Overall, the evidence in the minutes of the monetary policy committee meetings bears out the view that the temporary deviation of the actual base rate from the natural-rate-based Taylor rule is, at least partly, due to perception lags regarding the changing natural rate of unemployment. To a large extent, the monetary policy committee could not have possibly avoided them. Their presence reflects the gradual process of making sense of structural economic changes, under conditions of uncertainty, and based only on data available at the time the decision is made. Yet, the use of the multivariate unobserved components method to estimate the time-varying natural rate would have potentially helped reduce the length of perception lags.

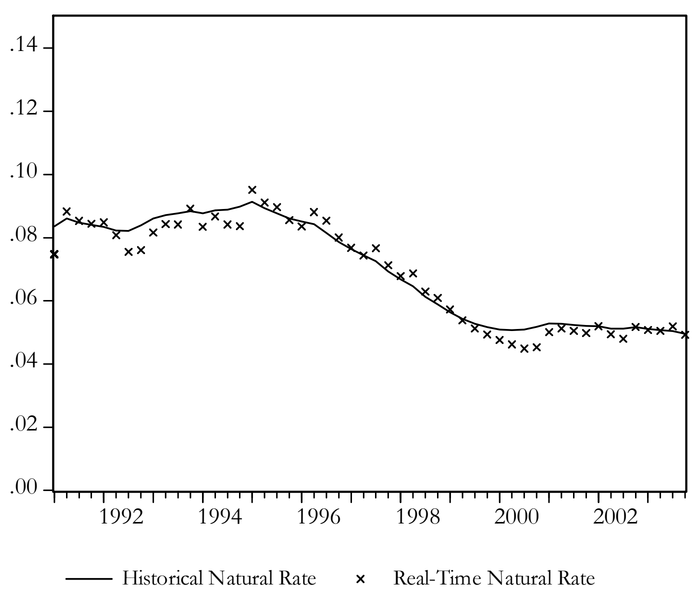

FIG 8. Real-Time vs Historical Estimates of the Time-Varying Natural Rate

Figure 8 plots the historical against the one-sided estimate of the natural rate, i.e. the estimate obtained with the benefit of hindsight against this obtained using model parameters estimated recursively by only using information available at the time of decision making. Although the latter are typically noisier, they contain timely and useful information about the behaviour of the natural rate and therefore could serve as an additional input in forming an early judgement about the state of the economy and the risks to inflation.

5 Conclusion

Since Milton Friedman's 1968 seminal paper on the role of monetary policy, the concept of a time-varying unemployment rate at which inflation remains stable has established itself as one of the most influential in macroeconomics. Yet, although few would dispute its analytical value, empirical estimates of the time-varying natural rate have largely been greeted with scepticism. To a large extent, this is due to the uncertainty that accompanies estimates of unobserved variables as well as the fact that competing methods of estimation have delivered quite dissimilar results. In this context, the paper employs a number of univariate and multivariate methods to estimate the time-varying natural rate of Britain during 1960:1-2003:4 and discerns which of these methods delivers estimates with the highest information content for future inflation. The main findings of the paper are as follows. First, the natural rate of unemployment has followed a bell-shaped pattern, rising from three percent in the early sixties to an average of eight percent towards the end of the eighties before falling back to an average of five percent around the turn of the century. The causes of the rise and fall of the natural rate have been discussed extensively elsewhere, yet, there still remain several questions to be answered, especially regarding its welcome decline during the past decade. Second, the multivariate unobserved components method delivers unambiguously superior natural rate estimates, at least, in so far as the power of the natural rate to predict inflation is its main desirable property. Third, in times of structural economic change, one-sided estimates of the natural rate can potentially help reduce inevitable perception lags in monetary policy, such as those observed in the behaviour of the Bank of England during the second half of the nineties. In this respect, they can, together with many other variables, provide useful information to monetary policy makers in their the attempt to assess as early as possible potential risks to inflation.

DATA DEFINITIONS AND SOURCES

Prices: implicit final consumption expenditure deflator. Source: Office for National Statistics (Code: (ABJQ+HAYE)/(ABJR+HAYO)).

Prices: retail prices index excluding mortgage interest payments (RPIX). Source: Office for National Statistics (Code: CHMK).

Prices: consumer price index (all items). Source: IMF International Financial Statistics (Code: 11264ZF).

Import Prices: implicit import price deflator. Source: Office for National Statistics (Code: IKBI/IKBL).

Oil Prices: quarterly average crude price (US$ per barrel). Source: IMF International Financial Statistics (Code: 00176AAZZF).

Exchange Rate: quarterly average US$/GBP market rate. Source: IMF International Financial Statistics (Code: 112RHZF).

Unemployment: LFS unemployment rate, 1971 Q1-2003 Q4, Source: Office for National

Statistics (Code: MGSX). The series is extrapolated backwards using the OECD Labour Force Statistics unemployment rate.

Unemployment: OECD standardized unemployment rate, 1970 Q1-2003Q4,. The series is extrapolated backwards using the OECD Labour Force Statistics unemployment rate.

Aggregate Output: GDP at market prices (chained volume index). Source: Office for National Statistics (Code: YBEZ).

Short-term Interest Rate: quarterly average base rate. Source: Bank of England (Code: IUQABEDR).

Incomes Policy Dummies: 1 for periods of incomes policies; 0 otherwise. Incomes policy dummies cover to the statutory wage freeze of 1966:3-1967:3 and the social contract of 1975:3-1977:2 (for details see Flanagan, Soskice & Ulman (1983) Unionism, Economic Stabilization, and Incomes Policies, The Brookings Institution, Washington DC).

The Minutes of the Monetary Policy Committee Meetings of the Bank of England are published as an appendix to the quarterly Inflation Report of the Bank; they are also available on the Bank's website.

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