External MPC Unit

Discussion Paper No.12

Measuring the UK Short-Run NAIRU

by Nicoletta Batini and Jennifer Greenslade

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"Measuring the UK Short-Run NAIRU"[1]

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Abstract

This paper derives alternative measures of the short-run NAIRU (SRN) for the UK, the rate for unemployment at which inflation will neither increase nor decrease in the short-run. We estimate the NAIRU jointly with price equations by using the Kalman filter. Our work suggests that both structural changes in the labour market and favourable supply shocks may have had a beneficial impact on RPIX inflation over the last few years. We show that deviations of unemployment from the short-run NAIRU measures prove helpful in predicting inflation and we demonstrate their usefulness in Taylor-type policy rules for the interest rate.

JEL classification: E24, E31, E50

Keywords: equilibrium unemployment, time-varying NAIRU, short-run NAIRU, Phillips curve, supply shocks

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1. Introduction

The second half of the 1990s and the early 2000s has been a period of remarkably low levels of unemployment without substantial wage and price inflation in the UK. This phenomenon is true also of the US, where inflation did not rise despite the fall in unemployment below levels that were believed to be compatible with stable inflation. Charts 1a and 1b below emphasise this point by showing the benign profile of GDP deflator inflation (as well as RPIX and PCE inflation for the UK and the US, respectively) and unemployment in the UK and the US since 1990.

Chart 1a: UK Inflation and Unemployment 1990-2001

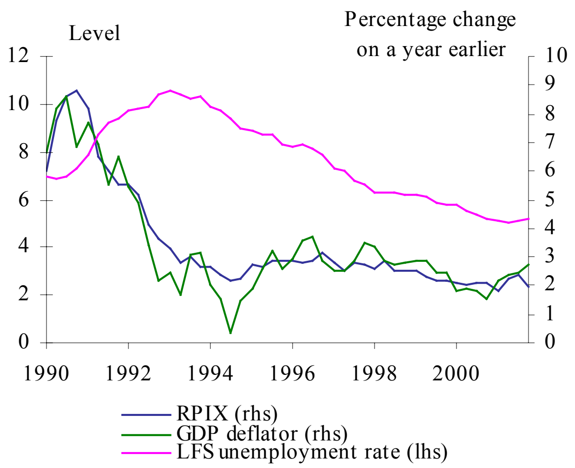
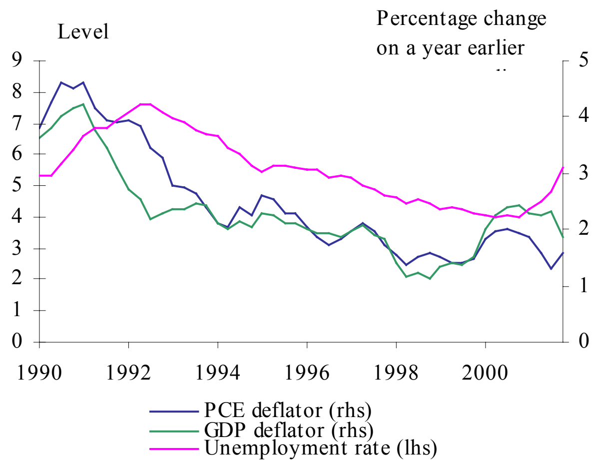


Chart 1b: US Inflation and Unemployment 1990-2001



One of the explanations for this happy state of affairs is that in both countries the NAIRU has fallen in recent years (see Cassino and Thornton (2002), Driver, Greenslade and Pierse (2003), Greenslade, Pierse and Saleheen (2003) for the UK. For the US see, among others, Staiger et al (1997a, 1997b), Gordon (1997, 1998), Stock (1998), Stock and Watson (1998), Katz and Krueger (1999), and Ball and Moffitt (2001)). Other explanations include the success of monetary policy in both countries to anchor inflation expectations; or the incidence of a series of favourable supply shocks, notably, exchange rate appreciations in both countries—which have driven down the cost to firms of intermediate imported goods and boosted workers' real consumption wages; and a shift towards a more rapid rate of productivity growth in the US—which has offset the inflationary impact of rising wage demands in the face of falling unemployment.

In this paper we investigate further two of these explanations for the low inflation-low unemployment outcomes in the UK case, namely, shifts in the unemployment level associated with stable inflation and the impact of shocks to inflation. For this purpose we derive alternative measures of the short-run or effective NAIRU (SRN). This is a reference rate for unemployment that reflects inflationary pressures over a short-run horizon. It can be thought of as the rate for unemployment at which inflation will neither increase nor decrease in the short-run, taking account not just of shifts in the longer-run NAIRU (LRN) —i.e. the rate of unemployment consistent with steady state inflation when the economy has fully adjusted to any shock or when there are no shocks—but also of temporary supply side shocks, like short-run shocks to oil prices or import prices.[1] Over the policy horizon that matters for monetary policy, inflation is influenced by changes in inflation expectations and shocks to labour and/or other input cost variables *in addition* to shifts in the gap between unemployment and the longer-run NAIRU (LRN). So focussing on deviations of unemployment from this shorter-run NAIRU concept may help explain why the outlook for UK inflation has been so benign, despite historically low levels of unemployment.

The paper is organised as follows. Section 2 derives measures of the short-run NAIRU by estimating three different models of price dynamics on UK data. The first assumes a quasi-constant longer-run NAIRU, while the other two allow it to be time-varying. In all cases we estimate the longer-run NAIRU jointly with the price equations by using the Kalman filter.[2] In section 3 we examine the information content of the unemployment/SRN gaps we have derived in predicting inflation and analyse the role of recent supply side shocks in explaining the present low inflation-low unemployment environment in the UK. The information content of our measures of the short-term unemployment gap, as well as their performance as feedback variable in policy rules à la Taylor is examined in section 4. Finally section 5 discusses policy implications and offers some concluding remarks. A Data Appendix describes the data that we have used throughout the paper.

2. Three alternative measures of short-run NAIRU

As first discussed by Friedman (1968) and Phelps (1968), in the long run the relationship between inflation and unemployment is vertical at the equilibrium or natural rate of unemployment, that is, there is no long-run trade-off between inflation and unemployment.

[1] Other temporary supply shock variables include short-run shocks to productivity and taxes.
[2] See Kalman (1960) and Kalman and Bucy (1961).

This is because in the long run, expectations of wages and prices are fully realised by the associated rate of inflation. In such circumstances, any fiscal or monetary stimulus aimed at moving the economy to a lower rate of unemployment is unsuccessful, as it ends up increasing expectations and hence pushing up prices and wages, which ultimately shifts the unemployment rate back to the natural rate—the long-run dichotomy proposition.

In practice, the natural rate is determined by the intersection of labour supply and demand curves. So, essentially, it is driven by structural labour market factors. These include, for instance, shifts in the exogenous separation rate of unemployment, in the degree of mismatch, in the level of benefits relative to post-tax earnings, in the market power of wage bargainers or in the elasticity of product demand facing the firm. Other factors include the effect of taxes, the extent of labour market insecurity and that of active labour market measures.[3] As these factors tend to vary slowly, the natural rate of unemployment typically changes only gradually over time.

When unemployment converges to its natural rate, and there are no supply shocks, inflation is constant. For this reason the natural rate of unemployment is also referred to in the literature as the Non-Accelerating Inflation Rate of Unemployment (NAIRU).[4] The constancy of inflation when unemployment is at its NAIRU level and supply shocks are absent can be illustrated by looking at a simple expectations-augmented Phillips curve à la Gordon [5] like equation (1) below, where inflation is modelled as a function of inflation inertia (ie backward-looking expectations), demand and supply shocks:

$$\pi_t = \alpha(L)\pi_{t-1} + \beta(L)(u_t - u_t^*) + \delta(L)z_t + \varepsilon_t \qquad (1)$$

In equation (1), π_t denotes inflation at time t,[6] u_t is the the actual unemployment rate, z_t is a vector of supply side shocks—such as changes in the value of the real oil price or in the value

[3] For a discussion of the determinants of the equilibrium rate of unemployment see, among others, Nickell and Layard (1999) and Coulton and Cromb (1993).

[4] In practice the NAIRU is distinct from the natural rate of unemployment. This is because the natural rate concept captures the long-run real equilibrium determined by the structural characteristics of the labour and product markets. Whereas the NAIRU is defined solely in relation to the level of unemployment that is consistent with a stable rate of inflation and so may it be affected by the adjustment of the economy to past economic shocks. As the effects of adjustment to shocks fade away, the NAIRU will tend towards the natural rate. See Carlin and Soskice (1995: 157).

[5] See Gordon (1997) and Staiger et al (1997a, 1997b).

[6] In (1) it is assumed that the inflation rate is integrated of order zero, so that π_t is stationary. If inflation is instead assumed to be integrated of order one, then $\Delta\pi$ will be stationary.

of the relative import price deflator. These have direct price effects because they affect directly the price of imported intermediate and final goods. L is a polynomial in the lag operator, and Δ is the difference operator. Demand shocks are captured by the deviation of u_t from u_t* or the long-term 'unemployment gap'—the NAIRU 'u_t*' being here the labour market equivalent to sustainable capacity utilisation in the goods market. $\beta < 0$, which implies that positive unemployment gaps (actual above NAIRU) have a deflationary impact and vice versa. In equation (1), inflation expectations are modelled as a purely backward-looking (inertial) process and so are approximated by a distributed lag on past inflation. Finally, ε_t is a serially uncorrelated disturbance. If the sum of the coefficients $\alpha(L)$ is equal to one, there will be a unique equilibrium or 'natural rate' level of u_t*, such that when $u_t = u_t$* and $z_t = 0$, inflation will be constant. So in this context, the NAIRU is the value of u_t at which both inflation and unemployment are stable. We call this value of unemployment 'longer-run NAIRU' (LRN) to distinguish it from the concept of a 'short-run NAIRU' (SRN) that we discuss below.

Use of the natural rate of unemployment to inform policy decision in practice is complicated on conceptual and practical grounds.

Conceptually, as evident from equation (1), it may not be sensible to attempt to stabilise inflation by driving u to u* in every period. As the unemployment gap is only one determinant of inflation, this may not be sufficient in itself to stabilise inflation. By the same token, it would be highly suboptimal to compensate for destabilising supply shocks or inertia in inflation by manoeuvring u above or below u*, as the unemployment and output costs of doing so could be potentially huge. Importantly, u* is the equilibrium level of unemployment in the (very) long run and it is not obvious that it will be at all possible to drive unemployment towards this distant-horizon natural level so as to hit a target for price stability defined over a much shorter policy horizon. So although, undoubtedly, knowledge about the natural rate of unemployment is informative because it tells us about the steady-state properties of the economy, there may be some difficulties when focussing on it for practical, day-to-day policy decisions.

Empirically, the longer-run NAIRU is unobservable. However, because it is one of the determinants of inflation in the long run, knowledge of its level can be relevant for policy purposes, and so there have been numerous attempts to measure it both in the UK and in the

US. Standard ways of deriving measures of the LRN include fitting the data to different types of models. Usually these assume that the LRN is constant over time; or that it can be captured by a linear transformation of some step function or spline; or that it follows a stochastic random walk. In general, estimates of the LRN tend to be rather imprecise, as uncertainties about the specifications of the wage-price systems or about measurement of structural labour market factors which underlie the LRN computation carry over to the latter.

Perhaps a more interesting concept of equilibrium for unemployment to use in policy is that of a short-run NAIRU (see Braun (1984), Layard and Bean (1989), Estrella and Mishkin (1999) and Meyer (2000)). This is the unemployment rate at which there is no tendency for inflation to rise or fall over a short to medium term policy horizon (one that is consistent with inflation stabilisation at time t in practice). In this sense it can be thought of as the longer-run NAIRU adjusted for supply shocks and inflation expectations, ie for all the determinants of inflation in the simple Phillips curve model outlined in equation (1). Unsurprisingly, as many other variables other than the unemployment gap drive inflation over shorter horizons, the SRN can be quite different from the LRN or natural rate of unemployment, u^*. And because it is a function of a variety of supply side shocks, the SRN will tend to bounce around much more than the gradually-moving LRN, which is instead uniquely driven by structural labour market factors. However, inasmuch as it provides a reference rate for unemployment that keeps track of the impact on inflation of cumulated shifts in LRN, supply shocks and expectations, the SRN is presumably more germane for policy in practice as it is for predicting inflation. Of course, from an empirical point of view, the SRN is also unobservable, so its derivation will be subject to uncertainties of various kinds, as in the case of the LRN.

2.1 Methodology

Below we construct three different measures of the SRN for the UK. Our approach consists of two steps. First we derive an estimate of the LRN. Second we obtain a measure of the SRN based on our LRN estimates. In what follows we describe both steps in more detail.

2.1.1 Step 1: Deriving the LRN

Since the LRN cannot be observed directly, we follow Greenslade, Pierse and Saleheen (2003) and model it as an unobserved stochastic random walk process. We then estimate it jointly with a reduced-form model of RPIX price dynamics with quarterly UK data from 1973 Q1 to 2001 Q4 by using the Kalman filter. In general, extraction of the LRN via multivariate filtering appears preferable to either use of univariate estimates—as the former allows more information to be encompassed than univariate methods—as well as to methods involving estimates of structural wage-price systems— and this method side-steps various modelling problems which are encountered when estimating a theoretical model of the NAIRU.[7] We follow a commonly used approach and estimate the model in first differences of inflation as this is a way of imposing dynamic homogeneity (see for example, Staiger, Stock and Watson (1997a)).[8] The approach generally used in the Kalman filter literature assumes that inflation expectations are implicit in the inflation dynamics, rather than being explicitly identified. Separate work suggests that inflation expectations play some role in determining inflation in the UK, though the evidence is not yet conclusive (see Driver, Greenslade and Pierse (2003)). It is possible that our NAIRU estimates are indirectly picking up any such changes (which could be related to changes in the UK monetary policy regime).

The resulting price system that we estimate is then:

$$\Delta\pi_t = \alpha(L)\Delta\pi_{t-1} + \beta(L)(u_t - u_t^*) + \delta(L)z_t + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \tag{2}$$

$$u_t^* = u_{t-1}^* + \eta_t \qquad \eta_t \sim N(0, \sigma_\eta^2),\ cov(\varepsilon_t, \eta_t) = 0 \tag{3}$$

where, relative to equation (1), we now assume that RPIX inflation depends on its own first lag (abstracting from the unemployment gap and supply side shocks) with a coefficient that we constrain to be exactly unity—to ensure long-run neutrality— plus lags of its first difference. As explained in Greenslade, Pierse and Saleheen (2003), estimating the LRN in conjunction with equation (3) gives a measure of equilibrium unemployment that works best in the reduced-form dynamic equation for prices and so provides a quite intuitive estimate of the level of the NAIRU in the long run. Though the variability of the NAIRU can in principle be estimated from the data, the extent to which the NAIRU can move around from quarter to quarter is usually restricted in the academic literature, reflecting the assumption that the

[7] See Cassino and Thornton (2002) for a discussion of the problems with finding UK labour market variables necessary for modelling the LRN as a function of labour market or demographic trends.
[8] Dynamic homogeneity is important as it ensures a meaningful NAIRU. Another way in which it can be imposed is to model inflation but impose the sum of lagged inflation terms to be equal to one. In terms of the RPIX models considered here, the NAIRU estimates do not appear to be very sensitive to such a choice of specification (see Driver, Greenslade and Pierse (2003) for details of models estimated using this latter approach).

NAIRU is determined by structural factors that evolve gradually over time. Obviously, the choice of this restriction (the signal-to-noise ratio) is to some degree arbitrary and there is no universally accepted rule as to how to impose it. The NAIRU profiles are influenced by this restriction and we shall show the sensitivity of the NAIRU profiles to two values for the signal-to-noise ratio.[9]

In this simple set-up, inflation changes either because the unemployment gap changes or because the *z* vector changes or because ε_t is non-zero at time *t*, in other words, a random shock puts upward or downward pressure on the growth rate of inflation. In turn, changes in the unemployment gap can originate from shifts in u_t*, the longer-run NAIRU. Assuming that system (2)-(3) is Gaussian (i.e. that ε_t, η_t and u_0* are normally distributed), we can evaluate its sample log-likelihood function via the Kalman filter and then find the maximum likelihood estimate of the vector of parameters $\alpha(L)$, $\beta(L)$ and $\delta(L)$ in the system together with a profile for the NAIRU (u_t*) by using a standard numerical optimisation algorithm. Throughout we concentrate on 'smooth' Kalman filter estimates (i.e., optimal estimators of the state vector given *all* the information that is available in the sample), rather than the filtered estimator that only uses information available period by period.

We derive three different measures of the LRN by estimating three separate parametrisations of system (2)-(3). More precisely, to derive the first LRN measure we restrict the noise-to-signal ratio, i.e. the ratio of the variance in the longer-run NAIRU (σ_η^2) relative to the variance of changes in inflation (σ_ε^2), to a very small number (0.002).[10] This implies that the ensuing LRN is almost constant. The second NAIRU measure adopts the same methodology as above, but imposes a signal-to-noise ratio of 0.16, which implies more volatile measures of the longer-run NAIRU. This ratio is more consistent with empirical priors in the UK (see Driver, Greenslade and Pierse (2003), Greenslade, Pierse and Saleheen (2003) and Cassino and Thornton (2002) among others) and produces NAIRU estimates that are in line with other empirical estimates (see Coulton and Cromb (1994)).[11] Because the choice of the noise-to-signal ratio is somewhat arbitrary, deriving SRNs for different values of this ratio provides

[9] See Greenslade, Pierse and Saleheen (2003) for a more thorough discussion of this issue.
[10] When we restrict this ratio to 0 results do not converge, so we opt for a small non-zero number in the analysis.
[11] Note that when the signal-to-noise ratio is freely estimated, the point estimate is numerically larger than the restriction used throughout this paper (0.16) but lies within the confidence interval. The resulting NAIRU estimates show implausibly large variation (perhaps because the model insufficiently captures supply side or expectations shocks, particularly in the 1970s), so we maintain the lower figure. Turner et al. (2001) also calculate short-run NAIRU estimates based on time-varying estimation techniques, though their LRN estimates are even less volatile than those reported in this paper and so are less plausible for the UK.

an idea of the sensitivity of our results. Finally, the third LRN measure also imposes a noise-to-signal ratio of 0.16, but differs from the second LRN measure because it excludes temporary supply shocks from the Phillips curve model. In other words, this third measure is estimated by restricting δ to zero, so that any information from the z_t vector is subsumed in the time-variation of u_t*. Because the longer-run NAIRU estimates from this third measure are subject to temporary supply shocks, they are close conceptually to estimates of the shorter-run NAIRU—although, as we shall see below, these two sets of estimates are not identical since the latter also include inertia in the inflation adjustment process. Maximum likelihood estimates of system (2)-(3) for these various specifications are reported in Table 1 below.

Table 1: Price Inflation Phillips Curve Models estimated using the Kalman filter, 1973Q1–2001Q4

Dependent variable	RPIX	RPIX	RPIX
$\Delta\pi_t$ (rpix)	(1)	(2)	(3)
Signal-to-noise restriction	0.002	0.16	0.16
u-u*	-0.10	-0.43	-0.70
	[-2.67]	[-4.59]	[-4.61]
$\Delta\pi_{t-4}$	-0.23	-0.32	-0.35
	[-3.08]	[-4.96]	[-5.21]
ΔReal Import Price Inflation $_{t-1}$	0.29	0.32	-
	[3.09]	[3.43]	
ΔReal Import Price Inflation $_{t-4}$	0.23	0.25	-
	[2.14]	[2.43]	
ΔReal Oil Price Inflation $_{t-4}$	0.12	0.19	-
	[1.13]	[1.89]	
D79/80	-3.99	-3.76	-3.79
	[-5.81]	[-6.72]	[-6.54]
LL	-153.28	-143.99	-157.23

LL is the log-likelihood, t-statistics are in parentheses.

To derive results in Table 1 we employ a general to specific estimation methodology. We start with a set of regressors including the current value of the unemployment gap, lagged annual RPIX inflation terms and lagged real import price inflation and real oil price inflation terms (which measure supply shocks) and test down to obtain a more parsimonious representation. The first row of the table shows that changes in inflation are negatively correlated with the unemployment gap, suggesting that when unemployment is below the NAIRU inflation will rise and vice versa, subject to additional effects from the inertia and supply components in the model.[12] Real import prices are strongly significant in model 1 (where the variance is restricted to be 0.002); by contrast, in this model real oil prices are not significant at standard levels of testing. When we increase the value of the noise-to-signal ratio to 0.16 (model 2), real oil prices are however significant at the 90% level of testing. The final column of Table 1 shows what happens when we exclude supply shock variables from the model (model 3). The zero restriction on the coefficients of the supply shock terms is strongly rejected by the data and so model 3 has a much lower likelihood than models 1 and 2.

2.1.2 Step 2: Deriving the SRN

Once we have estimates of the LRN we can easily recover measures of the SRN. In line with Braun (1984), Layard and Bean (1989), Estrella (1997) and Estrella and Mishkin (1999), using the analytical set up and the notation of equation (2) we define this as:

$$us_t^* = u_t - \frac{1}{\beta(0)}\left\{\alpha(L)\Delta\pi_{t-1} + \beta(L)\left(u_t - u_t^*\right) + \delta(L)z_t\right\} \tag{4}$$

which reduces to (5) below when, as in our case, changes in inflation depend significantly only on the current unemployment gap, $(u_t - u_t*)$ and not in lags of this gap :

$$\begin{aligned} us_t^* &= u_t - \frac{1}{\beta(0)}\left\{\alpha(L)\Delta\pi_{t-1} + \beta(0)\left(u_t - u_t^*\right) + \delta(L)z_t\right\} \\ &= -\frac{\alpha(L)}{\beta(0)}\Delta\pi_{t-1} + u_t^* - \frac{\delta(L)}{\beta(0)}z_t \end{aligned} \tag{5}$$

It is straightforward to show that the change in inflation on the left-hand-side of equation (2) can always be re-expressed as a function of the difference between unemployment and the SRN, us_t*, as follows:

$$\Delta\pi_t = \beta_0(u_t - us_t^*) + \varepsilon_t \tag{6}$$

[12] Preliminary work (based on an HP filtered NAIRU) suggested that the equation diagnostics were improved by the inclusion of a dummy (= –1 in 1979 Q3, 1 in 1980 Q3, 0 at all other times). A VAT change occurred at this

Equation (6) illustrates that the SRN 'us_t*' defined as in (4) and (5) is the unemployment level that would give no inflation change in quarter *t*. Modelling changes in inflation as in (6) instead of as in (2) may be advantageous because the SRN conditions on all short-run determinants of inflation, and so it provides a more intuitive benchmark against which to compare unemployment over the horizon relevant for policy. In addition, contrary to previous work assuming a constant longer-run NAIRU, the SRN here depends also on movements in the longer-run NAIRU. Thereby the SRN still captures shifts in structural unemployment, u_t*, inasmuch as they matter for changes in inflation in the immediate future. Finally, since the short-run unemployment gap embraces all the predictive power of the system (2)-(3), we expect it to be a good predictor of inflation over the policy horizon.

2.2 RPIX-based SRNs compared

In this subsection we present estimates of system (2)-(3) derived according to the different parameterisations outlined above, and also show estimates of the associated SRNs and short-run/long-run unemployment gaps. We examine each parameterisation in turn. In Section 3 we then analyse how good these various unemployment gaps are at explaining RPIX inflation in the UK.

2.2.1 SRN based on quasi-constant LRN

Our first measure of the short-run NAIRU assumes a quasi-constant LRN (LRN1, hereafter). As explained before, this implies that in this case the LRN is derived estimating system (2)-(3) by constraining the noise-to-signal ratio $\sigma_\eta^2/\sigma_\varepsilon^2$ to be equal to 0.002, so that the LRN is practically constant (when this ratio is zero, σ_η^2, the LRN is exactly constant). This is a restrictive assumption, and one not in line with empirical evidence on equilibrium unemployment in the UK. Indeed many contributions in the literature agree that the longer-run NAIRU has fallen in the UK over the last twenty years, following the barrage of structural reforms in the UK labour market—notably the decline in the role of the trade unions and their progress towards a more co-operative nature, especially in the private sector, the promotion of flexible working arrangements and the reduction in generosity of the benefit system.[13]

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time, and this result suggests that the shock was so large that normally distributed errors could only be achieved by including a dummy variable for this period.

[13] The slight decline in unemployment benefits, changes in the structure of the product market or the launch of the National Minimum Wage do not appear to have played a significant role. See Nickell (2001) for a detailed

However, looking at an almost constant LRN is still interesting here because it facilitates comparison with similar work by Estrella and Mishkin (1999), Ball and Moffit (2001) and Meyer (2000) on SRN for the US based on a similar assumption. Setting the ratio so low allows us to study the behaviour of a much less variable longer-run NAIRU in the same framework in which we analyse time-varying LRNs.

Estimates of the system (2)-(3) when $\sigma_\eta^2/\sigma_\varepsilon^2 = 0.002$ are shown in column (1) of Table 1. As pointed out before, all along we started with a fairly general specification of equation (2) with lags of both inflation changes, long-term unemployment gaps and *z*-vector dynamics and subsequently converged to a final, more parsimonious representation by discarding insignificant terms (typically, those with a *t*-statistic smaller than unity). The parsimonious specification of $\Delta\pi$ for this model includes among its regressors the current value of the long-term unemployment gap, and two predetermined supply-side shocks namely the first and fourth lag of real import price inflation and the fourth lag of real oil price inflation.

As expected, the estimation results shown in column (1) above suggests that changes in inflation depend negatively on the long-term unemployment gap, so that when u_t is below u_t*, inflation accelerates and vice versa. Changes in inflation also appear to be positively correlated with rises in real import price inflation and rises in the real growth of oil prices, in line with economic intuition.

Given values of estimated coefficients of system (2)-(3) in column (1), the associated profile for u_t* and the data on z_t, equation (4) defines a series for this first SRN (SRN1 hereafter). Chart 2 shows our estimates of LRN1 and SRN1 vis-à-vis Labour Force Survey unemployment since 1973 Q1. Chart 3 shows the associated short-term unemployment gap ($u_t - us_t$*).

Chart 2 indicates that LFS unemployment has been falling since 1993, and it is now at a level that is considerably lower than the previous trough in 1990 Q2.[14] The longer-run NAIRU (LRN1) is basically constant around a full-sample average of 7.1%.

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discussion of the main factors underlying the fall in the longer-run NAIRU in the UK. Subsection 2.2.2 examines in more detail the hypothesis of a fall in the longer-run NAIRU since the early 1990s.

[14] Note that since recently, the duration pattern of reductions in unemployment has changed. Whereas in 1999 the reductions were accounted for mainly by lower short-term unemployment, in 2000 the declines have been dominated by falls in long-term unemployment. These compositional shifts should exert smaller pressure on earnings, given the remaining supply shocks and changes in inflation expectations, because the short-term

A few other important points emerge by looking at Chart 2. First our measure of SRN is very volatile in the 1970s. SRN1 is even negative at times, which is probably a consequence of the quasi-constancy restriction on the LRN, as this implies a higher level of equilibrium unemployment in the 1970s than the plausible actual level at the time. Since the mid-1980s SRN1 seems to have oscillated around a lower mean than the LRN. For the same level of actual unemployment this means that the short-term unemployment gap (GAP1) in Chart 3 has in fact been positive for most of the past twenty years—though it was close to zero during 2000—and negative thereafter.

Chart 2: LFS Unemployment and NAIRU Estimates (Model 1)

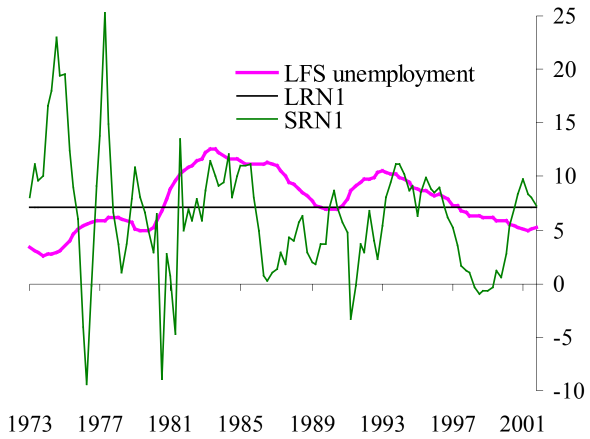
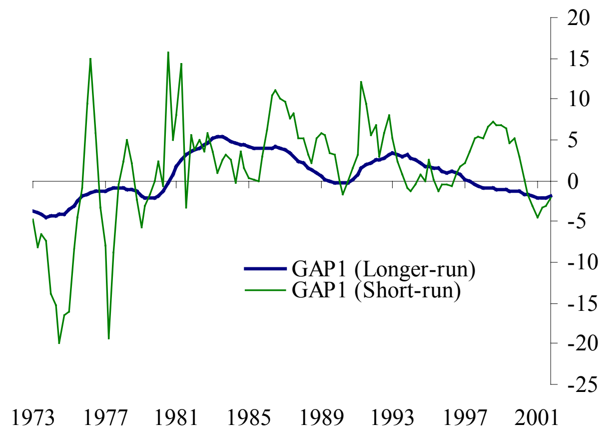


Chart 3: Unemployment Gaps (Model 1)



Since this measure of SRN1 is based on the assumption that LRN is almost constant, and this is contradicted by empirical studies on the UK equilibrium unemployment, in the next subsection we examine what happens to the SRN when we allow the LRN to vary more freely.

2.2.2 SRNs based on time-varying LRNs

In this subsection we focus on two alternative measures of SRNs based, in turn, on two distinct measures of the longer-run NAIRU.

unemployed tend to search more intensively for jobs than the long-term unemployed, reducing the need for firms to raise wages to fill vacancies. We do not analyse the implications of this when deriving and discussing our measures of short-run NAIRU.

The first, LRN2 is obtained by re-estimating the price equation-LRN system of the previous subsection [column (1) of Table 1], but this time setting the noise-to-signal ratio equal to a value of 0.16. As said before, this value of the ratio seems consistent with empirical priors in the UK. The SRN (SRN2) is then derived in the usual way. The third LRN (LRN3) measure also assumes $\sigma_\eta^2/\sigma_\varepsilon^2 = 0.16$ but is estimated by restricting δ to zero in the system (2)-(3), so that any information from the z_t vector is subsumed in the time-variation of u_t*. On one hand, since it excludes temporary supply shocks from the Phillips curve, the third longer-run NAIRU that we obtain is somewhat analogous to a short-run NAIRU. In fact, this third measure coincides with the level of unemployment that is compatible with stable prices *given* temporary supply side shocks. On the other hand, this third longer-run measure differs from a short-run NAIRU in that its variations do not account for changes in lagged inflation. So, as in the previous two cases, here as well we can derive a short-run measure of the NAIRU based on our estimate of the longer-run NAIRU. Maximum likelihood estimates of the system (2)-(3) when $\sigma_\eta^2/\sigma_\varepsilon^2 = 0.16$ under these two specifications are again shown in Table 1, columns (2) and (3) respectively.

Charts 4 and 5 plot respectively SRN2 and LRN2 vis-à-vis LFS unemployment (Chart 4), and the short-term unemployment gap, GAP2, (Chart 5). Chart 4 indicates that allowing for more realistic volatility in the longer-run NAIRU gives a profile for this which tracks actual unemployment more closely; the two series are, in fact, strongly positively correlated, with a contemporaneous correlation coefficient equal to 0.85.[15] The chart shows that the Kalman-filter-estimated longer-run NAIRU possibly peaked in the mid-1980s and fell back thereafter. This profile is broadly in line with numerous other empirical studies of time-varying NAIRUs for the UK (see Coulton and Cromb (1994)). Astley and Yates (1999), for instance, derive a measure of the long-run natural rate by using a structural VAR and find a zenith for the LRN around 1986, with the LRN well below actual unemployment from 1992 to 1997, and then gradually declining thereafter.

[15] The SRN estimates are volatile in the mid-1970s, despite allowing for more plausible variability of the LRN estimates. There were sharp movements in oil prices and import prices during this time. Since we are using changes in annual inflation rates, the large swings in these variables are likely to account for such volatility in our estimates.

Chart 4: LFS Unemployment and NAIRU Estimates (Model 2)

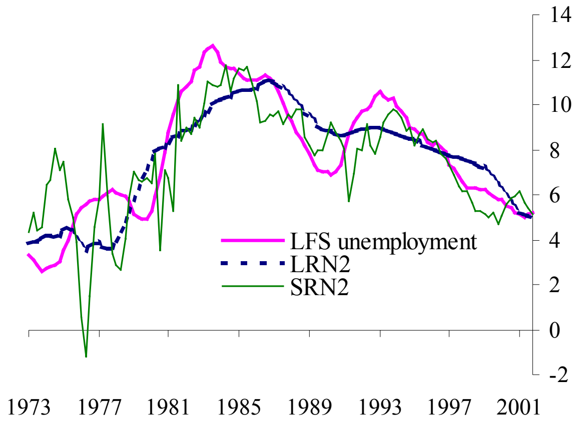
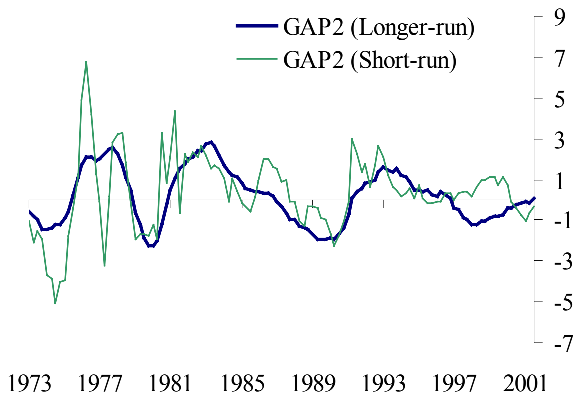


Chart 5: Unemployment Gaps (Model 2)



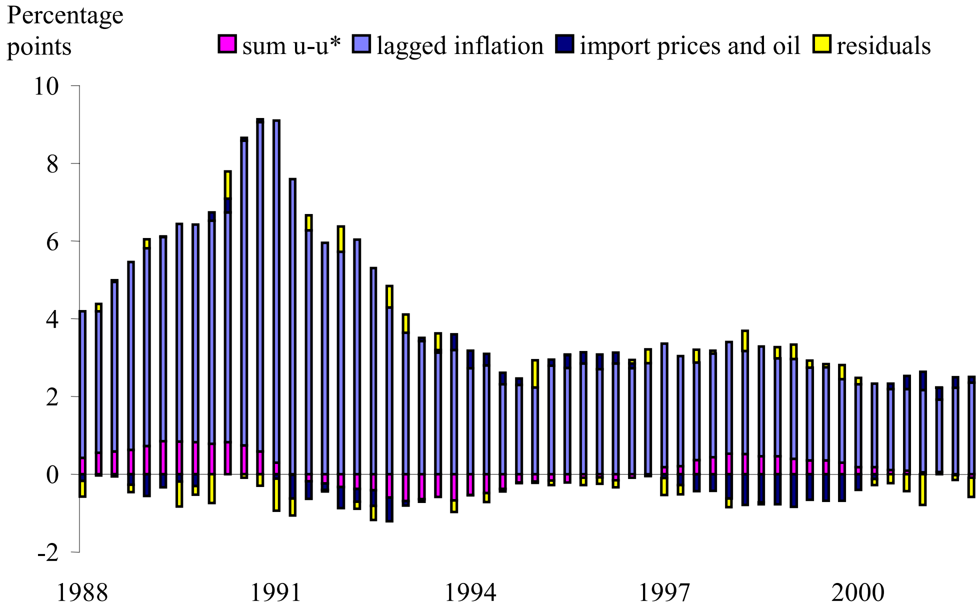
If we abstract from the oscillatory 1970s' period, under this new, considerably time-varying measure of the LRN, the short-run NAIRU (SRN2) now moves more in synchrony with both actual unemployment and equilibrium unemployment.[16] It follows that overall the short-term unemployment gap fluctuations are more muted than what suggested in Chart 3, although the short-term unemployment gap appears to have hit high points both in 1986 Q2 (+2%) and 1991 Q2 (+3%) and troughed in 1990 Q2 (–2%) and 2001 Q1 (–1%), suggesting alternate deflationary and inflationary pressures.

For example, in the 1985-1987 period, the short-run NAIRU was noticeably below actual unemployment, in contrast with its longer-run counterpart. This difference can be attributed to favourable supply shocks, as both real import prices and real oil prices declined at this time. The period from 1997 to early 2000 is also interesting to consider. During this period it appears that the longer-run NAIRU estimates have declined, though at a less rapid pace than have the short-run NAIRU estimates, providing different signals from the resulting unemployment gaps. Focussing on the short-run NAIRU, the fall in real import prices that occurred in the period from 1997 to early 2000 may have allowed unemployment to fall below the NAIRU without being accompanied by higher inflationary pressure. So, once we consider the simultaneous impact of favourable supply shocks, the short-run NAIRU indicates that there was in fact a lot of running room for unemployment to decline before giving rise to inflationary pressures. More recently in 2000 and early in 2001, as these shocks unravelled (particularly those to oil prices), the level of unemployment compatible with stable inflation in the short-run given our estimates seems higher than actual unemployment. This generates a negative short-term unemployment gap (see Chart 5), that in turn indicates upward pressure on inflation, though at the end of our sample, our unemployment gap is close to zero.

Chart 6 below plots static contributions to annual RPIX inflation. Two main messages can be drawn from this chart. First, the lagged inflation term appears to have played a major role in predicting inflation. This is equivalent to saying that inflation expectations (of the backward-looking kind) appear to have played a major role in inflation determination in the UK over the past fifteen years. Their contribution to inflation seems to have diminished more recently. This may be a consequence of the fact that expectations have stabilised around the announced inflation target, by virtue of the shift to a regime of explicit inflation targeting in 1992. Second, from the end of 1996 to late 1999, there seems to have been two opposite effects on inflation. On one side, the unemployment gap (LRN2) has been exerting upward pressure on inflation with the LRN above actual unemployment. There would of course have been more upward pressure from this source if the LRN had not fallen during this period. On the other side, low import and oil prices have depressed imported inflation and put downward pressure on RPIX inflation. Put differently, the downward pressure on inflation from import and oil prices has allowed lower levels of unemployment than longer-run NAIRU-implied to remain compatible with stable inflation—as implied by a SRN lower than the LRN, namely by the difference between the green and the blue lines in Chart 4. The surge in oil prices that then took place put upward pressure on RPIX inflation towards the end of 2000 which corresponds to the SRN being above the LRN estimates.

[16] Indeed, since the SRN is a direct function of the LRN, it will tend to follow this if changes in the latter are dominant relative to supply side shocks or changes in inflation expectations.

Chart 6: Contributions to annual RPIX inflation (based on model 2)



Finally, Charts 7 and 8 below graph two further measures of short and longer-run NAIRUs over the same sample. This time the LRN (LRN3) is estimated by restricting to zero the coefficients on supply side variables (i.e. the δ coefficients in equation (2)). So this LRN subsumes variation in not just the actual longer-run level of unemployment but also the explanatory power of these omitted variables. In this sense it can be interpreted as a measure of a shorter-run NAIRU. However, it still includes inertia in the dynamic inflation adjustment process. Thus we nevertheless need to derive a short-run measure of the NAIRU that is consistent with those in Charts 2-5, by stripping out such influences.

By looking at Charts 7 and 8, it emerges that both sets of NAIRU estimates that we obtain when the supply variables are excluded from the model (short- and long-run) have been mirroring almost exactly the profile of actual unemployment since early 1995. This implies that under this definition of short-run NAIRU, the level of unemployment that we have observed has been compatible with stable inflation since 1995 Q1 given the combination of real import price and real oil price shocks that materialised over this period. This is not true of the 1970s, or of the 1980s, albeit this measure of SRN suggests smaller variations (at a maximum ±3pp) in the short-term unemployment gap (GAP3, Chart 8) over the 1980s than those suggested by the previous SRN measure (see Chart 5).

Chart 7: LFS Unemployment and NAIRU Estimates (Model 3)

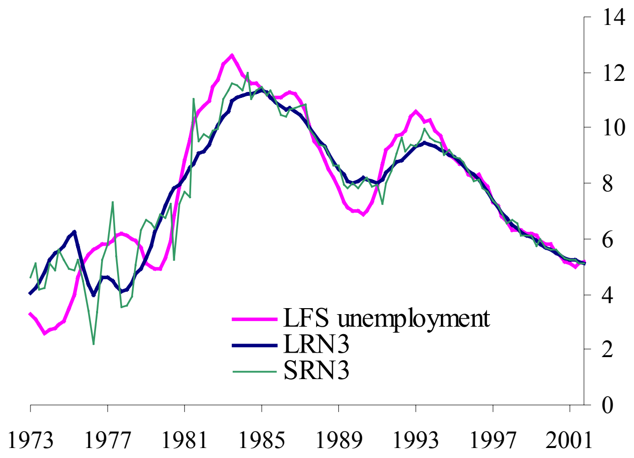
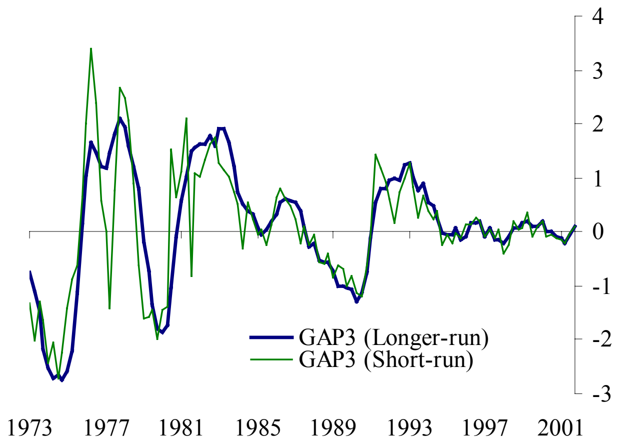


Chart 8: Unemployment Gaps (Model 3)



2.3 CPI-based SRNs compared

As a cross-check on our previous results, here we derive SRNs by re-estimating system (2)-(3) using the change in the annual rate of Consumer Price Index (CPI) inflation instead of the RPIX measure as the dependent variable. To do so, we use the same restriction for the noise-to-signal ratio used in models 2 and 3 (i.e. 0.16). The general profile of these NAIRU estimates is similar to those obtained for the RPIX based specification (Model 2).

Chart 9: LFS Unemployment and CPI based NAIRU Estimates (Model 4)

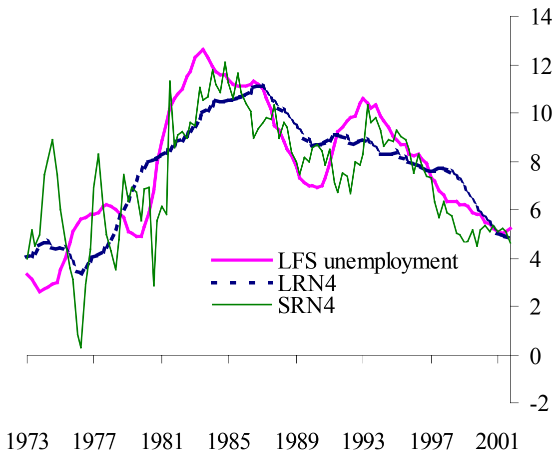
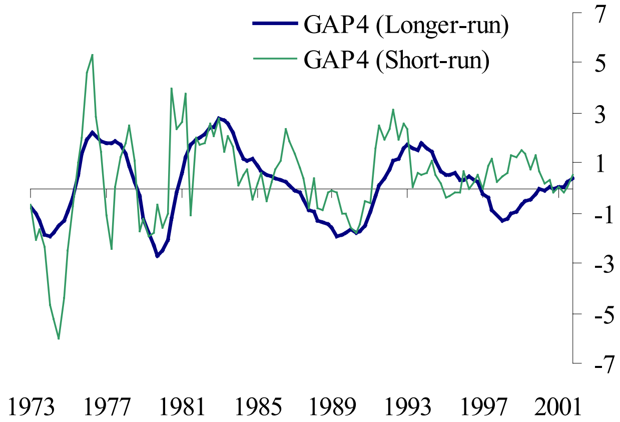


Chart 10: Unemployment Gaps (Model 4)



3. Indicator properties of the short-term unemployment gaps

What is the benefit of looking at a SRN gap for predicting inflation? One answer to this question can be obtained by looking at equation (6), which we rewrite below, for convenience.

$$\Delta\pi_t = \beta_0(u_t - us_t^*) + \varepsilon_t \qquad (6)$$

Equation (6) says that changes in inflation depend on the short-run unemployment gap at time *t*. In other words, given our definition of the short-run NAIRU in equation (5), deviations of the actual rate of unemployment from this rate should have the same information content as all the regressors of inflation (taken together) in equation (1).

Table 2 below lends some formal support to this view by presenting dynamic correlations computed over the period 1973 Q1 and 2001 Q4 between changes in the four-quarter change in RPIX ($D4RPIX_t$) and the various time-varying LRN-based SRN gaps GAP2 and GAP3 either in levels or in 5-quarter backward-looking moving averages ($MA5SRNs_t$). In addition, the table lists similar correlations between $D4RPIX_t$ and a measure of the SRN gap obtained by estimating system (2)-(3) by using CPI instead of RPIX inflation. We label this gap by $GAP2CPI_{t-k}$. Correlations between changes in RPIX inflation ($DD4RPIX_t$) and the gaps are also shown in the table. Finally, as a memo item, Table 2 also presents correlations between (i) changes in RPIX inflation and actual unemployment rates; (ii) changes in RPIX inflation and the deviation of LFS unemployment from a longer-run NAIRU (LRN2); and, finally, correlations between (iii) inflation (or changes in inflation) and a commonly-used measure of the output gap, namely the deviation of the log of real output, *y*, from its Hodrick-Prescott trend (smoothing parameter = 1,600), y^*. [17]

Intuitively, changes in inflation should be negatively correlated with the SRN gap variables (a positive SRN gap implying either unemployment above its long-run rate and/or favourable supply side shocks or expectations of lower inflation, and hence, falling inflation, and vice versa). By contrary, changes in inflation should in principle be positively correlated with the

[17] We measure potential output via real output HP trend for simplicity. Ideally, we should have re-estimated equation (2) substituting the unemployment gap with the output gap, and thus estimated potential output as a

output gap, as a positive gap, i.e. demand outstripping supply, typically exerts upward pressure on inflation.

Table 2: Dynamic correlations between RPIX inflation and the SRN gaps

	k				
Lags	*0*	*1*	*2*	*3*	*4*
Corr($D4RPIX_t$, $GAP2_{t-k}$)	–0.14[a,b]	–0.27 [a,b]	–0.34	–0.37	–0.38
Corr($D4RPIX_t$,$GAP3_{t-k}$)	–0.12 [a,b]	–0.26 [a,b]	–0.34	–0.38	–0.39
Corr($D4RPIX_t$, $GAP2CPI_{t-k}$	–0.14 [a,b]	–0.28 [a,b]	–0.37	–0.42	–0.46
Corr($D4RPIX_t$, $MA5GAP2_{t-k}$	–0.30	–0.38	–0.42	–0.44	–0.45
Corr($D4RPIX_t$,$MA5GAP3_{t-k}$)	–0.29	–0.36	–0.40	–0.42	–0.43
Corr($D4RPIX_t$, $MA5GAP2CPI_{t-k}$)	–0.34	–0.44	–0.49	–0.53	–0.54
Corr($DD4RPIX_t$, $GAP2_{t-k}$)	–0.75 [a,b]	–0.47 [a,b]	–0.19	0.03	0.10
Corr($DD4RPIX_t$,$GAP3_{t-k}$)	–0.77 [a,b]	–0.49 [a,b]	–0.23	–0.005	0.08
Corr($DD4RPIX_t$, $GAP2CPI_{t-k}$)	–0.66 [a,b]	–0.50 [a,b]	–0.23	–0.14	0.002
Memo item					
Corr ($DD4RPIX_t$,u_{t-k})	–0.15 [a,b]	–0.11 [a,b]	–0.07	–0.01	0.03
Corr ($DD4RPIX_t$,$u_{t-k} - LRN2_{t-k}$*)	–0.42 [a,b]	–0.34	–0.23	–0.10	–0.01
Corr ($D4RPIX_t$,$y_{t-k} - y_{t-k}$*)	–0.17	–0.09	–0.02	0.08	0.17
Corr ($DD4RPIX_t$,$y_{t-k} - y_{t-k}$*)	0.31	0.42	0.33	0.32	0.28

(a) Significantly different from zero using conventional *t*-test.
(b) Significantly different from zero using Newey-West *t*-test.

Two important messages emerge from Table 2. First, the correlations between the level of annual inflation and the SRN gaps have the 'right' (negative) sign at all lags. This is not true of the output gap, which exhibits the 'wrong' (negative) sign with inflation at lags 0, 1 and 2. Second, correlations between changes in inflation—as implied from a model assuming a vertical Phillips curve in the long run—and our gap measures (GAP2 and GAP3) are higher, at –0.75 and –0.77, for our short-run gap measures than any other predictor of inflation taken in isolation. Notably, they are stronger than the contemporaneous cross-correlation between changes in inflation and the output gap—the one of interest here given our definition of the short-run gap in equation (6). Importantly, correlations between inflation (or changes in) and our measures of SRNs gaps are significant (especially at shorter lags as we would expect by the definition of SRNs) whereas dynamic correlations between inflation (or changes in) and

latent variable. This way the comparison in cross correlations between our short-run unemployment gap measures and an output gap measure would have been on the same level playing field.

the output gap are not, at any lag.[18] Dynamic correlation coefficients between the level of inflation and the moving averages of the SRN gaps are also negative and very strong, especially at longer lags, although not significant.

Regressions of changes in RPIX inflation on four lags of itself, the time-*t* output gap and the time-*t* GAP2 as well as four lags of each of the latter estimated over the period 1973 Q1 – 2001 Q4, confirm this evidence by showing that the time-*t* SRN gap and its fourth lag enter the equation significantly, with both the short- and the long-run regression coefficients large and 'properly' signed (suggesting that a high level of the SRN is associated with falling inflation and vice versa). In contrast, the output gap is not significant in the long run equation and has the 'wrong' (negative) sign.[19] This implies that the output gap (defined as here) does not contain any incremental information relative to our measures of the SRN gap when used in an equation to predict inflation.

Taken together, these results seem to suggest that focusing on variations in inflation due to changes in the deviation of actual unemployment from these short-run NAIRU measures, i.e. the combination of shifts in LRN, supply shocks and changes to inflation expectations, helps predict inflation. They also suggest that SRN gaps may help forecasting inflation in a superior way than frequently advocated measures of goods' market capacity utilization like the output gap.

4. Applications

In this section we suggest examples of applications for our measures of the short-run NAIRU. More specifically, we show how we can derive unemployment levels compatible with stable inflation in the short run under alternative supply shock scenarios (Subsection 4.1). This exercise can help formulate forecasts by examining what would happen to the short-run NAIRU (and hence inflation) if some existing shocks unwind, say. It can also help interpret the source of inflationary pressures looking backwards. As a second application we then show how the short-run NAIRU can be used as a feedback variable in Taylor rules, instead of usual feedbacks, notably inflation deviations from target and the output gap (Subsection 4.2).

[18] Note however that the correlations above do not condition on lags of inflation. This may have implications for the differences that we observe in Table 2.

[19] Neiss and Nelson (2002) also find this. However, they argue that when the output gap is based on a theoretical model, then New Keynesian Phillips curve estimates deliver positive coefficients on the output gap.

4.1 Alternative supply shock scenario

Real import prices fell significantly after around mid-1996 (as a result of the appreciation of sterling). For illustrative purposes, we can experiment with what would have happened had these relative prices not behaved the way they have done historically—a counterfactual experiment. For instance we can study the implications for the SRN if the import price deflator in nominal terms had remained flat at its 1996 Q3 value (that is, real import prices inflation falls at around 2% per year). For simplicity we assume that RPIX inflation is unchanged, though in practice changes in import prices will of course influence RPIX inflation.[20] The longer-run NAIRU estimates for the actual import price outturns and alternative scenario are shown in Chart 11 below. If import prices had been held flat (ie if import prices had fallen by around 2% in real terms rather than the observed falls that were often in the 5-10% range), then given the outturns to RPIX inflation, this would be consistent with a lower longer-run NAIRU in the second half of the 1990s. And the associated alternative short-run NAIRU estimates would have been higher than the estimates based on the observed outcomes for import prices during much of this period. This is because the short-term supply shocks in the alternative scenario are less favourable than the observed decreases in real import prices that actually occurred, resulting in the short-run estimates falling less dramatically. Other interesting scenarios that can be examined within this analytical framework include the possible impact of the forthcoming changes in National Insurance Contributions (NICs). However, since the main impact of changes in NICs may be on wage inflation, it may be more appropriate to analyse these effects using SRNs derived from Kalman filter estimates of a system specified in terms of average earnings, rather than in terms of RPIX inflation.

[20] A possible alternative scenario is to consider real import prices being flat throughout this period. For brevity, these results are not shown.

Chart 11: LFS Unemployment and Longer-run NAIRU Estimates (Model 2)

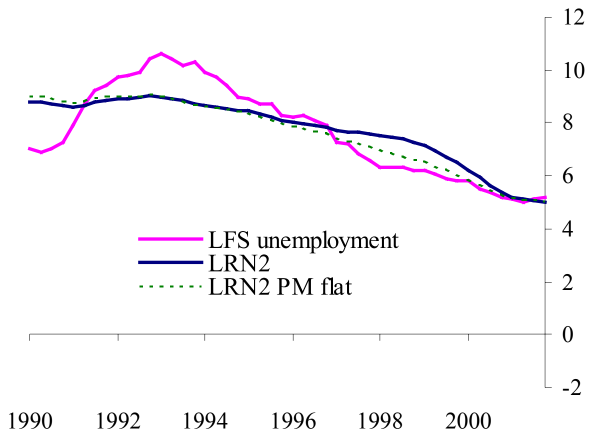
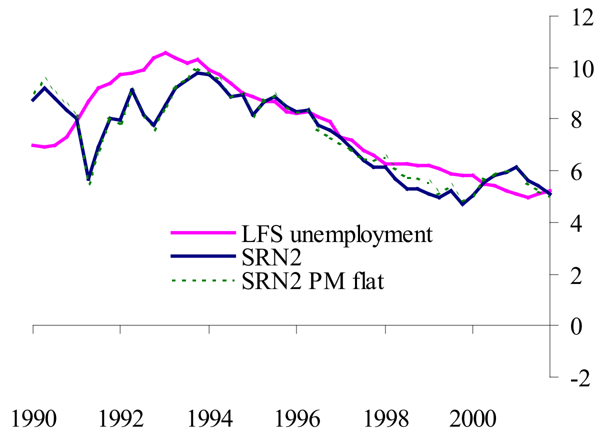


Chart 12: LFS Unemployment and Short-run NAIRU Estimates (Model 2)



4.2 Taylor rules based on short-run NAIRU gaps

One further possible use of our measures of the short-run NAIRU is as a proxy for one or more of the feedback variables in a rule for monetary policy, like that suggested in Taylor (1993).

There are various reasons for why it may be interesting to look at simple rules à la Taylor. First, Taylor-type rules seem to have tracked reasonably accurately the historical path of interest rates in the United States during periods of 'good' policy performance, but to have departed from actual policy during 'bad' periods—as in the 1960s when recession followed policy overtightening or in the 1970s when inflation accompanied excessive ease in policy (see Taylor 1993, 1999). To a lesser extent, this property of the rule seems to apply to other countries too, including the UK (see Batini and Tucker (1999)). Second, Taylor rules feed back on a limited set of variables, and so are 'simple' by definition, and therefore easy to use and update.[21] Third, Taylor rule mechanically generates interest rate paths using actual data. So it provides one potential crosscheck on policy. Put somewhat differently, simple rules might help guard against "big" mistakes, even if they are guilty of allowing small ones.

The main features of the Taylor rule are that, as any "feedback" rule, it seeks to correct through monetary policy any deviation between the growth of nominal magnitudes and their

[21] However, because the Taylor rule responds to the output gap and requires a measure of the real equilibrium interest rate, it can be difficult to compute in practice.

targeted values. In this sense, the rule is consistent *ex ante*, in the medium term, with the UK's 2.5% inflation target. Yet importantly, because it also responds to the output gap, the rule also guards against excessive fluctuations in real output in the course of hitting this medium-term inflation goal.

In short, the Taylor rule offers a path for the short-term nominal interest rate (R_t). Conceptually, however, it is easier to think of the rule as setting a path for the short-term ex-post *real* interest rate ($R_t - \pi_{t-1}$, where π_{t-1} refers to last period's inflation rate) relative to its equilibrium or "neutral" value (r^*). These deviations of real rates from their "neutral" value in turn depend on two feedback terms: the deviation of actual output (y) from its trend value (y^*); and the deviation of inflation from its target value (π^*). Both the output and inflation gap terms are lagged, on grounds of data availability.[22] The feedback terms are given weights of ω_1 and ω_2 respectively. The Taylor rule "formula" is hence:

$$R_t = \pi_{t-1} + \omega_1 (y - y^*)_{t-1} + \omega_2 (\pi - \pi^*)_{t-1} + r^* \qquad (7)$$

The conceptual basis of the Taylor rule is minimalist but entirely standard. Taylor interprets the rule as an "inverted" money demand relationship, with interest rates adjusted to maintain equilibrium in real and nominal magnitudes over the medium term (Taylor (1999)).
In constructing this rule for the UK we have to proxy all of the terms in (1). We concentrate on a quarterly version of the Taylor rule because our SRN GAP measures are quarterly in frequency. The proxies that we use are:

(i) For inflation (π), the annual rate of RPIX inflation;
(ii) For the inflation target (π^*), 2.5%;
(iii) For the equilibrium real interest rate, a Hodrick-Prescott filter (with smoothing parameter set equal to 10,000) of the ten-year real interest rate, derived from the index-linked yield curve;
(iv) For the output gap, we experiment with three different concepts. First, an output gap variable that we define in terms of the deviation of current output from a measure of potential output derived from a Cobb-Douglas production function (quarterly Taylor rule). Second, our preferred longer-run NAIRU gap (LRN GAP2), that is the difference between

[22] Taylor's (1993) original specification used current values of inflation and the output gap, but there are questions then about the operationality of such a specification if it is to be used in real time.

LFS unemployment rate and our Kalman-filter estimate of the longer-run NAIRU. Third, our measures of the SRN gaps, GAP1, GAP2 and GAP3, respectively.

(v) For the feedback weights ω_1 and ω_2,[23] we experiment with three sets of weights. Central weights are $\omega_1 = \omega_2 = 0.5$ from Taylor (1993). Alternative weights are $\omega_1 = 0.25$ and $\omega_2 = 0.75$ and $\omega_1 = 0.75$, $\omega_2 = 0.25$. This gives a range of desired interest rates levels for alternative sets of weights. We represent this range by plotting dashed paths around the Taylor rule with central weights. Note that in computing LRN gap or SRN gap-based rules, we always set the feedback coefficient on the SRN gap equal to – (ω_1), whatever the absolute value of ω_1 is. This is because—contrary to what happens with output gaps—negative SRN gaps involve upward inflationary pressures and vice versa. So if the policy rule is to be stabilising, the nominal interest rate will have to increase (decrease) when the LRN/SRN gap is negative (positive) to depress (sustain) aggregate demand (and factors' demand) which will prevent inflation from rising (falling).

Examples of the "output" from the standard two-feedback-variable (henceforth '2FV') as well as the one-feedback-variable (henceforth '1FV') Taylor rules are shown in Charts 13 and 14. More precisely, Chart 13 plots Taylor rule-implied paths for the base rate when we use our three measures of SRN gaps and the LRN gap instead of traditional output gap measures alongside a standard Taylor rule with the usual output gap term, and the historical path of the base rate are also shown. Whereas Chart 14 shows the standard output-gap-based Taylor rule with weights $\omega_1 = 0.75$, $\omega_2 = 0.25$ and vis-à-vis a SRN GAP2-based Taylor rule, again for those set of weights. Again the base rate is plotted for comparison.

A few important points emerge from Chart 13. First, the rule based on our preferred measure of short-run NAIRU gap (GAP2) has been tracking the actual base rate relatively closely from 1992 Q3 till 2001 Q4. In particular, the 'SRN GAP2' rule mimicked the behaviour of rates in a superior way than did the traditional output-gap based Taylor rule at the beginning of the period, asking for high interest rates and then a swift policy loosening in 1992-93. Since the

[23] Use of the unemployment gap instead of the output gap may imply that coefficients other than those suggested originally by Taylor (1993) are appropriate in the rule. One way of transforming output gap-consistent coefficients into unemployment gap-consistent ones consists in reparametrising the former into the latter via Okun's law. Okun (1970) noted that a one-percentage point movement in the unemployment rate was associated with a three percentage change in output in the opposite direction in the US. Since then, various empirical work has been conducted suggesting a lower figure, for example, Mankiw (1994) suggests a figure closer to two. For the UK, Attfield and Silverstone (1998) found a value of about 1.45. A crude exercise based on HP-filtered unemployment and output gaps suggested an even lower figure for the UK for our sample period. For this reason, here we experiment with various values of the coefficients on the unemployment gap.

end of 1996, our SRN GAP2-based rule advocated constantly a somewhat easier stance than that implied by both the LRN gap-based rule and the traditional rule. This is not surprising given that our rule fully accounts for first-order effects of supply shocks, like the ones associated with the rise in the sterling real effective exchange rate since 1996 Q3, whereas the other rules do not. Like the LRN gap-based rule, the SRN(2) gap-based rule also accounts for time-variations in the level of the longer-run NAIRU, which over this same period has been on a downward trend (see Chart 4 in subsection 2.2.2). Both of these shocks have put considerable downward pressure on inflation in the second half of the 1990s. Therefore, over that period, they motivate a more generous loosening in monetary setting according to our SRN GAP2-based rule, which accounts for the first-round effects of these shocks, than rules that pay no attention to one or both of these effects.

Second, rules based on alternative SRN gap measures, namely on SRN GAP1 and on SRN GAP3, diverge more markedly from both the traditional output-gap-based Taylor rule and the actual path of policy rates. More specifically, the SRN GAP1-based rule seems to ask for more extreme variations in the policy instrument, overall suggesting a softer stance than the historical one (apart from 2000 Q1 onwards since when the reverse is true). Whereas the SRN GAP3-based rule asks for higher rates than the standard Taylor rule at the beginning of the period (1992-1993); but demands lower rates than this (and actual ones) almost uniformly thereafter. This may be explained by the fact that the first rule responds to a SRN gap that is derived assuming a longer-run NAIRU, which is almost fixed.[24] As shown in Chart 3, this gap is always positive (implying actual unemployment above the rate at which inflation is destabilised), at least until 2000 Q1, and so elicits a loosening of rates throughout the period, up to 2000 Q1. Thereafter SRN GAP1 becomes negative and so the opposite is true. In the case of the second rule (the one based on SRN GAP3), this feeds back on a gap which is close to zero at all times (see discussion in subsection 2.2.2). So in practice, according to this rule, the nominal interest rates moves mainly because of inflation deviations from target rather than because of movements in the SRN gap itself. Since inflation has been falling, in turn, post-1995, the rule mechanistically suggests a falling level of rates thereafter.

[24] As noted previously, we do not consider this assumption to be plausible for the UK.

Chart 13: 2F Taylor rules (various SRN GAPs) and

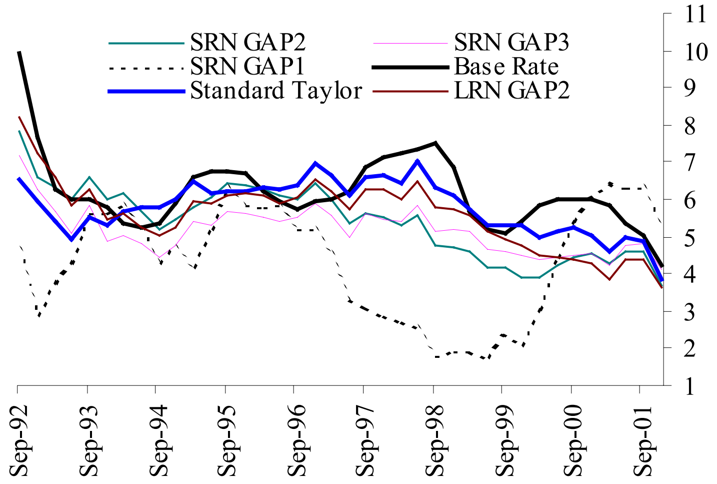
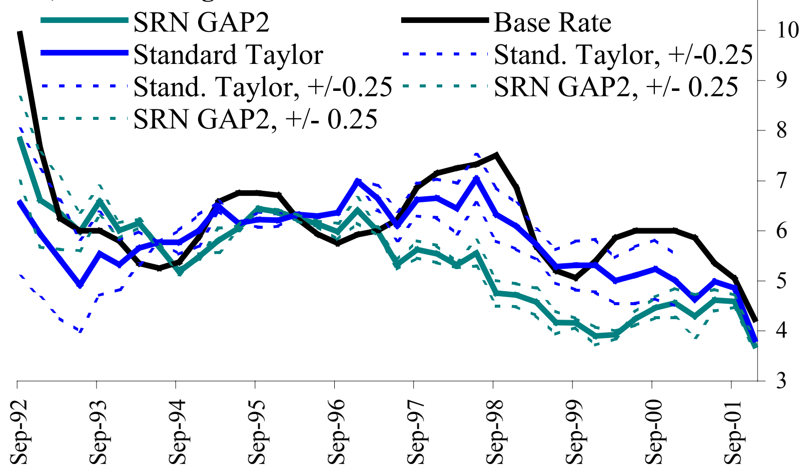


Chart 14 illustrates that reducing the feedback coefficients on inflation from 0.5 to 0.25 in the traditional output-gap-based Taylor rule (as indicates the blue dashed line below the solid blue standard Taylor rule path) widens the wedge between this and our SRN GAP2-based rule before 1994, but narrows it after 1996. This finding reaffirms the idea that full consideration of supply side shocks at both ends of the periods would have perhaps implied a tougher stance in 1992-1993 and a softer stance post-1996, respectively, than that asked for by a rule responding to inflation and the output gap instead—that is by a rule ignoring the immediate effects of these shocks on inflation. Variations in the weights in our SRN GAP2-based rule cause the implied interest-rate path to vary only marginally from the baseline rule output when $\omega_1 = \omega_2 = |0.5|$ weights are used.

Chart 14: 2F Taylor rules (standard and SRN2) and base rate, various weights



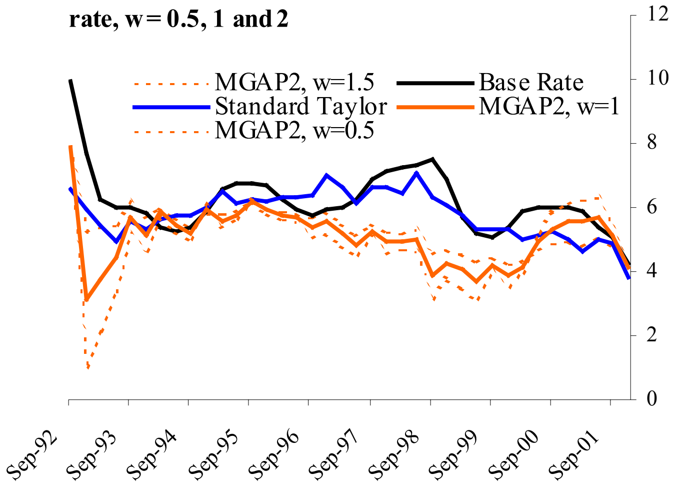
Since, conceptually, the SRN gaps summarise the predictive content of all regressors of inflation in an equation like (1), SRN gaps can alternatively be combined with an inflation target and a lag for inflation to serve as proxies for the inflation feedback variable in the Taylor rule.[25] We call this combined feedback variable 'modified SRN gap' (MSRN gap).

So, ideally, modified SRN gaps (individually) should serve in place of *both* the inflation *and* the output gap variable in a one-feedback-variable Taylor rule. The idea here is that the short-term nominal interest rate moves until the gap between actual unemployment and the short-run NAIRU is eliminated so that inflation gradually converges towards the target. In this case we may choose the feedback coefficient on the modified SRN gap to be equal to the sum of the inflation and output gap term weights in a standard Taylor rule. As before, we set this single feedback coefficient on the modified SRN gap, that we label ω_{GAP}, equal to whatever the absolute values of ω_1 and ω_2 are, but use opposite signs. For the baseline case where $\omega_1 = \omega_2 = 0.5$, the size of this unique coefficient is hence equal to -1 (i.e., $\omega_{GAP} = -(\omega_1 + \omega_2)$).

In this spirit, Chart 15 below plots the path implied by a one-feedback-variable Taylor rule, where deviations of the short-term real *ex ante* interest rate from its equilibrium level are assumed to respond (with a unit coefficient in bold) only to the modified SRN gap, MSRN GAP2. In particular, MSRN GAP2 is derived by combining our preferred measure of the short-run NAIRU gap, SRN GAP2, with the inflation target and a lag of inflation to proxy for the inflation gap feedback variable used in the standard Taylor rule. To check the sensitivity of the results, Chart 15 also shows the output from this rule when alternative weights are used for the single feedback coefficient ($\omega_{GAP} = -0.5$ and $\omega_{GAP} = -1.5$, respectively).

[25] Since SRNs proxy the *rate of change* of inflation, rather than the *level* of inflation, stabilising the SRN gives stable inflation but not necessarily inflation at target. So to replicate the 'inflation gap' feedback variable in the Taylor rule we need to modify the SRN to incorporate the target level for inflation. In symbols, a proxy for the inflation gap of the Taylor rule that uses the SRN gap will look like: (SRN GAP + $\pi_{t-1} - \pi^{TARGET}$), since SRN GAP $\approx \Delta\pi_t \approx \pi_t - \pi_{t-1}$, and the 'inflation gap' in the Taylor rule is given instead by: $\pi_t - \pi^{TARGET}$. We thank Roger Clews for pointing this out to us.

Chart 15: 1F Taylor rules (MSRN GAP2) and base rate, w = 0.5, 1 and 2



The bold red line in Chart 15 graphs the output of the one-feedback-variable policy rule for the baseline case ($\omega_{GAP} = -1$). The dashed red paths around it plot implied paths by the same rule when the alternative weights are used. The first thing to notice from this chart is that the interest rate path implied by the 1FV rule when $\omega_{GAP} = -1$ is similar, but not identical to that implied by the 2FV rule (also based on GAP2) in Chart 13. This suggests that the extra response to current inflation in a 2FV rule, which is already responding to the modified SRN gap, does make a difference relative to a policy prescription relying uniquely on responses to the modified SRN gap itself. This should not come as unexpected. We have shown that our preferred measure of SRN gap, GAP2, is a good proxy of changes in current inflation inasmuch as it summarises efficiently the information necessary to predict the growth in time-*t* inflation. Simple modifications of this adding a lag of inflation and subtracting a target will hence give a good measure of deviations of current inflation from target. So responding to inflation deviations from target directly, on top of this proxy, is equivalent to augmenting the feedback coefficient to the modified SRN gap (or put differently, to the inflation feedback variable in a standard Taylor rule). This seems to have implications for the prescribed interest rate path particularly at the beginning of the period analysed here—giving a lower level of rates than that implied by the standard Taylor rule in contrast to what is suggested by the 2FV GAP2-based rule—and at the end of that period—giving similar, if not higher level of rates than that implied by the standard Taylor rule in contrast to what the 2FV GAP2-based rule suggests.

Second, the mechanical one-feedback-variable rule indicates that rates should have been lowered much more aggressively following the appreciation of sterling in late 1996, relative to what the 2FV corresponding rule advocates: again a result of the lower response coefficient on inflation implied by the 1FV rule.

All in all, the 1FV SRN gap-based rule seems to demand lower interest rates on average than those advocated by the Taylor rule, as well as than actual historical rates. In general, this results from the fact that the modified SRN gap-based rule accounts directly for all channels of inflationary pressures, including supply shocks, whereas the Taylor rule only accounts for the second-round effects that these have on the output gap (and inflation).

Likewise, discrepancies between our 1FV rule and actual rates may be explained by a tendency of the UK monetary policymakers' to underestimate the extent of sterling ERI appreciation (see "The MPC's Forecasting Record", *Inflation Report*, August 2001, p. 59), as well as difficulties in predicting the exact extent of swings in the price of oil in the second half of the 1990s or declines in the longer-run NAIRU—and the inflationary impact thereof. In this sense, looking at a rule like that suggested here could provide a useful crosscheck for policy.

5. Conclusions

In this paper we have derived alternative measures of the short-run or effective NAIRU (SRN) for the United Kingdom. This is a reference rate for unemployment that reflects inflationary pressures over a short-run horizon —one which is more relevant for monetary policy in the UK. Contrary to the natural rate of unemployment, which is the rate of unemployment consistent with steady state inflation when the economy has fully adjusted to any shock or when there are no shocks, the short-run NAIRU can be thought of as the rate for unemployment at which inflation will neither increase nor decrease in the short-run, taking account of temporary supply side shocks, like short-run shocks to oil prices or import prices.

Our measures of short-run NAIRU are obtained by estimating three different models of price dynamics on UK data. The first assumes a quasi-constant longer-run NAIRU, while the other two assume that this is time varying. In all cases we estimated the LRN jointly with the price equations by using the Kalman filter.

Our preferred estimates suggest that the NAIRU may have peaked in the mid-1980s and has tended to fall back thereafter. There are some interesting differences highlighted between the patterns for the short and longer-run NAIRU estimates, especially during periods where there have been large supply side shocks. For example, in the 1985-1987 period, the short-run NAIRU (SRN2) was noticeably below actual unemployment, in contrast with its longer-run counterpart. This difference can be attributed to favourable supply shocks, as both real import prices and real oil prices declined at this time. Further, between 1997 to early 2000 the fall in real import prices may have allowed unemployment to fall below the longer-run NAIRU without being accompanied by higher inflationary pressure. Structural changes in the labour market are likely to have reduced inflationary pressure during this period. Once we consider the simultaneous impact of favourable supply shocks at the time, the short-run NAIRU estimates indicate that there was in fact a lot of room for unemployment to decline before giving rise to inflationary pressures. The surge in oil prices towards the end of 2000 has put some upward pressure back on RPIX inflation. Despite such shocks, the short-run NAIRU estimates were close to actual unemployment towards the end of our sample period. This suggests that it is not unreasonable to assume that the fortunate mix of low unemployment and low inflation enjoyed at the end of 2000 may persist. Of course, it is important not to place too much emphasis on any particular point estimate given that NAIRU estimates tend to be imprecisely measured.

The short-run NAIRU and deviations of the actual level of unemployment from it can have useful applications in the conduct of monetary policy when the ultimate goal is that of stabilising inflation at the minimum cost in terms of output gap variability. For instance, we show that focussing on variations in inflation due to changes in the deviation of actual unemployment from this or the other short-run NAIRU measures that we derive, i.e. the combination of shifts in LRN, supply shocks and changes to inflation expectations, helps predict inflation. We also show that SRN gaps may help forecast inflation in a superior way than frequently advocated measures of goods' market capacity utilization like the output gap.

In addition, we show that our measures of the SRN gap, either in their original specification or with simple modifications, can be successfully used in place of the output gap or of both the output gap and inflation in a policy rule à la Taylor. These alternative SRN gap-based rules track UK monetary policy more closely than the standard Taylor rule over the 1992-1995 period, but generally suggest a looser stance than the latter for the post-1996 period. This is because our rules acknowledges the first round effects on inflation of terms of trade shocks and other supply shocks (like those to the price of oil and the longer-run NAIRU), whereas the traditional output-gap-based Taylor rule does not. In this sense our rules are closer to fully optimal rules and so should be associated with lower welfare losses than Taylor's. We conclude that during periods of heightened uncertainty on either exchange rate, oil price or longer-run NAIRU developments, looking at rules like those suggested here may provide a useful crosscheck for policy.

References

Astley, M and Yates, A (1999), 'Inflation and Real Disequilibria', *Bank of England Working Paper* No 103.

Attfield, C and Silverstone, B (1998), 'Okun's Law, Cointegration and Gap Variables', *Journal of Macroeconomics*, Vol. 20, pages 625-37.

Ball, L and Moffitt, R, (2001), "Productivity and the Phillips Curve", mimeo, John Hopkins University.

Batini, N and Tucker, P, (1998), 'The Potential Contribution of Simple Rules to the Bank's Monetary Assessment', mimeo, Bank of England.

Boone, L (2000), 'Comparing Semi-Structural Methods to Estimate Unobserved Variables: The HPMV and Kalman Filter Approaches', *OECD Economic Department Working Paper* No 240.

Braun, S, (1984), "Productivity and the NIIRU (and other Phillips curve issues)", Board of Governors of the Federal Reserve System, Working Paper Series No 34, February 1984.

Carlin, W and Soskice, D, (1995), Macroeconomics and the Wage Bargain: A Modern Approach to Employment, Inflation, and the Exchange Rate, Oxford University Press.

Cassino, V and Thornton, R (2002), 'Reduced-Form Estimates of the Natural Rate of Unemployment Based on Structural Variables", *Bank of England Working Paper* No 153.

Coulton, B and Cromb, R (1994), 'The UK NAIRU', Government Economic Service Working Paper No 124.

Driver, R, Greenslade, J and Pierse, J (2003), 'Goldilocks and New Paridigm Economics: The Role of Expectations in Fairytales', *Bank of England Working Paper No. 180*.

Estrella, A (1997), 'Aggregate Supply and Demand Shocks: A Natural Rate Approach', *Federal Reserve Bank of New York Research Paper* No. 9737.

Estrella, A and Mishkin, F (1999), 'Rethinking the Role of NAIRU in Monetary Policy: Implications of Model Formulation and Uncertainty', in J B Taylor (ed.) *Monetary Policy Rules*, University of Chicago Press.

Fabiani, S, and Mestre, R (2000), 'Alternative Measures of the NAIRU in the Euro Area: Estimates and Assessment', *European Central Bank Working Paper No. 17*.

Friedman, M (1968), 'The Role of Monetary Policy', *American Economic Review*, Vol 58, pages 1–17.

Gordon, R J (1997), 'The Time-Varying NAIRU and Its Implications for Economic Policy', *Journal of Economic-Perspectives,* Vol 11(1), pages 11–32.

Gordon, R J (1998), 'Foundations of the Goldilocks Economy: Supply Shocks and the Time-Varying NAIRU', *Brookings Papers on Economic Activity*, Vol. II, pages 297–346.

Greenslade, J V , Pierse, R G , and Saleheen, J , (2003), 'A Kalman Filter Approach to Estimating a UK NAIRU', *Bank of England Working Paper No. 179*.

Harvey, A C (1989), *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge University Press.

Harvey, A C (1993), *Time Series Models*, Harvester Wheatsheaf.

Hamilton, J (1994), *Time Series Analysis*, Princeton University Press.

Kalman, R E (1960), 'A New Approach to Linear Filtering and Prediction Theory', *Journal of Basic Engineering, Transactions* ASME. Series D, Vol83, pages 35–45.

Kalman, R E and R S Bucy (1961), 'New Results in Linear Filtering and Prediction Theory', *Journal of Basic Engineering, Transactions ASME*, Series D, 83, pages 95–108.

Katz, L M. and Krueger, A B (1999), 'The High-Pressure U.S. labor market of the 1990s', *Brookings Papers on Economic Activity*, Vol. (1), pages 1–65.

King, M (1999), ' Monetary Policy and the Labour Market', *Bank of England Quarterly Bulletin*, Volume 1, pages 90–97.

Layard, R and Bean C (1989), 'Why Does Unemployment Persist?', *Scandinavian Journal of Economics*, Vol. 91(2), pages 371-96.

Layard, R, Nickell, S and Jackman, R (1991), '*Unemployment: Macroeconomic Performance and the Labour Market*', Oxford University Press, Oxford.

Mankiw, N G (1994), **Macroeconomics**, New York: Worth Publishers

Meyer, L H, (2000), "The Economic Outlook and the Challenges Facing Monetary Policy". Speech given at the Century Club Breakfast Series, Washington University, St. Louis, Missouri, October 19, 2000.

Neiss, K and Nelson, E (2002), 'Inflation Dynamics, Marginal Cost, and the Output Gap: Evidence from Three Countries', paper presented to the Macroeconomic Models and Monetary Policy Conference at the Federal Reserve Bank of San Francisco, March 1-2.

Nickell, S and Layard, R, (1999), "Labor Market Institutions and Economic Performance", in *Handbook of Labor Economics*, Vol. 3C, North-Holland.

Nickell, S, (2001), "Has Labour Market Perfomance Changed?". Paper presented at the Society of Business Economists on 16 May 2001.

Okun, A (1970), 'Potential GNP: Its Measurement and Significance' in *The Political Economy of Prosperity*, pages 132-45, Norton.

Phelps, E S (1968), 'Money-Wage Dynamics and Labour Market Equilibrium', *Journal of Political Economy*, Vol. 76, pages 678–711.

Richardson, P, Boone, L, Giorno, C, Meacci, M, Rae D and Turner, D (2000), 'The Concept, Policy Use and Measurement of Structural Unemployment: Estimating a Time Varying NAIRU Across 21 OECD Countries', *OECD Economic Department Working Paper* No 250.

Staiger, D, Stock, J H and Watson, M W (1997a), 'How Precise are Estimates of the Natural Rate of Unemployment?', in Romer, C D and Romer, DH eds *Reducing Inflation: Motivation and Strategy*, (NBER Research Studies in Business Cycles, Vol 30, University of Chicago Press).

Staiger, D, Stock, J H and Watson, M W (1997b), 'The NAIRU, Unemployment and Monetary Policy', *Journal of Economic Perspectives,* Vol 11(1), pages 33–49.

Stock, J H (1998), "Discussion of Gordon's 'Foundation of the Goldilocks Economy'", *Brookings Papers on Economic Activity* 1998(2), pages 334-341.

Stock, J H, and Watson, M W (1998), "Median Unbiased Estimation of Coefficient Variance in a Time Varying Parameter Model", *Journal of the American Statistical Association*, 93, pages 349-358.

Taylor, J. (1993), "Discretion versus Policy Rules in Practice", Carnegie-Rochester Conference Series on Public Policy, 39, pages 195-214.

Taylor, J B, (1999), "An Historical Analysis of Monetary policy rules", *in Monetary Policy Rules*, University of Chicago Press.

Turner, D, Boone, L, Giorno, C, Meacci, M, Rae, D and Richardson, P (2001), 'Estimating the Structural Rate of Unemployment for the OECD Countries', *OECD Economic Studies*, No. 33, pages 171–216.

Data Appendix

Data definitions

We use ONS data where available (ONS codes in parentheses).

Prices: Retail Price Index excluding mortgage interest payments (RPIX) since 1974 [code CHMK]. Prior to 1974, we obtain a series for RPIX by applying the growth rates on the changes in the RPI index [code CHAW] to the level of RPIX in 1974.

Prices: Total Final Consumers' Expenditure deflator (PC) [code (ABJK+HAYE) / (ABJR+HAYO)]

Unemployment: LFS unemployment from 1984 [code MGSX] and OECD measure prior to 1984.

Real Import Prices: Nominal total import prices are given by the implicit import price deflator [code = IKBI/IKBL] and import prices less oil are total trade in goods less oil [code BQKL]. In both cases import prices are deflated using RPIX or relevant price deflator.

Real Oil Prices: Brent oil prices in US dollars [code IFS.UK.IFS.11276AAZZF] converted into pounds sterling [code AJFA]. This series is also deflated using RPIX or relevant price deflator.