UNEMPLOYMENT AND CAPITAL ACCUMULATION IN INTERWAR BRITAIN

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Abstract: The paper uses the Kalman filter method to estimate the time-varying NAIRU of interwar Britain and shows that, during the 1930s, the NAIRU drifted upwards by approximately four per cent. Also, the paper presents an imperfect competition model which predicts that, in the medium run, the NAIRU depends on labour market institutions, unanticipated total factor productivity growth and capital accumulation. Econometric evidence based on data from interwar Britain does not contradict this hypothesis. In particular, it supports the hypothesis that the rising trend of the NAIRU during the 1930s is partly due to a slowdown in capital accumulation demonstrating, thus, that adverse demand shocks may have long-lasting effects.

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Looking at the pattern of unemployment in Britain over a long time period, one cannot avoid noticing that a significant change occurs during the interwar years. Although during 1870-1914 unemployment in Britain could be described as cyclical and stationary, hovering around a fairly stable average of 5.8 per cent[2], during 1921-1939, the unemployment rate rose step-wise with no tendency to return to its previous mean. A number of studies have attempted to account for this upward drift in unemployment in terms of various negative supply shocks. Aldcroft (1970), for example, emphasizes the problems of structural adjustment from the old staples to the new industries. Benjamin and Kochin (1979) ascribe the secular rise in unemployment to a decline in the search activity of the unemployed due to a rise in replacement ratios. Broadberry (1986) emphasizes the long-run effects of a widening real wage gap that emerged in the wake of the reduction of working week in 1919. Crafts (1989) emphasizes the significance of rising long-term unemployment for the wage-setting process and, more recently, Hatton (2002) suggests that long-run swings in equilibrium unemployment can be partly explained with reference to changes in the pace of productivity growth.

A common feature of the above studies is that they explain variations in equilibrium unemployment mainly in terms of institutional changes, more particularly, changes in labour market variables. Recent work by Blanchard (1997, 1998) and Rowthorn (1995), however, shows that, in addition to labour market institutions, changes in equilibrium unemployment may also be driven by variations in capital accumulation, technical change, and labour force growth. This relatively new line of research implies that the upward drift in equilibrium unemployment in interwar Britain, may have been due to the slowdown in capital stock growth and not necessarily due to labour market sclerosis. Surprisingly, there is no work done to bear out the predictions of this line of research and the aim of this paper is to fill this gap.

The paper is divided in four sections. First, I develop an imperfect competition model of equilibrium unemployment which predicts that, in the medium-run, equilibrium unemployment depends on labour market institutions, unanticipated total factor productivity growth, and capital accumulation. Second, I use the Kalman filter method – an econometric technique that is used for the estimation of unobserved time-varying parameters – to estimate the equilibrium rate of unemployment in Britain, 1923-1938. Third, I estimate the effect of capital accumulation and labour market institutions on equilibrium unemployment in interwar Britain and, finally, I draw some policy lessons for today and conclude.

I. THE NAIRU, CAPITAL ACCUMULATION, AND TECHNICAL CHANGE.

In this section, I present a simple imperfect competition model that provides the framework within which data can be studied in a systematic way. The model, which builds upon the work of Layard, Nickell, and Jackman (1991) and Blanchard (1997, 1998), investigates the possible relation between equilibrium unemployment, capital accumulation, and technical change. As I am interested in equilibrium, I will ignore the role of nominal rigidities and concentrate on the medium-run effects of various shifts.

(i) The behaviour of firms

[2] See recent evidence in Boyer and Hatton (2002).

Suppose that the economy consists of a number of identical firms which operate under monopolistic competition. In order to consider the firm's pricing and employment decisions we must first specify technology and demand conditions.

Suppose that each firm has a constant returns to scale technology described by:

$$Y_i = K_i^{\alpha}(AN_i)^{1-\alpha} \tag{1}$$

where Y_i is total output, A is labour-augmenting technical progress, K_i is the capital stock, N_i is employment, α is the share of profits in total output, and i denotes the firm.

Suppose also that each firm faces the following demand function:

$$Y_i = Y(\frac{P_i}{P})^{-\eta} \tag{2}$$

where Y is real aggregate demand, η (>1) is the absolute price elasticity of demand, P_i is the product price of the firm, and P is an aggregate price index.

Profit maximization requires:

$$W_i = \frac{P(1-\alpha)}{\mu}(\frac{Y_i}{Y})^{-\frac{1}{\eta}} A^{1-\alpha}(\frac{K_i}{N_i})^{\alpha} \tag{3}$$

where W_i is the money wage and μ $(=\frac{\eta}{\eta-1})$ is the gross mark up of price over the marginal cost.

As firms face identical wages, equation (3) implies:

$$W = \frac{P(1-\alpha)}{\mu} A^{1-\alpha}(\frac{K}{N})^{\alpha} \tag{4}$$

or

$$\frac{W}{P} = \frac{(1-\alpha)}{\mu} A(\frac{K}{AN})^{\alpha} \tag{5}$$

Equation (5) gives the economy-wide warranted real wage, i.e. the real wage that is consistent with the profit maximization of firms under imperfect competition.

Taking logs:

$$w - p = \gamma + a + \alpha(k - a - n) \tag{6}$$

or

$$w - p = \gamma + a + \alpha(k - a - l) + \alpha u \tag{7}$$

or

$$w - p = \gamma + a + \alpha\kappa + \alpha u \tag{8}$$

where lower case letters denote logarithms, $\gamma = \log(\frac{1-\alpha}{\mu})$, l denotes the labour force, u $(\cong l - n)$ is the rate of unemployment, and κ $(= k - a - l)$ is capital stock per unit of effective labour.

Equation (8) shows that the economy-wide warranted real wage depends on three factors: the level of economic activity, trend productivity, and the degree of product market competition. A rise in economic activity will raise marginal costs and, ceteris paribus, reduce the real wage that firms are ready to pay. Trend productivity effects may arise from two sources – changes in capital stock per unit of effective labour and changes in total factor productivity. Clearly, a rise in trend productivity enables the economy to accommodate higher real wages for any given rate of unemployment. Finally, a decline in the degree of monopoly (μ) would also permit higher real wages at any given rate of unemployment. Note that, here, the degree of monopoly is independent from demand conditions but could shift as a result of exogenous shocks in market structure.

Equation (8) is a standard price-setting equation which extends the first-order condition that marginal product equals the wage by allowing for a wedge between the two parameterized by μ.

(ii) Wage determination

Suppose that the target real wage is influenced by the level of activity in the labour market; by various supply side factors such as the level and coverage of unemployment insurance, the degree of mismatch, or trade union strength; and by the anticipated level of trend productivity:

$$\frac{W}{P} = Z(\frac{N}{L})^{\beta} Q^{e} \tag{9}$$

where Z captures all relevant labour market factors, Q $(= \frac{Y}{L})$ denotes trend productivity, and e denotes expectations.

Taking logs:

$$w - p = z - \beta(l - n) + q^{e} \tag{10}$$

or

$$w - p = z - \beta u + a^e + \alpha(k - a - l)^e \tag{11}$$

or

$$w - p = z - \beta u + a^e + \alpha\kappa^e \tag{12}$$

Equation (12) is a standard wage-setting equation consistent with various wage determination models.

Suppose now that the expected total factor productivity is given by:

$$a_t^e = a_{t-1} + \vartheta \tag{13}$$

where ϑ denotes the trend growth rate of total factor productivity.

Suppose also that the expected level of capital stock per effective labour equals its current level, i.e.:

$$\kappa_t^e = \kappa_{t-1} \tag{14}$$

The assumption of static expectations in this context implies that wage-setters assume that the economy is at steady state, i.e. it lies on its balanced growth path – as an economy actually does over the long run[3].

(iii) Equilibrium unemployment

In the long run, all expectations should equal actual values, hence:

$$a = a^e \tag{15a}$$

and

$$\kappa = \kappa^e \tag{15b}$$

Define thus the long-run NAIRU as the rate of unemployment at which the warranted real wage equals the target real wage and expected productivity equals actual productivity. Combining equations (8), (12), and (15) and denoting equilibrium unemployment by an asterisk:

$$u_{LR}^* = \frac{z - \gamma}{\alpha + \beta} \tag{16}$$

[3] The fact that the capital-output ratio has been, over the last century, approximately constant is often taken as evidence that, indeed, it is reasonable to think of the advanced industrial economies as Solow model economies on their balanced growth paths.

Equation (16) implies that, in the long run, i.e. when $\dot{a} = \vartheta$ and $\dot{\kappa} = 0$, equilibrium unemployment is driven only by supply side factors – which is the result obtained by the standard Layard and Nickell model.

In the medium run, though, if actual productivity growth deviates from anticipated productivity growth or capital stock grows slower than its steady state rate would require, equilibrium unemployment will drift away from its long-run value. More particularly, define the medium-run NAIRU as the rate of unemployment at which the warranted real wage equals the target real wage *in the presence of unanticipated productivity growth*:

$$u^*_{MR} = \frac{1}{\alpha + \beta}[z - \gamma - (a - a^e) - \alpha(\kappa - \kappa^e)] \tag{17}$$

Insert (13) and (14) into (17):

$$u^*_{MR} = \frac{1}{\alpha + \beta}[z - \gamma - (\dot{a} - \vartheta) - \alpha\dot{\kappa}] \tag{18}$$

where $(\dot{a} - \vartheta)$ denotes unanticipated total factor productivity growth, $\dot{\kappa}$ denotes the growth of capital per effective worker, and a dot above a variable denotes a time derivative.

Taken together, equations (16) and (18) suggest that, in the medium-run, equilibrium unemployment may lie above its long-run value either as a result of an unanticipated slowdown in TFP growth or as a result of a slowdown of capital accumulation relative to its steady-state rate. To be sure, in the long run, equilibrium unemployment will gravitate towards its long-run rate as workers update their expected TFP growth and/or as capital stock converges toward its steady-state level[4]. However, periods of adjustment may be long enough to produce considerable swings of equilibrium unemployment around its long-run value. Recent research has indeed indicated that waves of acceleration and slowdown in productivity growth may be associated with swings in equilibrium unemployment[5]. More relevant for our case, the historically low rates of capital accumulation that prevailed in interwar Britain in the aftermath of the 1920-21 recession might have induced a rise in equilibrium unemployment.

An obvious problem that someone encounters in attempting to investigate this hypothesis is the fact that equilibrium unemployment is a theoretical construct and therefore unobservable.

II. THE TIME-VARYING NAIRU IN INTERWAR BRITAIN.

(i) Estimating the time-varying NAIRU

A common way to track the evolution of the NAIRU in interwar Britain would be to estimate the structural model discussed in the previous section. This is indeed the approach adopted by Layard and Nickell in their several studies on postwar

[4] For an illustration of the comparative static effects, see Figures 1a and 1b.
[5] See Ball and Moffitt (2001) and Hatton (2002b).

unemployment. Although this approach has the advantage of identifying directly the underlying causes of changes in the NAIRU, recent research has suggested that estimates of the NAIRU based on structural labour market models are very sensitive to small changes in model specification[6]. In light of considerable disagreements as to which factors should be considered in determining the NAIRU, estimates obtained by this approach are often received with scepticism. A recent alternative approach is based on the use of the Kalman filter. The Kalman filter technique allows for the joint estimation of an expectations-augmented Phillips curve and the NAIRU - the latter being modelled as a stochastic time-varying parameter. In effect, the estimated NAIRU is derived from its ability to explain changes in inflation subject to various constraints on its evolution over time. The Kalman filter technique has been recently used to estimate the United States NAIRU but, to the best of my knowledge, in has not yet been applied on macroeconomic historical data[7].

The estimation of the time-varying NAIRU requires the specification of an inflation equation as well as a stochastic process that generates the unobservable variable. In line with Gordon's triangle model, I assume that the behaviour of inflation is described by the following equation:

$$\pi_t = \pi^e - b(L)(u_t - u_t^*) + c(L)s_t + e_t \tag{19}$$

where π denotes inflation, π^e expected inflation, u denotes the observed unemployment rate, u^* the unobservable NAIRU, s denotes a vector of temporary supply shock variables, e is a random error with zero mean and variance σ_e^2, and L is the lag operator.

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

$$u_t^* = u_{t-1}^* + v_t \tag{20a}$$

where v_t is a random error with zero mean and variance σ_v^2.

A more general univariate stochastic process defines the change in the NAIRU as a first-order autoregressive process, i.e.:

$$\Delta u_t^* = \varphi \Delta u_{t-1}^* + \upsilon_t \tag{20b}$$

where $0 \leq \varphi < 1$ and υ_t is a random error with zero mean and variance σ_υ^2.

In principle, an environment where the NAIRU changes slowly in response to supply-side shocks is better described by equation (20b). In practice, though, as there are no grounds to rule out one of the two processes in favour of the other, I will use both and choose

[6] See Ball and Mankiw (2002).
[7] See Gordon (1997, 1998).

between them on the basis of the statistical significance of the autocorrelation coefficient φ[8].

Equations (19) and (20) contain all necessary economic information for the estimation of the time-varying NAIRU using the Kalman filter technique. Before proceeding further, though, a few comments on the triangle model and the variables involved are necessary. Equation (19) suggests that inflation is determined by expectations, demand conditions, and temporary supply shocks - taken here to be those shocks that might be reasonably expected to revert to zero over a horizon of one to two years.

The treatment of inflation expectations requires some discussion. Recent studies on the behaviour of inflation often assume that inflation exhibits persistence, i.e. the stochastic process that drives inflation is a random walk. Without doubt, this is a legitimate assumption to make when studying the post-1973 period but I believe it would be a rather inappropriate way to model the behaviour of prices during the interwar years given that the anticipation, and then the reality, of the Gold Standard provided a nominal anchor to inflation expectations[9]. To take into account the effect of the prevailing monetary rule on inflation expectations, I relax the conventional assumption of random walk and model inflation as an autoregressive process. More particularly, I assume that inflation is driven by the process:

$$\pi_t = \lambda \pi_{t-1} + \eta_t \tag{21}$$

where $0 \le \lambda \le 1$ and η is a random shock with zero expectation. Then:

$$\pi^e = \lambda \pi_{t-1} \tag{22}$$

Combining (19) and (22):

$$\pi = \lambda \pi_{t-1} - b(L)(u_t - u_t^*) + c(L)s_t + e_t \tag{23}$$

or

$$\Delta\pi = \chi \pi_{t-1} - b(L)(u_t - u_t^*) + c(L)s_t + e_t \tag{24}$$

where Δ is the first difference operator and $\chi = \lambda - 1$.

Equation (22) is the triangle model of inflation under the assumption that inflation follows a first-order autoregressive process[10]. Note that if χ is not significantly different from zero, inflation follows a random walk whereas if $\chi < 0$ inflation is mean reverting. In the extreme case where $\chi = -1$, inflation is a white noise and, on average, the public expects zero inflation. This is, of course, an extreme example of monetary policy credibility.

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[8] Note that if φ is not significantly different from zero, equations (20a) and (20b) are identical.

[9] See Bordo et al (1999).

[10] Using data from Britain 1865-1987, Alogoskoufis and Smith (1991) show that the hypothesis that inflation is driven by a first-order autoregressive process cannot be rejected.

The inclusion of temporary supply shocks in an otherwise standard expectations-augmented Phillips curve implies that the u_t^* of equation (24) is, to use Gordon's terminology, the NAIRU *in the absence of temporary supply shocks*. More particularly, the time-varying NAIRU that would emerge from the estimation of equation (24) is the rate of unemployment consistent with stable inflation once the influence of temporary supply shocks on inflation has been controlled for. If the supply shock variables were excluded, the estimated NAIRU would jump up and down in response to these temporary supply shocks – a rather undesirable behaviour given that the medium-run NAIRU that I derived in section I should, in principle, be a slow-moving series which does not exhibit high frequency variations. Drawing a line between temporary and long-lasting supply shocks is inevitably a rather arbitrary exercise. Following convention, s includes two temporary supply shocks: changes in real import prices (weighted by the degree of openness of the British interwar economy) and changes in real fuel prices – both of which are standard supply shocks expected to have a transitory effect on inflation for any given demand conditions.

Finally, the series on inflation is based on implicit GDP deflator data and the series on unemployment on working population and employment data – both from Feinstein (1972).

(ii) Empirical results

The Kalman filter technique was carried out using a maximum likelihood method where equation (24) was estimated jointly with each of the two stochastic processes driving the time-varying NAIRU (20a) and (20b) – all repeated below for convenience:

$$\Delta\pi = \chi\pi_{t-1} - b(L)(u_t - u_t^*) + c(L)s_t + e_t \qquad (24)$$

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

$$u_t^* = u_{t-1}^* + v_t \qquad (20a)$$

where $v_t \sim N(0, \sigma_v^2)$

or

$$\Delta u_t^* = \varphi \Delta u_{t-1}^* + \upsilon_t \qquad (20b)$$

where $\upsilon_t \sim N(0, \sigma_\upsilon^2)$

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 variances of the error terms in the two equations, i.e. the variance of the error term in the stochastic process driving the NAIRU relative to the variance of the error term in the inflation equation, and determines the smoothness of the resulting time-varying NAIRU series[11]. 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 NAIRU, hence, the NAIRU series is very volatile. On the other extreme, a signal-to-noise ratio equal to zero implies a constant NAIRU. In principle, the Kalman filter makes it possible to estimate all the parameters of the model - including the signal-to-noise ratio. In practise, however, estimating the NAIRU without restricting the ratio leads to a NAIRU 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 NAIRU to move about as much as it likes without though exhibiting high frequency variation.

Table 1 shows the results of the inflation equation, which has been estimated jointly with each of the two processes that drive the NAIRU over the period 1923-38. Row 1 shows the results obtained from the estimation of the inflation equation (24) under the assumption that the NAIRU follows a random walk while row 2 shows the results obtained from the estimation of the inflation equation under the assumption that the NAIRU is driven by the stochastic process described by equation (20b). There are three issues to note. First, all regressors are signed as expected with the unemployment gap having a negative effect and the temporary supply shocks a positive effect on the change in inflation. Second, the coefficient on lagged inflation (χ) is significantly different from zero at the one per cent level of significance, indicating that inflation is mean-reverting, perhaps, due to the credibility of the prevailing monetary rule. Third, the hypothesis that the autocorrelation coefficient (φ) is not significantly different from zero cannot be rejected, implying that the stochastic process that generates the time-varying NAIRU resembles a random walk. In light of this last piece of evidence, it is not surprising that the two estimated equations give almost identical results.

Figure 2 illustrates graphically that, indeed, the estimated time-varying NAIRU series derived from the two alternative stochastic processes are identical. As the evidence suggests that the stochastic process that generates the NAIRU resembles a random walk, below, I restrict my attention on this case.

Figure 3 shows the profiles of alternative time-varying NAIRU series, derived under various signal-to-noise ratios, together with the actual unemployment rate. Not surprisingly, the series derived on the basis of the higher signal-to-noise ratio exhibits a mildly higher variation. Yet, all three series exhibit the same overall pattern: starting from a relatively high level, the NAIRU declines smoothly during the second half of the 1920s while towards the late 1920s it stabilizes around 8 per cent. From 1929 onwards, the NAIRU starts rising steadily and by the end of the 1930s it stands above 12 per cent. The estimates suggest that, on average, the NAIRU in interwar Britain was approximately 9.9 per cent[12]. All in all, the three estimates show that, during the 1930s, the time-varying NAIRU increased by approximately four percentage points.

Figure 4 shows three alternative measures of the unemployment gap constructed on the basis of the time-varying NAIRU series of Figure 3. As a matter of definition, the unemployment gap is the difference between the actual unemployment rate and the

[11] See Harvey (1989).
[12] An average that is almost identical to Hatton's own average of 9.8 per cent (see Hatton (2002b)).

NAIRU. Thus, a positive unemployment gap indicates a rise in labour market slack whereas a negative one indicates overheating. All three time-varying NAIRU series reveal the same story. The striking feature of the graph, as one would expect, is the positive unemployment gap that emerged in 1929 and lasted up to 1935 – a clear manifestation of the Great Depression. The other interesting aspect of the graph is the negative unemployment gap that characterised the second half of the 1930s – an indication that the British economy was running up against supply constraints. This is perhaps what Keynes referred to in an article in the Times when, while unemployment was still as high as 10.8 per cent, he said: "I believe that we are approaching, or have reached, the point where there is not much advantage in applying a further general stimulus at the centre."[13]

To find out which of the three unemployment gaps fits better the expectations-augmented Phillips curve of interwar Britain, I estimate the inflation equation (24) using Ordinary Least Squares. The OLS estimates, together with a number of diagnostic tests, are reported in Table 2 - each row of which corresponds to one of the unemployment gap series illustrated in Figure 4. Not surprisingly, the regression results say the same story as the Kalman filter estimation. All regressors are correctly signed and significantly different from zero and there is no evidence of misspecification or structural break in any of the three models. Hence, all three estimated time-varying NAIRU series seem to track changes in inflation equally well. As conventional statistical criteria do not permit the selection of one of the estimated NAIRU series against the others, in what follows, I will be using two alternative time-varying NAIRU series (those estimated on the basis of the higher and the lower signal-to-noise ratios). By so doing, I minimize the chance that my statistical results will depend on an arbitrary choice of the NAIRU series.

To summarize, using the Kalman filter method, and under certain assumptions about the evolution of the NAIRU over time, I estimated the NAIRU for interwar Britain. The estimated series suggests that, following the onset of the Great Depression, the NAIRU drifted upwards by approximately four per cent. Why did equilibrium unemployment in Britain rise during the 1930s is the question that I will address next.

III. THE RISE IN THE NAIRU: SUPPLY OR DEMAND SHOCKS?

The average annual rate of capital accumulation in interwar Britain was 1.4 per cent – which is a low rate by historical standards. Figure 5 plots the log of capital stock for two different historical periods: 1921-1938 and 1951-1968 – the latter being a period of stable inflation and full employment. The difference in the growth rates between the two series is rather striking. Capital stock growth in interwar Britain is also unfavourably compared with other, less successful, times in the history of the capitalist economies. The years 1891-1908, for example, witnessed an average annual rate of capital stock growth of 1.8 per cent, i.e., 30 percentage points higher than this of the interwar years.

As the model of section I illustrates, slower capital accumulation should not be a matter of concern for equilibrium unemployment, if the growth rate of labour supply in efficiency units were equally slow. The data however suggests that capital accumulation during the interwar years failed to keep up with the expansion of labour supply in efficiency units. Figure 6 shows that, over the interwar period as a whole, capital

[13] See Solomou (1996), p. 79.

accumulation was growing at a slower pace than this required by the natural rate of growth, leading, thus, to a fall in the capital per effective labour ratio and, ceteris paribus, to a lower warranted real wage. A careful look at the data also shows that the slowdown of capital accumulation has been especially dramatic – and hence the widening gap between capital stock and labour supply in efficiency units particularly fast – during the period preceding the return of Britain to Gold as well as during the Great Depression. Did slower capital accumulation relative to labour in efficiency units contribute to the upward drift in equilibrium unemployment during the 1930s? My objective for the rest of the paper is to investigate this hypothesis. I will do so by estimating the equilibrium unemployment equation that I derived in section I, whose general functional form I repeat below for convenience. If the model that I advanced there is correct, one should expect the following effects on the NAIRU:

$$u^* = f(\underset{+}{z}, \underset{-}{(\dot{a} - \vartheta)}, \underset{-}{\dot{\kappa}})$$

To take into account the possibility of slow adjustment of the NAIRU to changes in the right-hand side variables, I specify the above equation as an error correction model. Thus the estimated equation is:

$$\Delta u^* = \alpha_0 + \alpha_1(L)\Delta z_t + \alpha_2(L)\Delta(\dot{a} - \vartheta)_t + \alpha_3(L)\Delta\dot{\kappa}_t + \alpha_4 ec_{t-1} + \xi_t \qquad (25)$$

where α_0 is an intercept, the parameters $\alpha_1, \alpha_2, \alpha_3$ denote the impact multipliers of their respective variables, the parameter α_4 indicates the speed of adjustment of equilibrium unemployment in the event of shocks, ec is the error-correction term, and ξ_t is a random error with zero mean and variance σ^2_ξ.

Following convention, the vector of supply side variables (z) contains the replacement ratio, adjusted to take into account changes in the coverage of the system of unemployment insurance; an index of mismatch; and an index of trade union density. As the analytical framework of section I suggests, changes in the three variables would affect the NAIRU by shifting the wage-setting curve. In particular, a rise in any of the three variables would shift the wage-setting curve upwards and, thus, raise the rate of unemployment that is consistent with stable inflation. The sources and definitions of these variables are provided in the Appendix.

As a matter of definition, unanticipated productivity growth ($\dot{a} - \vartheta$) is the difference between actual and expected total factor productivity growth. Total factor productivity is an unobservable variable which I estimated using growth accounting. Under the assumption of constant returns to scale and Harrod-neutral technical change, total factor productivity is given by:

$$a_t = \frac{1}{\sigma_L}[(y-l)_t - (1-\sigma_L)(k-l)_t] \qquad (26)$$

where σ_L is the share of labour in gross valued added. Note that, under the above assumptions, total factor productivity is the Solow residual divided by the share of labour in gross value added. There are clearly more than one ways to quantify expected total factor productivity growth (ϑ) - none of which is unambiguously superior to the rest. Here, I assume that the target real wage is set on the basis of the recent record of TFP growth, thus, I set expected productivity growth equal to a three-year moving average of actual TFP growth.

By definition, the growth of labour supply in efficiency units is the sum of labour force growth and total factor productivity growth. Both labour force and total factor productivity series have a strong cyclical pattern – the first due to the 'discouraged worker' effect and the second by construction – which, in calculating the natural rate of growth one should remove. I did so by applying the Hodrick-Prescott filter, setting its smoothing parameter to 100. Thus, the growth of capital stock per effective labour (κ) is the difference between the rate of capital accumulation and the trend growth of labour supply in efficiency units.

The error correction term of equation (25) captures the response of the dependent variable to deviations from its long-run equilibrium value. As an instrument for this term, I use the residuals from the estimation of the long-run equilibrium relationship (18).

Finally, Crafts (1989) has shown that one important factor behind the rise in the NAIRU during the 1930s has been the increase in the share of the long-term unemployed in total unemployment – an effect that operated through the diminished influence of the long-term unemployed in wage-setting. The share of the long-term unemployed tracks closely actual unemployment, hence, to take into account this effect, I use lagged unemployment as an instrument.

Table 3 presents OLS estimates of equation (25) estimated over the period 1923-38. Columns 1 and 2 correspond to two alternative time-varying NAIRU series. The first is based on a signal-to-noise ratio of 0.09 while the second on a signal-to-noise ratio of 0.25, thus, the first is mildly smoother than the second. Initial estimates showed that unanticipated productivity growth is not significantly different from zero and the variable is not reported in the Table. The reported estimates strongly suggest that the rate of capital accumulation contributed to the upward drift of equilibrium unemployment. No matter how the dependent variable is specified, the coefficient on capital accumulation has a negative sign and is significantly different from zero at the five per cent level of significance. The supply side factors and lagged unemployment are correctly signed and significantly different from zero too. Finally, the hypothesis that the coefficient on the error correction term is unity could not be rejected. This last result indicates that, in the event of a shock, the adjustment of the NAIRU towards its equilibrium is rapid – a result that ties well with our earlier finding that the NAIRU follows a random walk.

In theory, a slowdown of capital accumulation relative to the natural rate of growth could be the result of several factors. It could, for example, come about as a consequence of a negative supply shock, such as an exogenous rise in the real target wage, which may depress business profitability below the prevailing rate of interest[14]. It could also result from a negative demand shock: falling prices coupled with nominal wage rigidity and/or sticky nominal interest rates would not only cause an immediate rise in actual unemployment but, through their effect on profitability and the user cost of capital, they

[14] See Blanchard (1998).

may also induce a slowdown in capital accumulation and therefore a rise in equilibrium unemployment too. The role of nominal wage and interest rate rigidities as a transmission mechanism in the Great Depression has been extensively studied and well documented elsewhere. Newell and Symons (1988) or Dimsdale, Nickell and Horsewood (1989), for example, both emphasize the role of nominal rigidities in the labour and credit markets as the propagation mechanism behind the rise in actual unemployment during 1929-32. If, however, medium-run equilibrium unemployment is determined by the pace of capital accumulation, as the evidence above seems to suggest, then the same nominal demand shocks that caused a rise in actual unemployment may have also affected equilibrium unemployment, through their effect on profitability and the user cost of capital. With the possible exception of Broadberry and Ritschl (1995), this is an unexplored hypothesis. The remaining two regressions attempt to investigate it by estimating the effect of the user cost of capital on equilibrium unemployment, where as an instrument for the user cost of capital I use the lag of the real consol yields.

Columns 3 and 4 correspond to the two alternative time-varying NAIRU series in the same way as columns 1 and 2 do. The results seem to suggest a strong positive effect of the real interest rate on equilibrium unemployment. The coefficients on lagged real consol yields are positive and significantly different from zero at the one per cent level of significance. As before, the supply side variables and lagged unemployment are all signed as expected and significantly different from zero at the five per cent level of significance.

IV. CONCLUSION

I presented a model of equilibrium unemployment which predicts that, in the medium run, the NAIRU is determined by labour market institutions, unanticipated total factor productivity growth, and capital accumulation. Using the Kalman filter method, I estimated the time-varying NAIRU of interwar Britain and showed that, during the 1930s, equilibrium unemployment drifted upwards by approximately four per cent. Evidence suggests that this upward trend in the NAIRU should be partly ascribed to the low rate of capital accumulation, relative to the growth of labour supply in efficiency units, as well as to various other exogenous supply shocks.

The above evidence complements the findings of several other studies on the role of negative demand shocks in generating mass unemployment during the interwar years. More particularly, my findings suggest that the very same shocks and transmission mechanisms identified by Newell and Symons (1988) and Dimsdale, Nickell and Horsewood (1989) as causing the rise in actual unemployment during 1929-32, may also be partly responsible for the rise in equilibrium unemployment through their effect on capital accumulation.

These findings may have important policy implications. They suggest that negative demand shocks may potentially have long-lasting effects on sustainable output and employment. They also show that the NAIRU may be endogenous to monetary policy making, thus, its use as an intermediate monetary policy target should perhaps be qualified. Finally the findings imply that the case for labour market reforms as the only route to achieving a lower NAIRU in continental Europe today may be overstated.

DATA APPENDIX

Capital stock: total net capital stock at 1938 constant replacement cost. Source: Feinstein (1972).
Degree of Openness: share of imports of goods and services in GDP at factor cost (1938 prices) Source: Feinstein (1972).
Fuel Prices: fuel and light price index. Source: Feinstein (1972).
Import Prices: implicit import price deflator based on imports of goods and services. Source: Feinstein (1972).
Labour force: a Hodrick-Prescott trend of working population series. Source: Feinstein (1972).
Mismatch: an index of structural change defined as $S_t = \Sigma_i w_i \left| g_{i,t} - g_t \right|$ where w_i are value added weights and g_i and g_t are annual growth rates of individual sectors and GDP respectively, calculated across 11 sectors. Source: calculated by Hatton, see Hatton (2002b).
Output Prices: implicit GDP deflator based on GDP at factor cost. Source: Feinstein (1972).
Interest Rates: three per cent consol yields; Source: Sheppard (1971).
Replacement Ratio: unemployment benefits per average earnings of a full-time manual employee, adjusted for changes in eligibility. Source: calculated by Hatton, see Hatton (2002b).
TFP: an index of labour augmented technical progress, calculated as a Hodrick-Prescott trend of the residuals from a Cobb-Douglas production function. Source: author's own calculations.
Unemployment Rate: total unemployment (including persons temporarily stopped) as a share of working population. Source: Feinstein (1972).
Union: an index of trade union density defined as the ratio of union membership over the labour force. Source: calculated by Hatton, see Hatton (2002b).

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Table 1. Estimation of Expectations-Augmented Phillips Curves using the Kalman filter: Britain 1923-1938

Regression (row)	Dependent variable	Regressors					Log Likelihood
		Lagged Inflation	Unemployment Gap	Δ Real Import Prices	Δ Real Fuel Prices	φ	
1	$\Delta\pi_t$	-0.45 (0.14)	-0.21 (0.09)	0.77 (0.19)	0.08 (0.08)		31.6
2	$\Delta\pi_t$	-0.45 (0.15)	-0.21 (0.09)	0.77 (0.19)	0.08 (0.08)	-0.01 (0.82)	31.6

Notes: Standard errors in parentheses below the estimated coefficients. Δ is the first difference operator. For data definitions and sources see the Data Appendix.

Table 2. OLS Estimation of Expectations-Augmented Phillips Curves: Britain 1923-1938

Regression (row)	Dependent variable	Regressors				R^2	Serial Correlation LM Test	RESET Test	Parameter Stability Test
		Lagged Inflation	Unemployment Gap*	Δ Real Import Prices	Δ Real Fuel Prices				
1	$\Delta\pi_t$	-0.46 (0.06)	-0.26 (0.07)	0.73 (0.17)	0.08 (0.03)	0.94	0.05	0.51	0.74
2	$\Delta\pi_t$	-0.47 (0.05)	-0.26 (0.07)	0.69 (0.16)	0.08 (0.03)	0.95	0.16	0.28	0.69
3	$\Delta\pi_t$	-0.47 (0.05)	-0.26 (0.06)	0.68 (0.15)	0.08 (0.03)	0.96	0.36	0.12	0.70

Notes: Standard errors in parentheses below the estimated coefficients. Δ is the first difference operator. The serial correlation LM test refers to the F statistic of the Breusch-Godfrey test. The RESET test refers to the F statistic of the Ramsey RESET test and the parameter stability test refers to the F statistic of the Chow Forecast test. For data definitions and sources see the Data Appendix.

* The unemployment gap is the actual unemployment rate minus the time-varying NAIRU. Unemployment gaps in regressions 1, 2 and 3 are based respectively on time-varying NAIRUs with signal-to-noise ratios of 0.09, 0.16 and 0.25.

Table 3. OLS Estimates of the NAIRU Equation: Britain 1923-1938

Regressions:	1	2	3	4
Dependent variable:	$\Delta u^*(0.09)$	$\Delta u^*(0.25)$	$\Delta u^*(0.09)$	$\Delta u^*(0.25)$
Independent variable				
Constant	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Δcapital accumulation	-0.51 (0.17)	-0.78 (0.32)		
Δreal interest rate(-1)			0.06 (0.02)	0.11 (0.02)
Δreal interest rate(-2)			0.09 (0.02)	0.19 (0.02)
Δunemployment(-1)	0.16 (0.05)	0.32 (0.13)	0.13 (0.03)	0.23 (0.04)
Δreplacement ratio	0.22 (0.05)	0.40 (0.10)	0.27 (0.05)	0.54 (0.05)
Δmismatch(-1)	0.06 (0.02)	0.10 (0.05)	0.05 (0.02)	0.09 (0.03)
Δunion strength	0.37 (0.07)	0.71 (0.14)	0.14 (0.04)	0.20 (0.06)
Δunion strength(-1)	-0.26 (0.07)	-0.45 (0.14)		
Error correction term	-1.09 (0.48)	-1.00 (0.46)	-0.92 (0.47)	-1.50 (0.36)
R^2	0.872	0.861	0.937	0.970
s	0.002	0.004	0.001	0.002
Serial correlation LM	0.744	0.616	0.019	0.205

Notes: The number in parenthesis next to the dependent variable refers to the signal-to-noise ratio on the basis of which the dependent variable was constructed. Standard errors in parentheses below the estimated coefficients. Δ is the first difference operator. s is the standard error of regression. The serial correlation LM test refers to the F statistic of the Breusch-Godfrey test. For data definitions and sources see the Data Appendix.

Figure 1a. Slowdown in Capital Accumulation and Equilibrium Unemployment

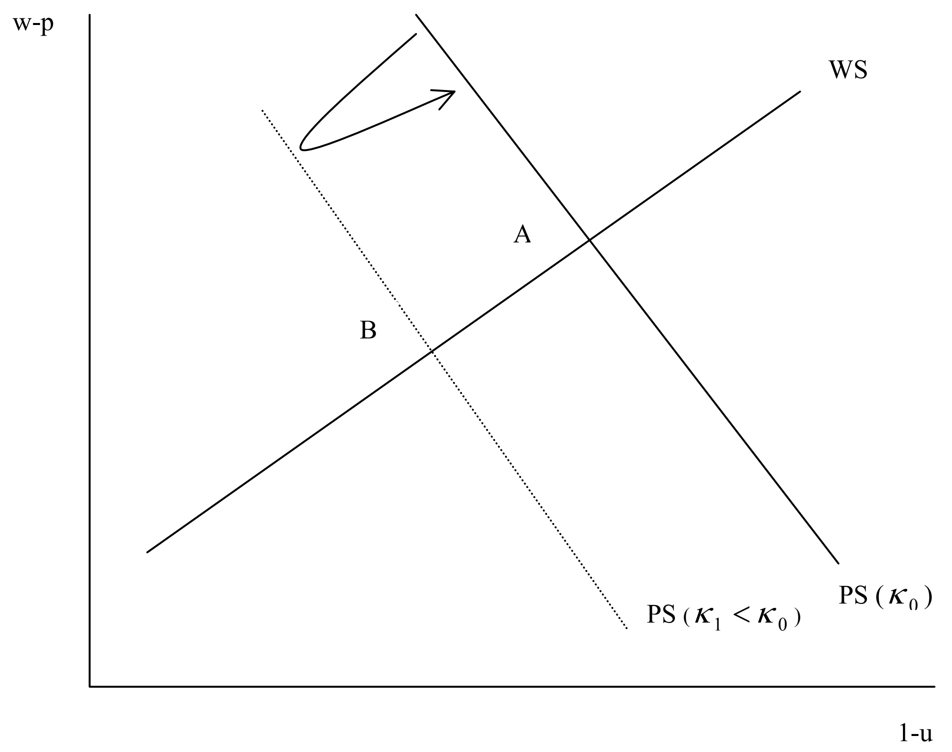


Figure 1b. Total Factor Productivity and Equilibrium Unemployment

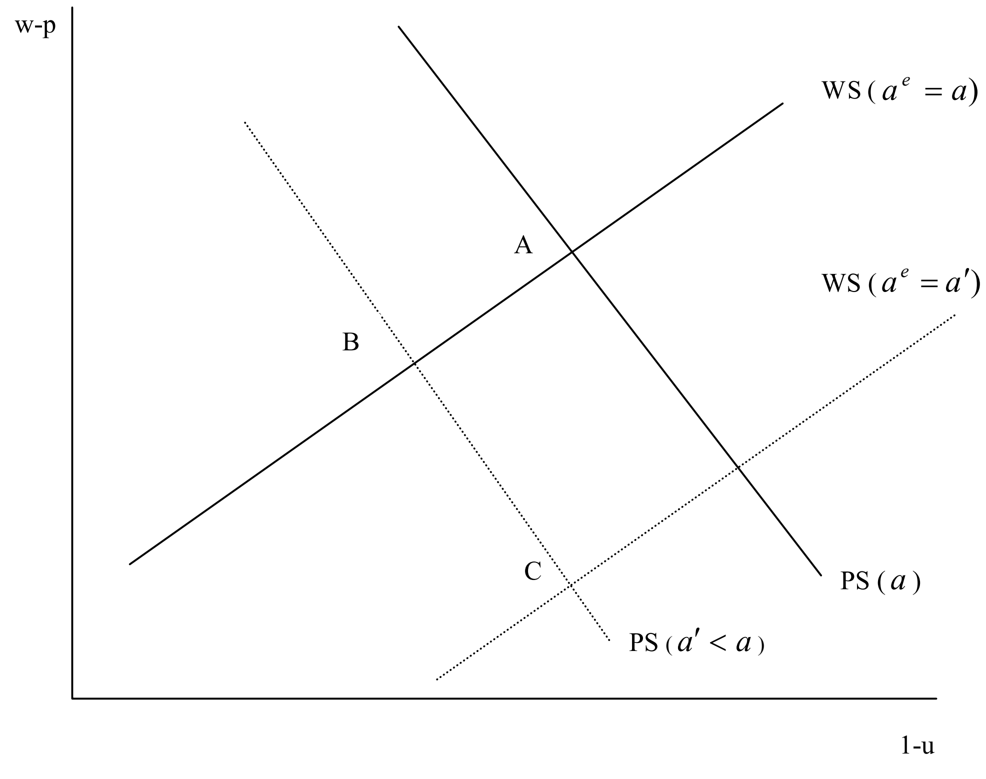
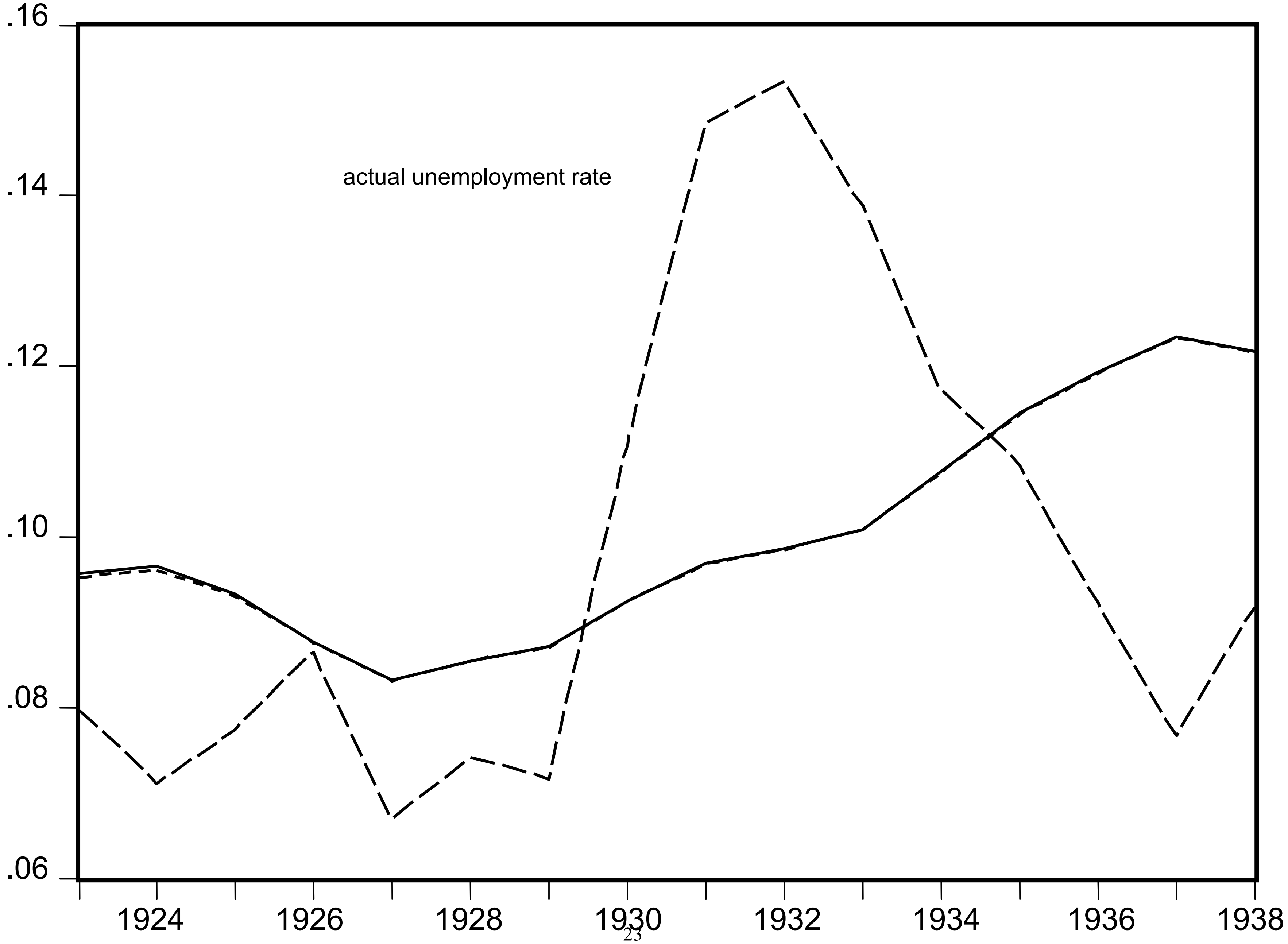


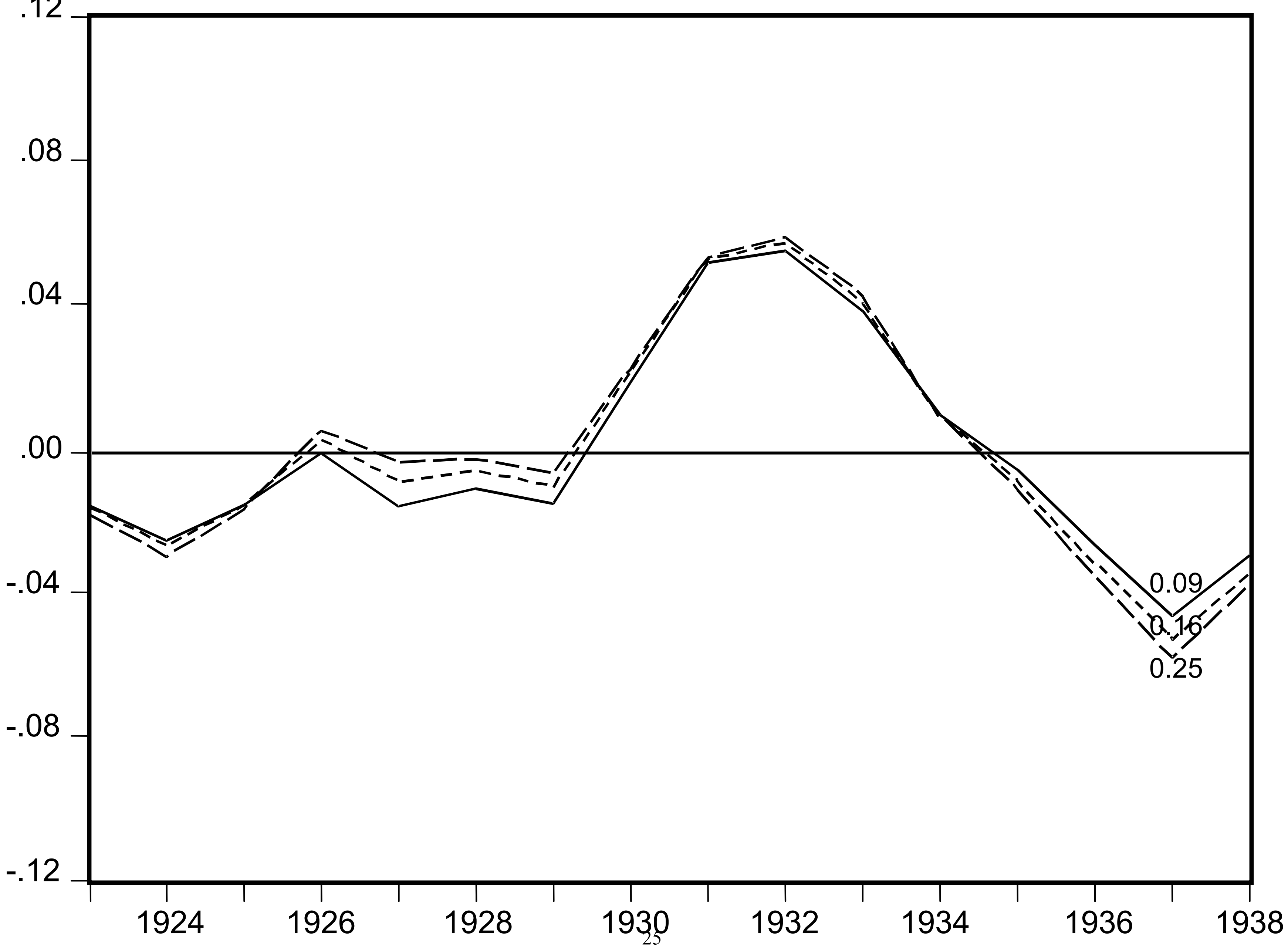
Figure 2. Time-Varying NAIRUs, Alternative Transition Equations



Note: The time-varying NAIRU series are based on a signal-to-noise ratio of 0.09.

Figure 3. Time-Varying NAIRUS, Alternative Signal-to-Noise Ratios

Figure 4. Unemployment Gaps, Alternative Signal-to-Noise Ratios



Note: The numbers on the graph refer to the signal-to-noise ratios of the underlying time-varying NAIRUs.

Figure 5. Log Capital Stock in Britain During Two Historical Periods

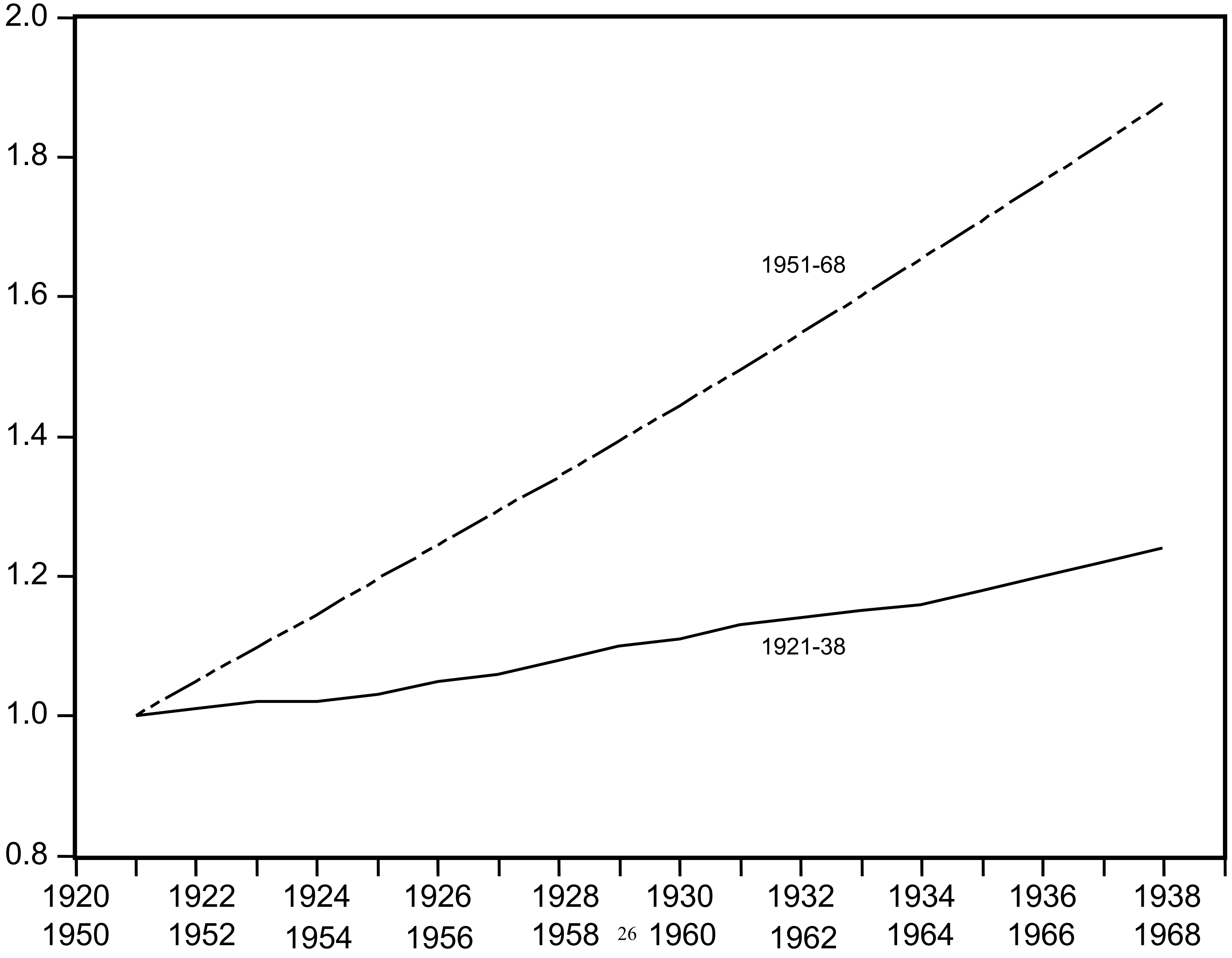


Figure 6. Capital Stock and Effective Labour Supply in Interwar Britain