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No 28

Testing a discrete switching disequilibrium model of the UK labour market

by

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M Pemberton is at University College, London. The views expressed in this paper are those of the authors and do not necessarily represent those of the Bank of England or University College. The authors would like to thank the Bulletin Group for editorial assistance in producing this paper.

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CONTENTS

Testing a discrete switching disequilibrium model of the UK labour market

This paper develops and applies tests for serial correlation in a model of a market in which the price does not necessarily adjust immediately to equate supply and demand. Rather than always being at the intersection of the demand and supply functions the quantity traded may then, given the price, be the lesser of the two and can be said to be demand constrained or supply constrained as the case may be. That markets may be characterised by such constrained behaviour has been recognised for some time. The labour market is often advanced as being a likely candidate, where particular, the level of employment may be less than the market clearing level because the real wage is above its equilibrium value. There are considerable statistical problems in applying such 'discrete switching' models in practice. One is that it is difficult to tell whether the demand and supply equations underlying the estimated relations have serially correlated errors, which would imply that they were misspecified. The present paper derives an extended concept of the residual in these underlying structural equations. Using this concept, the paper provides estimates of the aggregate UK labour market and these show that a supply curve which depends upon conventional factors including real unemployment benefits and unionisation rates is dynamically misspecified. Correcting for this misspecification, supply is shown to depend on the consumption real wage and the working population only. Moreover, the complete model reveals evidence that over the 1980s employment has been constrained by the demand for labour.

TESTING A DISCRETE SWITCHING DISEQUILIBRIUM MODEL OF THE UK LABOUR MARKET

1 Introduction

Following the seminal work of Maddala and Nelson (1974) and Rosen and Quandt (1978) a number of studies have demonstrated the practical usefulness of the single market discrete switching disequilibrium model in applied work. Applications include Smyth (1983), Sneessens (1981), Quandt and Rosen (1986), Briguglio (1984), Artus, Laroque and Michel (1984), Hall and Urwin (1989) and Hall, Henry, Markandya and Pemberton (1989). While these studies have demonstrated that the technique can yield both satisfactory and plausible results there remain serious problems of testing the underlying model. In contrast with conventional dynamic single equation modelling, where there are an extensive range of diagnostic test statistics, disequilibrium modelling has generally undertaken little or no testing of the underlying hypotheses. It is comparatively easy to construct standard likelihood ratio tests of specific restrictions for such models and Wald tests of the significance of individual parameters may also be constructed in the usual way. But there are major problems when we want to test the underlying assumptions regarding the error process (that they are normally distributed white noise). These problems arise because we are not on either side of the market with complete certainty and so cannot directly observe any of the structural error processes.

The purpose of this paper is to describe tests of the distribution of the error process for a single market disequilibrium model with endogenous switching and to provide an illustration of this applied to the UK labour market. We will take the model of Hall, Henry, Markandya and Pemberton (HHMP) and re-estimate it on more up-to-date data. We will then use a range of tests to check the validity of the specification and illustrate the way in which these tests lead us to respecify the model. The tests we use are an extension to the procedures described by Quandt (1988). The specific model used by Quandt to obtain tests for serial correlation is the structural model of the form

$$D_t = \beta_1' X_{1t} + u_{1t}$$

$$S_t = \beta_2' X_{2t} + u_{2t} \qquad (1)$$

$$Q_t = Min\ (D_t, S_t)$$

where, in fairly obvious notation, D is demand, S supply, X_1 and X_2 distinct sets of weakly exogenous variables, and u_1 and u_2 are error processes. Then Q is the quantity exchanged on the market determined by a min condition. Dynamics enter the model by virtue of the assumption that the errors follow first-order Markov processes, ie,

$$u_{i_t} = \rho_i\, u_{i_{t-1}} + \varepsilon_{i_t}, \qquad i = 1, 2 \qquad (2)$$

where the ε_i are spherical normal errors. The tests proposed by Quandt for first-order serial correlation are based on the score vector $\delta \ln L / \delta$ vec R evaluated under the null hypotheses $H_0 : R = 0$, where L is the likelihood function of the observable Q's, and $u_t = R\, u_{t-1} + \varepsilon_t$ is (2) rewritten in vector form, where R is a square matrix (see (4) below). [This is described in more detail in Section 2. See Quandt (1988) Chapter 4 for a full account.]

The model which is evaluated here in contrast incorporates both systematic dynamics and a price adjustment equation. In general terms it may be expressed as

$$D_t = a_1\, P_t + b_1' X_{1t} + u_{1t}$$

$$S_t = a_2 P_t + b_2' X_{2t} + u_{2t} \tag{3}$$

$$P_t = a_3 (D - S)_t + P_{t-1} + b_3' X_{3t} + u_{3t}$$

$$Q_t = Min (D_t , S_t)$$

and the vector error process is again,

$$u_t = R u_{t-1} + \varepsilon_t \tag{4}$$

In this model, systematic dynamics enter both the demand and supply functions as lagged values of the quantity exchanged (Q), an element of the sets X_1 and X_2 respectively. In the application described in Section 3, this entails that lagged (actual) employment is a determinant of both the demand and supply plan. Such an assumption needs to be sharply distinguished from the case where demand and supply depend upon lagged *latent* endogenous variables, as eg when the demand and supply functions are

$$D_t = a_1 P_t + b_1' X_{1t} + \Phi_{11} D_{t-1} + \Phi_{12} S_{t-1} + u_{1t}$$

$$S_t = a_2 P_t + b_2' X_{2t} + \Phi_{21} D_{t-1} + \Phi_{22} S_{t-1} + u_{2t}$$

The probability density for this model has four different forms depending upon the signs of current and lagged ΔP. Moreover the likelihood function involves a T-fold multiple integral of the normal density and is intractable so that proper maximum likelihood estimates do not seem possible for this case (see Quandt (1988) p 135-40). In contrast, the model of the labour market we estimate in Section 3 introduces systematic dynamics based upon adjustment costs on both the demand and supply side. According to this assumption, firms and households experience costs in adjusting planned demand/supply from *actual* lagged employment levels. Hence the model uses lagged employment and not the lagged latent variable as a determinant of the current plan. It is worth noting that, given the intractability of the full likelihood function when lagged latent variables are used, Quandt has derived a quasi-likelihood approach which does not use lagged values of the latent variables making the estimates similar to those we derive below (Quandt (1981)).

The other important extension which the model given by (3) and (4) offers over (1) and (2) is that sample separation is provided by a stochastic price equation. Prices are thus treated as endogenous variables. In addition, we allow for additional weakly exogenous variables (such as incomes policies) to affect this adjustment equation [see Section 3 below for details].

The next section describes in more detail how the tests for serial correlation for the model given by (3) above are obtained. Then in Section 3 we re-estimate the model of HHMP first to show that the model seems fairly robust to a new data set and still appears to perform plausibly. We then subject it to the tests we derived in Section 2. These tests find that the model is misspecified. This finding leads us to respecify the model in a way which changes its implications in a significant way although the broad story told by the model remains much the same. Section 4 provides conclusions.

2 Testing for Serial Correlation

For model (1) above Quandt has derived LM tests for first-order serial correlation. This section describes a development to these tests which are applicable to the model given by equations (3) and (4) above. (See also

Gourieroux, Monfort and Trognon [1985]). It is this model which we will be reporting upon in the third section of the paper.

Following the discussion earlier, we will write the systematic part of the model as

$$
\begin{aligned}
D_t &= a_1 P_t + b_{1t} + u_{1t} \\
S_t &= a_2 P_t + b_{2t} + u_{2t} \\
P_t &= a_3 (D_t - S_t) + P_{t-1} + b_{3t} + u_{3t} \\
Q_t &= Min(D_t, S_t)
\end{aligned} \tag{5}
$$

Recall that lagged values of Q_t may appear in the set of weakly exogenous variables influencing demand and supply. These, and other weakly exogenous variables are included in the linear *functions* b_{1t}, b_{2t} and b_{3t}.

We assume that the vector of error terms

$$u_t = \left(u_{1t}, u_{2t}, u_{3t} \right)^T$$

satisfies equation (3) above, ie

$$u_t = R u_{t-1} + \varepsilon_t$$

where R is now a 3 x 3 nonsingular matrix whose eigenvalues are inside the unit circle and ε_t ($t \in N$) are independent identically distributed vectors of random variables each with distribution $N(0, \Omega)$.

The hypothesis of no serial correlation is H0: R = 0. Denote by

$$E_0(\,.\mid Q_t)$$

the conditional expectation under the null, and let

$$\tilde{u}_t = E_0(u_t \mid Q_t)$$

be the prediction of the disturbance vector u_t, evaluated under the null, where $\tilde{u}_t$ is its estimate under the null. The predicted residuals, $\tilde{u}_t$, are called *generalized residuals* by Gourieroux, Monfort and Trognon [1985].

The score test statistic of the hypothesis of no serial correlation H_0:R = 0 is given, in terms of the generalized residuals, by the expression

$$S = \left(\sum_{t=2}^{T} \hat{\tilde{u}}_t \; \hat{\tilde{u}}_{t-1} \right)' \left(\sum_{t=2}^{T} \left(\hat{\tilde{u}}_t \; \hat{\tilde{u}}_t' \right) \left(\hat{\tilde{u}}_{t-1} \; \hat{\tilde{u}}_{t-1}' \right) \right)^{-1} \left(\sum_{t=2}^{T} \hat{\tilde{u}}_t \; \hat{\tilde{u}}_{t-1}' \right) \tag{8}$$

This is distributed under the null as χ^2 (9).

Throughout our work in estimating the disequilibrium model, we have assumed, as part of our maintained hypothesis, that the variance-covariance matrix of the error terms is diagonal. In the present context of testing for serial correlation, this amounts to assuming that Ω is diagonal and that the off-diagonal elements of R are constrained to be zero.

As a first stage, consider the case where Ω is diagonal and all the elements of R are constrained to be zero except the jth diagonal elements (j = 1, 2, 3). The alternative hypothesis here is that the jth equation exhibits serial correlation.

The test statistic, S, reduces to
$$S_j = \frac{\left(\sum_{t=2}^{T} \hat{u}_{jt}\, \hat{u}_{j,t-1}\right)^2}{\sum_{t=2}^{T} \left(\hat{u}_{jt}\right)^2 \left(\hat{u}_{j,t-1}\right)^2} \qquad (9)$$

where $\tilde{u}_{jt}$ is the generalized residual corresponding to u_{jt}. The statistic S_j is distributed under the null as $\chi^2(1)$.

Now consider the more general case where Ω is diagonal and the off-diagonal elements of R are constrained to be zero, ie where the diagonality assumption on the variance-covariance matrix of the error terms is part of the maintained hypothesis. This time the test statistic, S, reduces to

$$S_{DIAG} = V' M^{-1} V \qquad (10)$$

where V is the 3 x 1 vector

$$\begin{pmatrix} \sum_{t=2}^{T} \hat{u}_{1t}\, \hat{u}_{1,t-1} \\ \sum_{t=2}^{T} \hat{u}_{2t}\, \hat{u}_{2,t-1} \\ \sum_{t=2}^{T} \hat{u}_{3t}\, \hat{u}_{3,t-1} \end{pmatrix}$$

and M is the 3 x 3 matrix

$$\begin{pmatrix} \sum_{t=2}^{T} \hat{u}_{1t}^2\, \hat{u}_{1,t-1}^2 & \sum_{t=2}^{T} \hat{u}_{1t}\, \hat{u}_{1,t-1} \hat{u}_{2t}\, \hat{u}_{2,t-1} & \sum_{t=2}^{T} \hat{u}_{1t}\, \hat{u}_{1,t-1} \hat{u}_{3t}\, \hat{u}_{3,t-1} \\ \sum_{t=2}^{T} \hat{u}_{1t}\, \hat{u}_{1,t-1} \hat{u}_{2t}\, \hat{u}_{2,t-1} & \sum_{t=2}^{T} \hat{u}_{2t}^2\, \hat{u}_{2,t-1}^2 & \sum_{t=2}^{T} \hat{u}_{2t}\, \hat{u}_{2,t-1} \hat{u}_{3t}\, \hat{u}_{3,t-1} \\ \sum_{t=2}^{T} \hat{u}_{1t}\, \hat{u}_{1,t-1} \hat{u}_{3t}\, \hat{u}_{3,t-1} & \sum_{t=2}^{T} \hat{u}_{2t}\, \hat{u}_{2,t-1} \hat{u}_{3t}\, \hat{u}_{3,t-1} & \sum_{t=2}^{T} \hat{u}_{3t}^2\, \hat{u}_{3,t-1}^2 \end{pmatrix}$$

The statistic S_{DIAG} is distributed under the null as $\chi^2(3)$.

The test statistic described above involves the generalized residuals $\tilde{u}_t$. We now indicate how to calculate these.

The approach we use is to compute the analytic form of the prediction of the disturbance vector under the null and then to replace the parameters by their constrained maximum likelihood estimates.

Using the notation for conditional expectations already described and denoting by

$$P_0[\,.\mid Q_t\,] \tag{11}$$

the conditional probability of an event under the null, we have

$$\begin{aligned}\hat{u}_{1t} &= E_0\ (u_{1t} \mid Q_t) \\ &= P_0\,[D_t > S_t \mid Q_t]\ E_0\ (u_{1t} \mid Q_t, D_t > S_t) + P_0\ [D_t \le S_t \mid Q_t]\ E_0\ (u_{1t} \mid Q_t, D_t, D_t \le S_t)\end{aligned} \tag{12}$$

Taking Ω to be

$$\begin{pmatrix}\sigma_1^2 & 0 & 0\\ 0 & \sigma_2^2 & 0\\ 0 & 0 & \sigma_3^2\end{pmatrix}$$

and denoting by $g\ (D_t, S_t, P_t\,)$ the density function under the null, the various terms in the above decomposition can be computed as follows:

$$P_0\ [D_t > S_t \mid Q_t] = \frac{\int_{Q_t}^{\infty} g\ (D_t, Q_t, P_t)\ dD_t}{\int_{Q_t}^{\infty} g\ (D_t, Q_t, P_t)\ dD_t + \int_{Q_t}^{\infty} g\ (Q_t, S_t, P_t)\ dS_t} \tag{13}$$

$$P_0\,[D_t \le S_t \mid Q_t] = \frac{\int_{Q_t}^{\infty} g\ (Q_t, S_t, P_t)\ dS_t}{\int_{Q_t}^{\infty} g\ (D_t, Q_t, P_t)\ dD_t + \int_{Q_t}^{\infty} g\ (Q_t, S_t, P_t)\ dS_t} \tag{14}$$

$$E_0\ (u_{1t} \mid Q_t, D_t > S_t) = \frac{\sigma_1\,\psi\left(\dfrac{Q_t - a_1 P_t - b_{1t}}{\sigma_1}\right)}{1 - \Phi\left(\dfrac{Q_t - a_1 P_t - b_{1t}}{\sigma_1}\right)} \tag{15}$$

$$E_0\ (u_{1t} \mid Q_t, D_t \le S_t) = Q_t - a_1 P_t - b_{1t} \tag{16}$$

where ψ denotes the standard normal density and Φ the cumulative function of the standard normal.

Similarly

$$\begin{aligned}\hat{u}_{2t} &= E_0\ (u_{2t} \mid Q_t) \\ &= P_0\ [D_t > S_t \mid Q_t]\ E_0\ (u_{2t} \mid Q_t, D_t > S_t) + P_0\ [D_t \le S_t \mid Q_t]\ E_0\ (u_{2t} \mid Q_t, D_t \le S_t)\end{aligned}$$

where the conditional probabilities are as given in (13) and (14) above and the conditional expectations are given by the following expressions:

$$E_0\,(u_{2t} \mid Q_t, D_t > S_t) = Q_t - a_2 P_t - b_{2t}$$

$$E_0(u_{2t} \mid Q_t, D_t \le S_t) = \frac{\sigma_2 \psi\left(\dfrac{Q_t - a_2 P_t - b_{2t}}{\sigma_2}\right)}{1 - \Phi\left(\dfrac{Q_t - a_2 P_t - b_{2t}}{\sigma_2}\right)}$$

The expression for $\tilde{u}_{3t}$ can be decomposed analogously:

$$\hat{u}_{3t} = E_0(u_{3t} \mid Q_t)$$
$$= P_0[D_t > S_t \mid Q_t]\, E_0(u_{3t} \mid Q_t, D_t > S_t) + P_0[D_t \le S_t \mid Q_t]\, E_0(u_{3t} \mid Q_t, D_t \le S_t)$$

The conditional probabilities are again as given in (13) and (14). The conditional expectations are given by the following expressions:

$$E_0(u_{3t} \mid Q_t, D_t > S_t) = P_t - P_{t-1} - a_3(D_t - Q_t) - b_{3t}$$

$$E_0(u_{3t} \mid Q_t, D_t \le S_t) = P_t - P_{t-1} - a_3(Q_t - S_t) - b_{3t}$$

where D_t and S_t may be replaced by their estimates given by the model (5).

Having derived the formulaes for the three sets of generalized residuals we can use these to construct the test statistics Sj and S_{DIAG} [equations (9) and (10)], we can also go on to construct a range of more conventional descriptive tests and statistics based on the generalized residuals. In the next section we will make use of the correlogram of the generalized residuals and the Ljung-Box test for examining the question of higher order serial correlation in the errors. We will also use the correlogram and Ljung-Box test of the squared residuals to examine the possibility of Auto Regressive Conditional Heteroskedasticity (ARCH) and we will use estimates of skewness and kurtosis in the residuals to construct the Berra-Jarque test for normality of the residuals.

The next section applies this method of computing generalized residuals, and uses these and other tests for serial correlation in testing for the appropriate dynamic structure for a model of the UK labour market.

3 An Empirical Application

The model we use here has been described in detail elsewhere, so only its salient features are given here. For further detail, the reader is referred to Hall, Henry, Markandya and Pemberton (1989). Briefly then, the model is (variables in logs unless otherwise stated).

$$E_t^D = A_0 + A_1 (W/P)_t' + A_2 Q_t^e + A_3 T + A_4 E_{t-1} + A_5 E_{t-2} \quad (17)$$

$$E_t^S = B_0 + B_1 (W/P)_t + B_2 BN_t + B_3 PoP_t + B_4 UP_t + B_5 E_{t-1} \quad (18)$$

$$E_t = Min\ (E^D, E^S) \quad (19)$$

$$(W/P)' = D_0 (W/P) \quad (20)$$

$$\Delta_4 (W/P) = C_0 + C_1 (E^D - E^S) + C_2 \Delta_4 UP_t + C_3 + \Delta_4 NTAX_t + C_4 IP_t + C_5 \Delta_4 (W/P)_{t-1} \quad (21)$$

In the demand equation $(W/P)^1$ is the demand price for labour, given by gross earnings per employee deflated by producer prices. The variable Q^e is expected output, and this will be described more fully below. The variable T is a time trend to represent exogenous technical progress. The supply equation (18) includes the supply price of labour (the net level of earnings per worker deflated by the consumer price deflator, the level of real unemployment benefit *(BW)*, the working population *(PoP)*, and a measure of union strength *(UP)*. The fourth equation in the model is a technical equation between the two real wages (demand and supply real wages) so the model can be expressed in terms of two variables, W/P and E. In the final equation for the adjustment of the real wage, the remaining undefined variables are employers tax as a proportion of employees income *(NTAX)* and an incomes policy variable *(IP)* (see Whitley (1983)).

Although the purpose of this paper is not to emphasize the behavioural properties of the above model, it should at least be mentioned that it is taken to cover the essential ingredients of a range of models which have been advanced recently in the UK. These include both New Classical (see, eg Minford (1983)) and imperfectly competitive (see eg Nickell (1988)). The other feature which needs to be detailed is the expected output variable Q^e. In the present application this is a quantified series based on the responses to the CBI survey on output expectations.[(1)] In addition, the variable is entered as a restricted, forward, convolution the weights of which depend upon the estimated parameters on the lagged levels of employment in the demand equation. This formulation is a direct implication of the model of labour demand based on an optimal plan by the typical firm in the presence of adjustment costs on labour. [See Hall, Henry and Wren-Lewis (1986) and Hall and Henry (1988).]

The original HHMP model imposed B_5 and C_5 to be zero and was estimated over the period 1964 Q4 to 1982 Q4. The present work estimates the model over the period 1966 Q4 to 1988 Q1 thus representing a considerable extension of the data period (the start date is a little later because of the use of the Wren-Lewis output expectations series which is not available over the earlier period). Given that the data has been revised, as some of the definitions have been changed slightly (the output series) and the data period has been extended, nonetheless the re-estimation of the model shown in column 1 of Table 1 is very satisfactory. No parameters change sign, the numerical estimates of the parameters are very similar to the original HHMP model and the sample split between supply and demand (shown in Figure 1) tells a very similar story with the supply curve failing completely to capture the collapse in employment after 1979. So judging the model by the original criteria used the model still performs well and seems to have stood up to re-estimation reasonably convincingly.

However, in the top half of Table 2 we present some of the residual diagnostics outlined in section 2, and these show that the supply function and the real wage adjustment equation for model 1 have severe problems. The null hypothesis of zero first order residual autocorrelation is not rejected according to the S_j test in the case of the demand and supply curve although it is rejected in the case of the wage equation. The system test for first order serial correlation S_{DIAG} also finds significant serial correlation in the model as a whole. When we examine the correlogram and Ljung-Box statistics for higher order serial correlation we also find serious evidence of higher order serial correlation in the wage equation and the supply curve. The correlogram of the squared residuals suggests that there are signs of a higher order ARCH and all three equations fail the test of normality.

In the re-specified model shown in column 2 of Table 1, the main additions are terms in lagged employment in the labour supply equation and lagged wage inflation in the wage equation. The addition of these terms lead to both the unionization and benefits effects having the wrong sign and being highly insignificant so these terms were dropped from the supply equation. Given the interest in real wage effects, this variable is retained in the demand equation, although it proves to be insignificant in both versions of the model. The major change in model 2 is a dynamic respecification of the labour supply function and the real wage adjustment equation. This apparently improves the performance of the equation considerably, and the LB statistics are now acceptable. The real wage adjustment

(1) We are grateful to Simon Wren-Lewis of NIESR for providing us with these data

equation does not fare quite so well. Introducing the lagged value of the dependent variable, lowers the value of the *S* test noticeably. It is now not rejecting the null hypothesis. The LB(4) test, however, though very much lower than in the previous model, still shows evidence of residual autocorrelation, so overall the evidence is mixed. All equations still have evidence of non-normal errors, though the LB statistic computed on the residuals squared is reassuring on the absence of heteroskedasticity.

The test for normality is in fact almost bound to be failed if there are any observations in the sample which are assigned exclusively to one or other of the curves, as in this case the generalized residuals for the other curve will be set to zero. Having a sample where some observations have a zero standard error and other observations have a non-zero standard error is likely to show up as non-normality. It may therefore be more appropriate to test for normality using only the non-zero residuals and if this is done the normality tests for the supply curve take on a much more reasonable magnitude.

Figures 3 and 4 show the pattern of supply and demand for model 2 and the estimated generalized residuals. Figure 3 shows that the behaviour of the supply function is much improved in Model 2 over that shown in Figure 1 for model 1. The period post 1974 is one of demand constraint according to these results, a feature which extends into the 1980s. Finally Chart 4 shows a fairly random pattern of residuals for both the demand and supply functions in this model.

4 Conclusions

This paper has derived tests for serial correlation for the disequilibrium model with endogenous stochastic price formation and sample separation. The tests have been illustrated by an application to the UK labour market, and the test results used to respecify the dynamics of the model.

Table 1: Estimates of the Labour Market Model

Model	(1)			(2)		
Demand equation						
A_1	-0.35	(10^{-3})	(0.05)	-0.75	(10^{-3})	(0.1)
A_2	0.022	(7.4)		0.024	(8.8)	
A_3	-0.4	(10^{-4})	(0.7)	-0.4	(10^{-4})	(1.0)
A_4	1.606	(514.8)		1.615	(7905.8)	
A_5	-0.657	(40.2)		-0.667	(353.1)	
Supply equation						
B_1	0.064	(0.8)		0.030	(2.2)	
B_2	-0.098	(2.5)		—		
B_3	0.668	(55.8)		0.023	(4.5)	
B_4	-0.029	(1.0)		—		
B_5	—			0.973	(402.5)	
Real wage adjustment						
C_1	0.19	(10^{-3})	(0.004)	0.16	(10^{-3})	(0.001)
C_2	—			—		
C_3	-1.147	(6.9)		-0.883	(5.7)	
C_4	0.008	(6.2)		0.005	(3.8)	
C_5	—			0.433	(5.6)	

Table 2: Error Analysis

	S Test(a)	Normal	LB(4)	LB(8)	LB2(1)	LB2(8)
Model 1						
Demand	1.07	17.748	3.00	14.63	1.1	14.6
Supply	0.02	1796.5	13.34	36.47	22.3	57.7
Real wage adjustment	22.47	7.033	47.63	57.7	0.5	6.5
System (DIAG)(b)	22.54					
Model 2						
Demand	1.69	32.266	5.76	8.41	2.3	5.1
Supply	0.26	1330.289	5.72	16.8	0.8	3.6
Real wage adjustment	2.71	56.867	1.72	6.39	—	6.3
System(DIAG)(b)	3.711					

(a) Distributed as χ^2 (1).

(b) Distributed as χ^2 (3), normal is the Berra-Jarque test for normality distributed as χ^2 (2), *LB(n)* is the Ljung-Box test for a random correlogram up to order *n*, distributed as χ^2 (*n*), $LB_2(n)$ is the Ljung-Box test performed on the squared residuals.

Figure 1
Demand and supply; the HHMP model

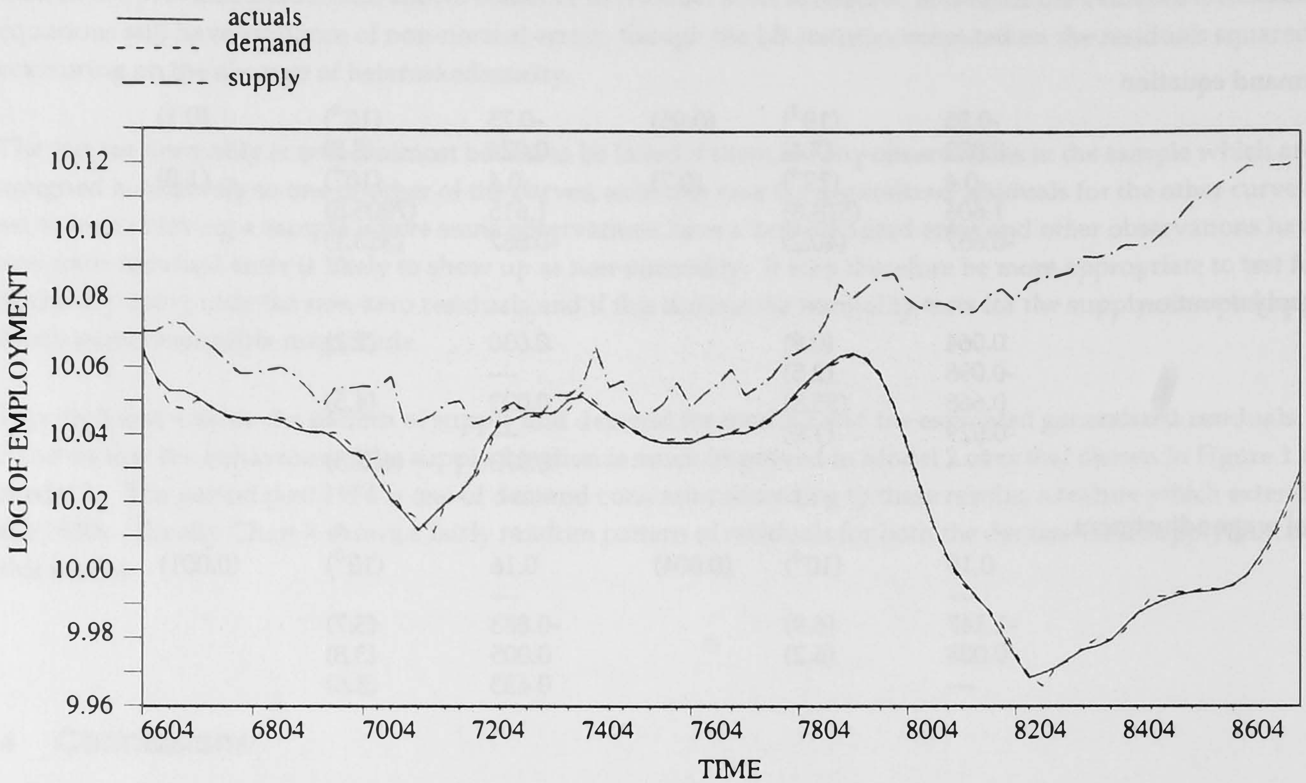


Figure 2
Residuals; the HHMP model

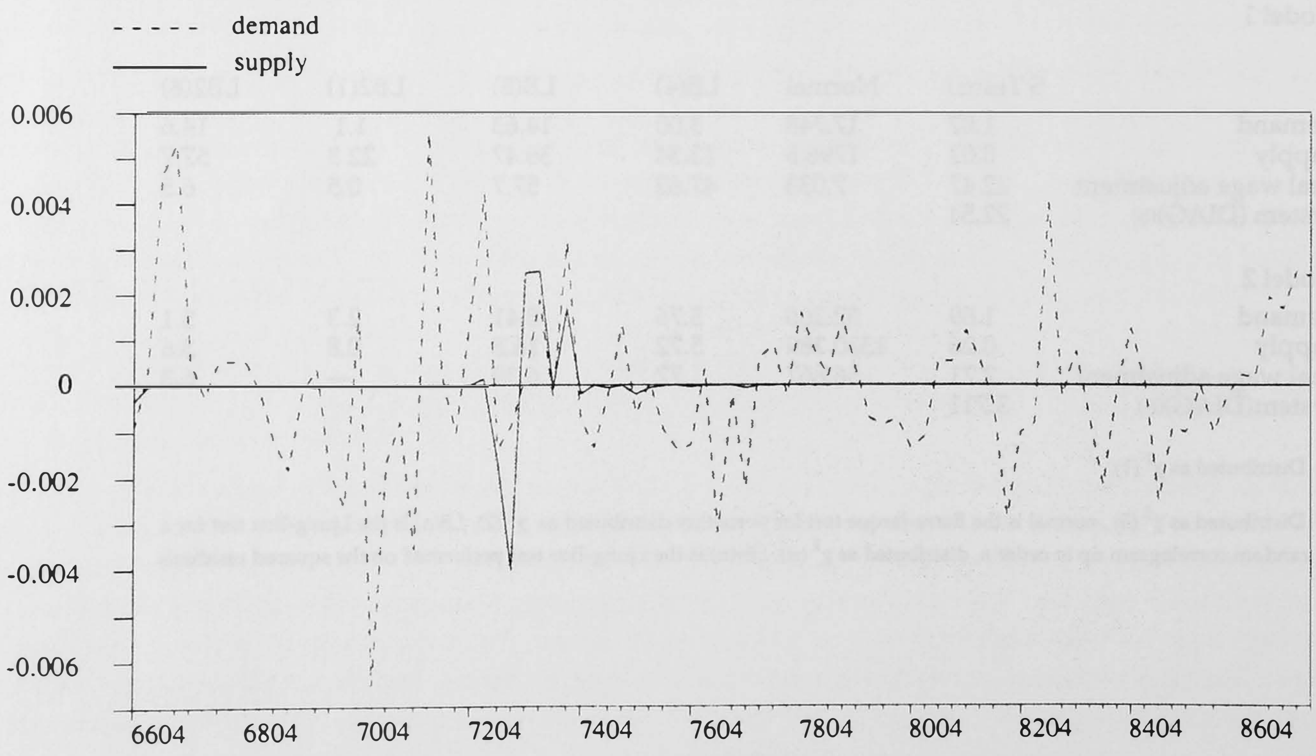


Figure 3
Demand and supply; the preferred model

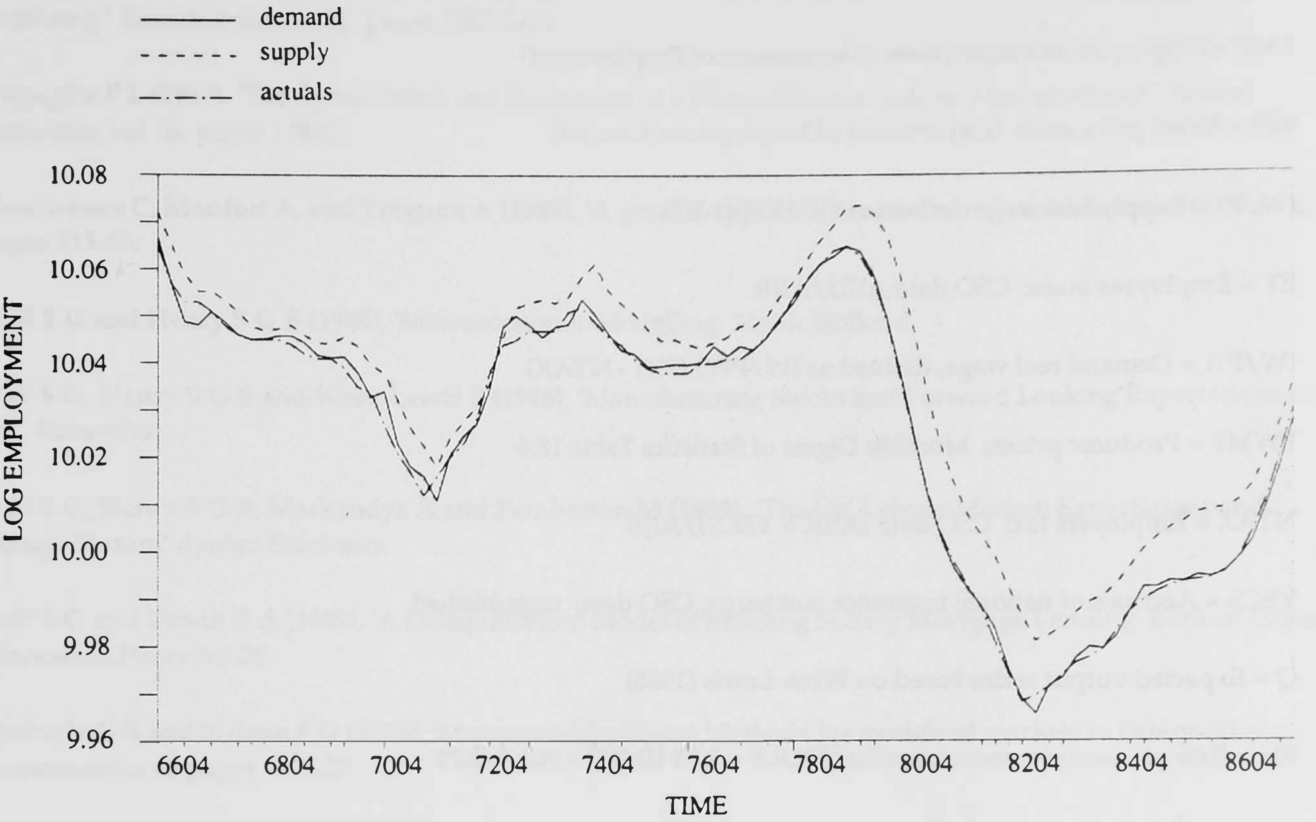
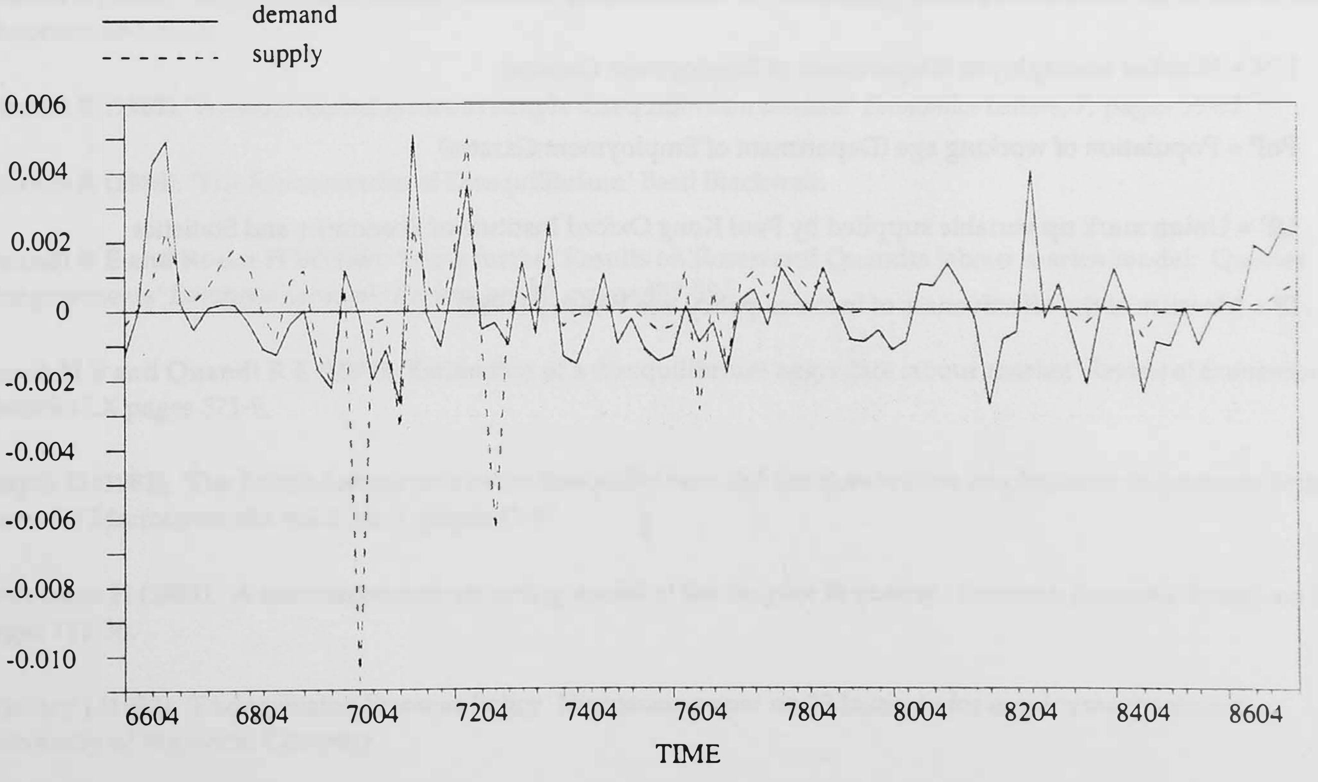


Figure 4
Residuals; the preferred model



Data Appendix

W = Average earnings (CSO Data: AIJB/EMP)

EMP = Employees in employment (Department of Employment)

RPI = Retail price index (Department of Employment Gazette)

(W/P) = Supply real wage defined as (W/RPI)(1-ET)

ET = Employees taxes: CSO data AIIU/AIJB

(W/P)1 = Demand real wage, defined as (W/PWMF)(1 - NTAX)

PWMF = Producer prices; Monthly Digest of Statistics Table 18.6

NTAX = Employers tax: CSO data (AIIR + YECS)/AIJB

YECS = Accruals of national insurance surcharge, CSO data; unpublished

Q = Expected output series based on Wren-Lewis (1986)

BN = Rate of unemployment benefits [(DOLE + 0.73 UNSP)))/UN]/RPI

DOLE = Payments of unemployment benefits to unemployed; source HM Treasury

UNSP = Payments of supplementary benefit to the unemployed; source HM Treasury

UN = Number unemployed (Department of Employment Gazette)

PoP = Population of working age (Department of Employment Gazette)

UP = Union mark up variable supplied by Paul Kong Oxford Institute of Economics and Statistics

IP = Measure of the effectiveness of incomes policy, see Whitley (1983)

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