An Empirical Study of Interest Rate Determination Rules

Keshab Bhattarai
Lecturer in Economics, Business School
University of Hull
K.R.Bhattarai@hull.ac.uk.

Abstract

This paper finds empirical support for Taylor (1993) type interest rate determination rule. The model is solved analytically, estimated and used for simulation, impulse response analyses and forecasting with quarterly time series data for the UK and annual time series data for Germany, France, Japan, UK and the US. Results support that such rules implicitly exists during the period of analysis.

Key words: Inflation gap, output gap, interest rate

JEL Classification: E37 and E43

May 2005
Revision July 2006

I. Introduction

Changes in the interest rates have profound impacts on saving and consumption behaviours of households, on investment and capital accumulation decisions of firms, and on portfolio allocation of domestic and foreign traders in the financial and exchange rate markets. It is generally agreed that these changes affect the aggregate demand and aggregate supply positions in an economy that may occur immediately or over a lag of up to two years ((Keynes (1936), Hicks (1937), Phillips (1958), Friedman (1968), Phelps (1968), Tobin (1969), Kydland and Prescott (1977), Laidler and Parkin (1975), Taylor (1987), Nickell (1990), Taylor (1993)). They also influence the expectations and plans of economic agents about their own future and their perceptions about welfare and redistribution of income and about the prospects of the economy. As public fears that the policy makers may react unpredictably even violating promises they might have made for dynamic time consistency and credibility of policy the process of determination of interest requires transparency and co-ordination at national and international levels. UK, Europe and the majority of industrial economies have tried to solve these time inconsistency and credibility problems by making their central banks independent from the whims of the policy makers and initiated a rule based monetary policies aimed to achieve a pre-set inflation target. The short term interest rates have become key instruments to be determined by economic realities rather than by the discretion of the policy makers. When the interest rate policy is based on rules like this it is possible to trace out the potential effects of interest rates on market rates on various types of financial transactions and subsequent impacts on asset prices, expectations of households and firms and the exchange rates and ultimately through these prices into the aggregate demand, inflation and the rate of unemployment systematically with minimum errors.

How could macroeconomic stability and higher growth rate of output be achieved under such policy rules is explained sufficiently in non-technical terms in MPC (1999) and Bernanke and Mishkin (1997). Taylor (1993) uses a small scale model which shows how the interest rate can be systematically determined looking at the output gaps and inflation gaps to insure internal and external stability and to reduce the degree of fluctuations in aggregate economic activities. Woodford (2001) has shown how even a small Taylor type model can be consistent to detailed optimisation in more elaborate general equilibrium models though more detailed analyses of consequences of the interest rates by a central bank is often analysed using more comprehensive econometric and general equilibrium models, as discussed in Altig, Carlstrom and Lansing (1995) or in Holly and Weale (2000) or in HM Treasury (2002).

Given the strengths of a small scale model in explaining changes in the interest rate and its contribution in reducing the fluctuations in an economy, this paper aims to investigate how Taylor (1993) model fits to the interest rate series of the UK and five major industrial economies over last three decades. It complements to applied economic studies on this topics that have appeared in recent years; particularly those relating to the interdependency of real interest rates among G7 economies (Cheung and Westerman (2002), Ghazali and Ramlee (2003)) or to G3 economies (Yamada (2002)) or to Fisher hypothesis (Berument and Jelashi (2002), Silvapulle and Hewarathna (2002)). Model discussed in this paper neither directly derives the interest rate rules using optimising models with non-negativity constraints on the interest rate as found in Sugo and Teranishi (2005) nor uses predominance of the majority vote rule over the consensus in setting policy as discussed in Gerlack-Kristen (2005). The empirical results emerging from single equation or simultaneous equations or panel data or VAR-cointegration models generate results that are comparable to findings seen in studies by Asimakopoulos, Goddard and Siriopoulos (2000), Brooks and Skinner(2000), Castelnouvo (2003), Camarero, Ordonez and Tamarit (2002), Bacchetta and Ballabriga (2000) Lee (2002), Butter and Jenson (2004), Ferris and Galbraith(2003), Valente (2003), Ghazali and Ramlee (2003),Wetherilt (2003), Buch (2004),Staikouras(2004), Mills and Wood (2002). Some details on issues, methods and major findings of these various studies are given in the appendix. Study reported here also focuses on the long run relationship of the determinants of interest rate and its impacts on output and prices based on cointegration analyses for long run relationship between the interest rate and time series of output gap and inflation gaps in the UK and G7 economies. A simultaneous equation model is used to investigate the interdependency among these variables and a VAR impulse response model is used for analysing the impacts of unit shocks in output, inflation and the interest rate and for forecasting future values of these variables using information contained in their time series. Determinants of the interest rate in this paper are based analytically on the solutions of a second order difference equation for interest determination rule similar to that of Taylor (1993) in section II. A brief discussion of data set used for study is in section III. Empirical relevance of this model is tested with quarterly macro economic time series data for the UK and annual data for five major industrial economies during last three decades in section IV and conclusions and references are in section V.

II. A simple Interest Rate Determination Model

A simple interest rate determination model, originally proposed by Taylor (1993) for the Federal Reserves in the US, can be constructed using three equations.

First equation states the current output gap $(y_t - y^*)$, the actual output relative to the trend output, as a function of the deviation of the interest rate one period earlier from the target interest rate of the monetary authority $(i_{t-1} - i^*)$. This relationship is expected to be negative one as the higher interest rate is expected to slow down expenses by consumers and firms and generate contractionary impacts in the economy such as:

$$y_t - y_t{}^* = -d\left(i_{t-1} - i_{t-1}^*\right) \qquad d > 0 \qquad (1)$$

where y_t and y_t^* are actual and natural level of output, i_t is the actual rate of interest in period *t*, i_t^* is the target or the natural rate of interest for the monetary authority. This is similar to the equation for the investment-saving equilibrium relation (*IS* curve) in Woodford (2001), particularly when trends and targets are treated as expectations. More than one period lag can be assumed between the periods of the decisions of the interest rate and the changes in the output, though it was found not necessary for the current study.

The next equation shows how the price level in this economy responds to the level of economic activities, the aggregate supply. The expectation augmented Phillips curve in terms of output is given by:

$$\pi_t = \pi_t^* + c\left(y_{t-1} - y_{t-1}^*\right) \qquad c > 0 \qquad (2)$$

where π_t and π_t^* are actual and target rates of inflation. When the output is above the trend in the last period, it creates an upward pressure in the labour market which raises the wage rate. Increase in the wage rate translates into higher prices and higher rates of inflation. Again this is similar to equation (3) in Woodford (2001) when target inflation rate is treated as expected rate of inflation. A simple interest rate rule is derived by combining (1) and (2) to show how the policy makers like to reduce interest rate when both output and inflation rates are higher relative to their natural rates as:

$$i_t = i_t^* + a\left(y_t - y_t^*\right) + b\left(\pi_t - \pi_t^*\right) \qquad a > 0\,; b > 0 \qquad (3)$$

If the output gap from (1) and inflation rate gap from (2) are substituted in the interest rate rule in (3) it generates autoregressive reduced form single equation of interest that can explain the cycles of interest rate in terms of reduced form parameters as :.

$$i_t = i_t^* - ad\left(i_{t-1} - i_{t-1}^*\right) - bcd\left(i_{t-2} - i_{t-2}^*\right)$$

$$i_t + adi_{t-1} + bcdi_{t-2} = i_t^* + adi_{t-1}^* + bcdi_{t-2}^* \qquad (4)$$

The stability or convergence properties of the second order difference equation (4) essentially depends upon values of the parameters *a b*, *c* and *d* and two initial conditions for i_0 and i_1. For simplicity define $\beta_0 = \left(i_t^* + adi_{t-1}^* + bcdi_{t-2}^*\right)$, and $\beta_1 = ad$ and $\beta_2 = bcd$. Then equation (4) can be written as:

$$i_t + \beta_1 i_{t-1} + \beta_2 i_{t-2} = \beta_0 \qquad (5)$$

The general solution to the reduced form difference equation (5) has complementary and particular parts. The particular solution refers to the steady state and the complementary solution shows a dynamic adjustment towards that steady state when the interest rate is above or below its natural rate. It explains the dynamics of the interest rate series. The convergence or divergence from the steady state or the natural rate of interest rate depend on this part of the equation.

The particular or steady state solution is easy, as interest rate in each period equals the steady state interest rate which can be also considered a natural rate of interest, i.e. $i_t = i_{t+1} = i_{t+2} = \ldots = i_{t+n}$. Thus with some manipulation the steady state or the natural rate of interest rate for the above model can be expressed as:

$\bar{i} = \dfrac{i_t^* + adi_{t-1}^* + bcdi_{t-2}^*}{1+\beta_1+\beta_2}$ or $\bar{i} = \dfrac{i_t^* + adi_{t-1}^* + bcdi_{t-2}^*}{1+ad+bcd}$ in terms of the original model parameters with flexible targets i_{t-2}^* i_{t-1}^* and i_t^* and as $\bar{i} = \dfrac{i_t^*(1+ad+bcd)}{1+ad+bcd}$ with fixed targets i_t^*. (6)

Any short run disturbances from this natural rate should ultimately return to it due to forces of demand and supply in the financial markets and is represented by a homogeneous part of the solution.

$$i_t + \beta_1 i_{t-1} + \beta_2 i_{t-2} = 0 \qquad (7)$$

Theoretically the complementary solutions of (7) can have three different cases depending on the values of parameters β_0, and β_1 and β_2:

(a) real and distinct root, when $\beta_1^2 - 4\beta_2 > 0$, guarantees convergence to the steady state.

(b) real and equal roots case, $\beta_1^2 - 4\beta_2 = 0$, generates repeated cycles and

(c) complex roots case with $\beta_1^2 - 4\beta_2 < 0$ gives a cyclical pattern which may converge or diverge from the steady state rate depending the absolute values of parameters.

The general solutions of the model in these three different cases are:

$$i_t = A_1\lambda_1^t + A_2\lambda_2^t + \bar{i} \qquad (8)$$

where A_1 and A_2 are arbitrary constants and λ_1^t and λ_2^t are the characteristic roots.

In case (a) the value of $\lambda_1^t = \dfrac{-\beta_1 + \sqrt{\beta_1^2 - 4\beta_2}}{2}$ and $\lambda_2^t = \dfrac{-\beta_1 - \sqrt{\beta_1^2 - 4\beta_2}}{2}$.

Therefore the general solution (8) can be written as:

$$i_t = A_1\left(\frac{-\beta_1 + \sqrt{\beta_1^2 - 4\beta_2}}{2}\right)^t + A_2\left(\frac{-\beta_1 - \sqrt{\beta_1^2 - 4\beta_2}}{2}\right)^t + \bar{i} \qquad (9)$$

More specifically using all the parameters of the model this turns to be

$$i_t = A_1\left(\frac{-ad + \sqrt{(ad)^2 - 4bcd}}{2}\right)^t + A_2\left(\frac{ad - \sqrt{(ad)^2 - 4bcd}}{2}\right)^t + \bar{i} \tag{10}$$

The definite solution requires values of constant terms A_1 and A_2, which can be obtained using the two initial conditions, i_0 and i_1. Values of *a*, *b*, *c* and *d* parameters can be obtained from an econometric estimation. Literature suggests that interest rate, determined objectively in this manner, can be used to achieve price stability and real growth in the economy (Fisher (1977), Hanson (1980), Barro and Gordon (1983), Sargent (1986), Mankiw (1987), Driffil (1988), Goodhart (1989) Ball and Romer (1990), Alesina and Summers (1993), Nordhaus (1995), Dornbush and Fisher (1993), Lockwood, Miller and Zhang (1998), Vickers (1999), Nelson (2000), Corsetti and Pesenti (2001), Benigno(2002)).

III. Data Set

Interest rates have changed significantly over the years as shown in Figures 1a-1c. In general they were low and helped to generate unprecedented rate of economic growth in major industrial economies till late 1960s; increased and varied significantly and unpredictably in 1970s and 1980s characterising economic problems and have started changing systematically in a predictable manner as many western economies adopted rule based policy of determining these rates after mid 1990. Interest rates have become major tool for stabilising prices and the markets activities more in recent years.

Figure 1a

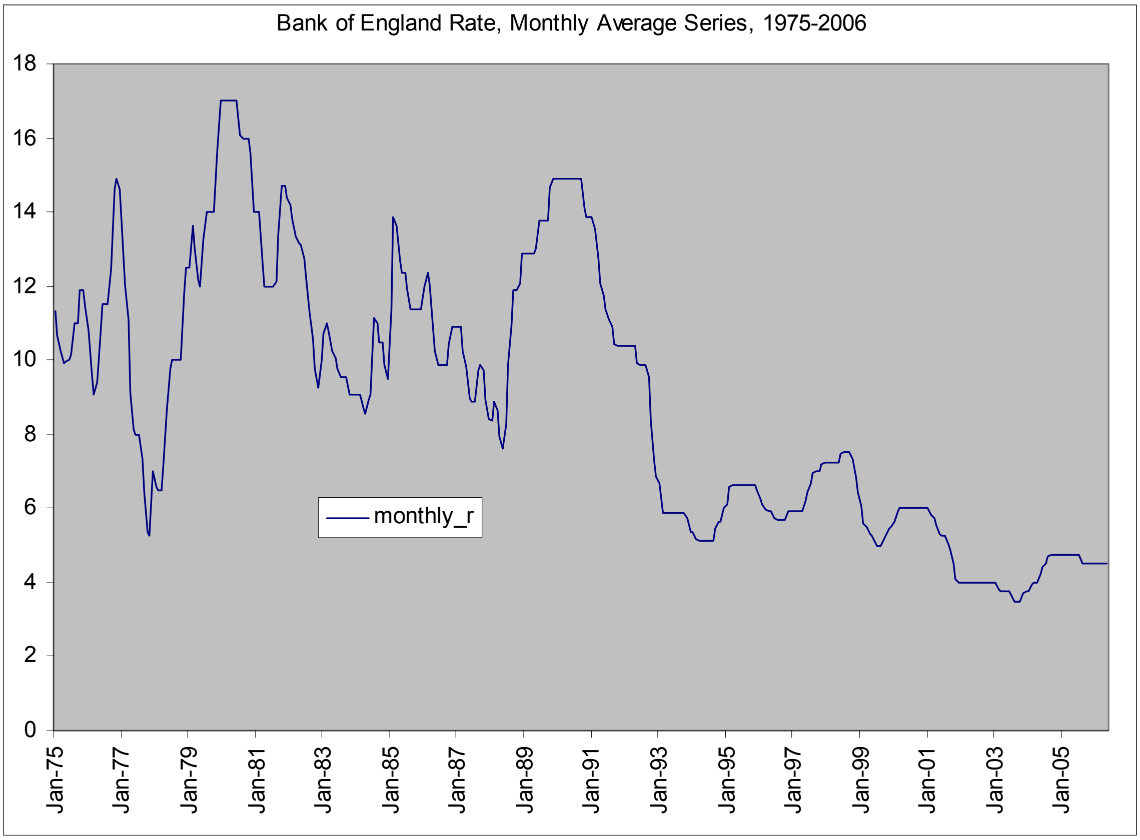


Figure 1b

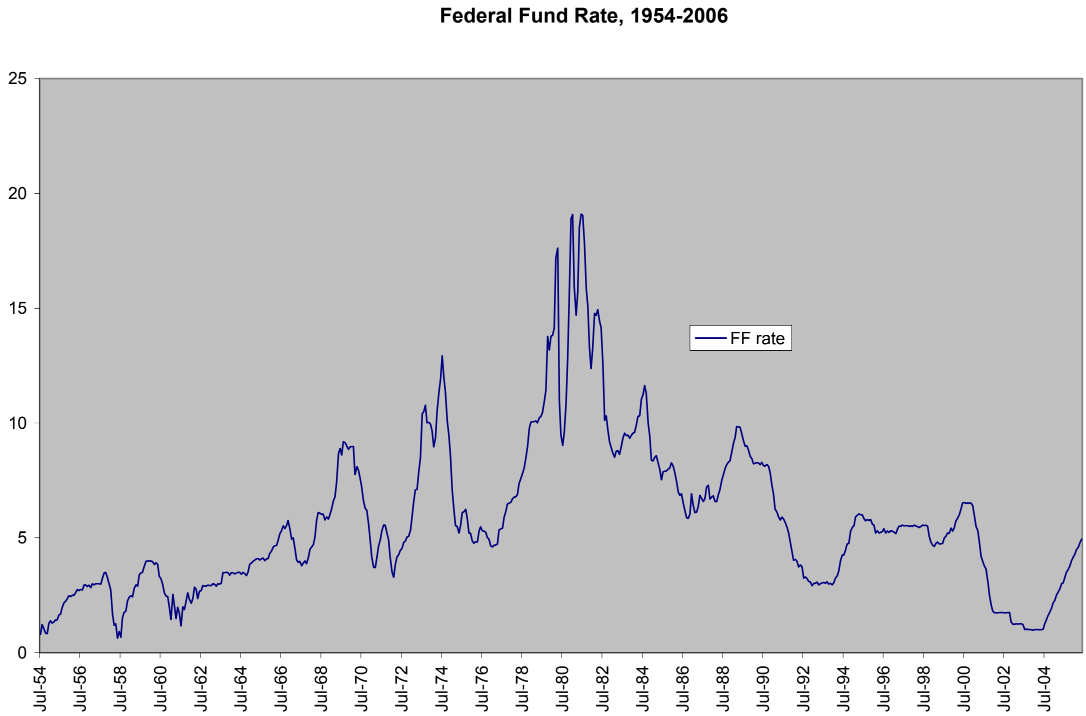
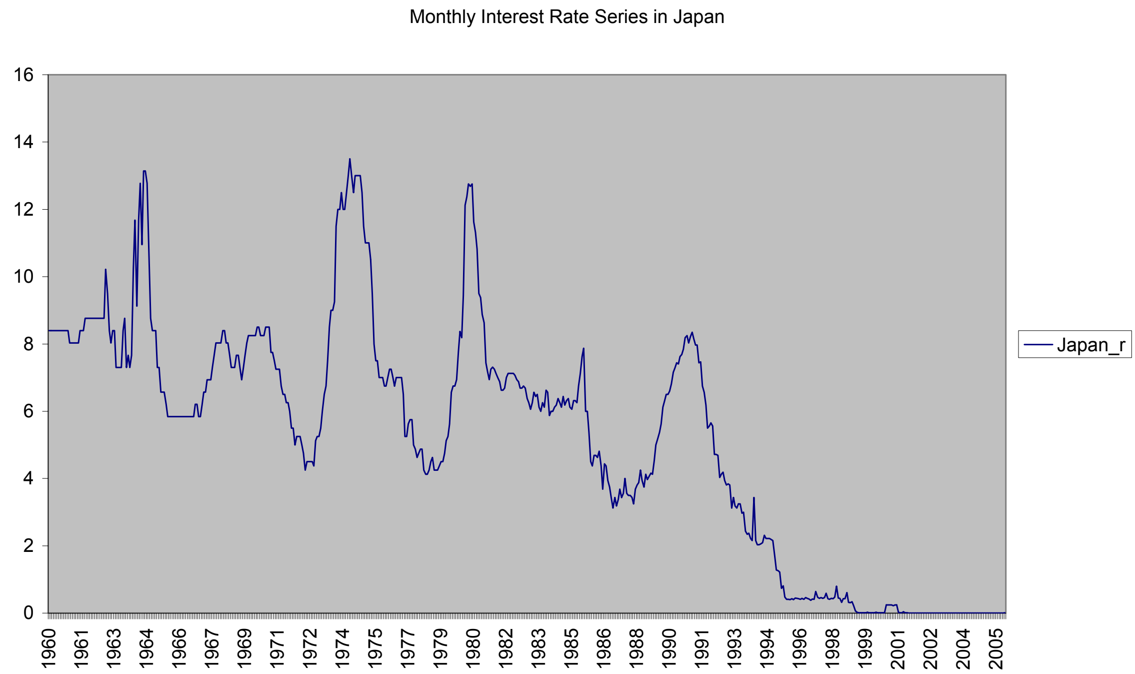


Figure 1c



Quarterly fluctuations in the series for the retail price index, growth rate of the real GDP and the Treasury bill rates, which represent the whole varieties of interest rate, from 1970:q2 to 1999:q4 are as presented in Figure 2. These series were obtained from the macro time series data archive in Essex (http://www.data-archive.ac.uk).

The fluctuations in the rate of interest, inflation and the growth of output were more serious in 1980s than in 1990. The UK economy has been stabilised and moving more towards its natural rate after 1995 particularly after the adoption of inflation targeting rule in 1997 (see Nelson (2000) for more division between sub periods). Similar pattern can be obtained from analysis of the annual data on growth rates output, rates of inflation and interest for Germany, France, Japan, and USA from 1978 to 2000 as shown in Figure 3. Quarterly time series shown in Figures 2 and annual series in Figure 3 are used for estimation of the interest rule model explained in the previous sections.

Figure 2
Growth rates of output, interest rate and inflation in the UK

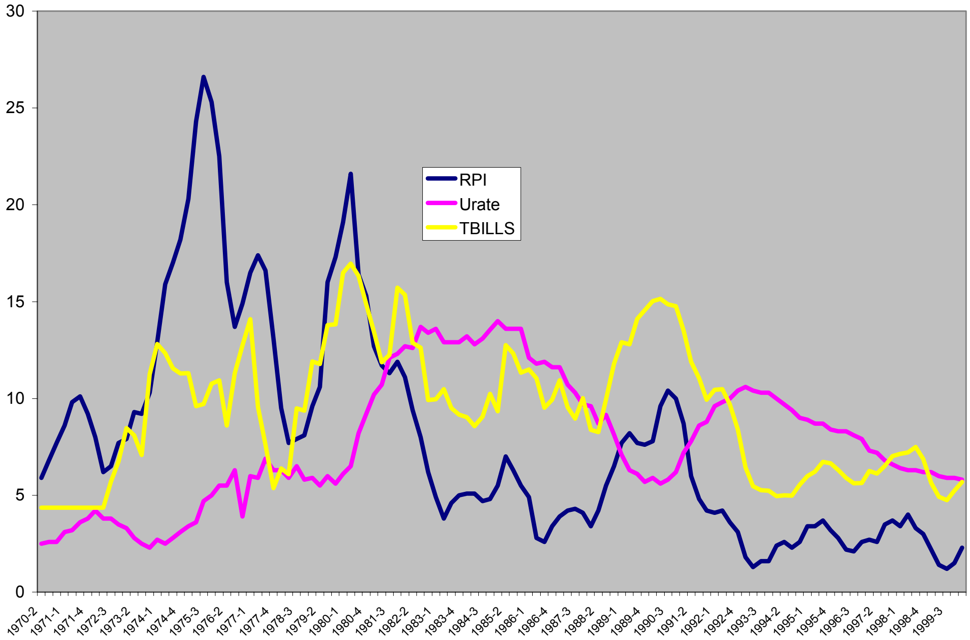
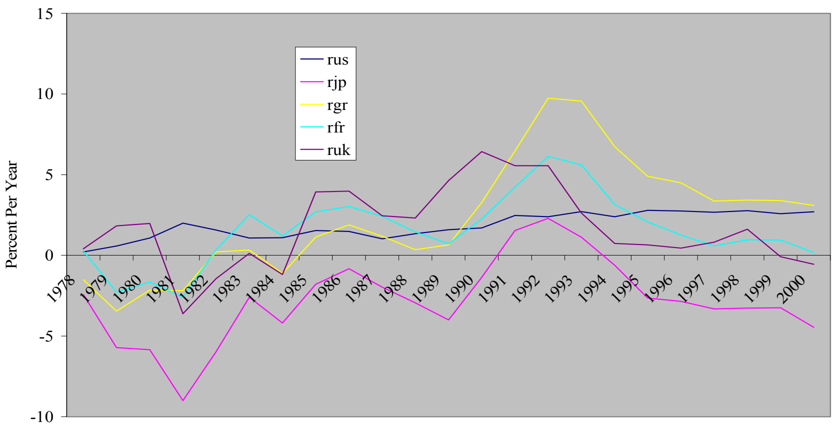


Figure 3

Real Interest Rates in Major Industrial Economies



IV. Analysis of Results

Many factors other than the output gap and inflation gap influence the rate of interest in an economy. The econometric models incorporate these missing elements in the model given by equations (1)-(3) including error terms to each equation to represent the influence of these unknown factors. Some of these omitted factors have positive effect and others have negative effects. In aggregate the influences of omitted variables or specification bias elements tend to cancel out each other making their mean to be zero. Further they are assumed to have constant variance to express no systematic relation among the errors. Technically speaking these errors are distributed normally, identically and independently. These assumptions imply that those errors are homoscedastic and have no autocorrelation and there is no multi-collinearity among the explanatory variables.

$$y_t - y_t^* = d\left(i_{t-1} - i_{t-1}^*\right) + \varepsilon_{1,t} \tag{11}$$

$$\pi_t = \pi_t^* + c\left(y_{t-1} - y_{t-1}^*\right) + \varepsilon_{2,t} \tag{12}$$

$$i_t = i_t^* + a\left(y_t - y_t^*\right) + b\left(\pi_t - \pi_t^*\right) + \varepsilon_{3,t} \tag{13}$$

Even if relations may be perfect there is still chance of regressions being spurious as the relation may be between nonstationary variables. We follow Dickey-Fuller (1976) Engle and Granger (1987) and Johansen and Juselius (1990) procedures to determine existence or absence of unit roots of a variable or cointegration among variable sin the model.

Unit root test suggests that the interest rate variable is integrated of order one, *I(1)*, and becomes stationary after differencing once. Both output gap and inflation gaps are stationary. The critical and estimated values of coefficients of the unit root for equation of these three variables (from the PC-Give outputs) are as shown in Table 1, along with significant lag lengths.

Table 1
Stationarity of variables in the model
ADF tests (T=116, Constant; 5%=-2.89 1%=-3.49)

	Interest rate	1st Difference of the interest rate	Output gap	Inflation gap
Coefficient	-2.723	-6.463**	-6.160**	-7.428**
Lags	2	2	3	1

Next it is shown how the Engle and Granger (1987) or Johansen (1988) procedure can be used to obtain a non-spurious regression between the interest rate and output and inflation gaps even if the interest rate series is non-stationary.

The basic relation between the interest rate and inflation gap and output gap for the UK is as given below.

$$i_t = 9.446 - 0.183\left(y_t - y_t^*\right) + 0.370\left(\pi_t - \pi_t^*\right)$$

t (32.2) (-1.1) (2.84)

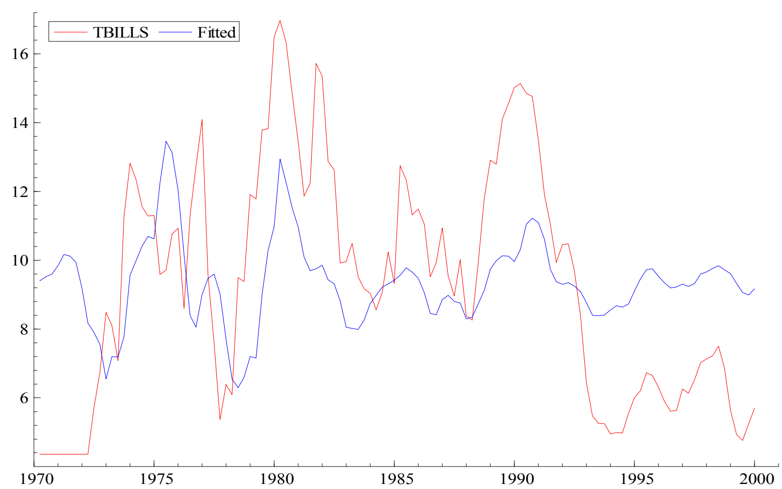
(SE) (0.29) (0.13) (0.181)

Normality test: Chi^2(2) = 11.279 [0.0036]**

Interest rate rises with an increase in inflation and the coefficient is significant. The coefficient in the output gap does not have expected positive sign and it is also statistically insignificant. Above result also suggests that interest rate is more responsive to the inflation rate than to the output gap since the coefficient on output is not significant. These test results are comparable to that of Berument and Jelashi (2002), Silvapulle and Hewarathna (2002).

Figure 3:

Interest Rate Determination Model: Actual and Predicted Series



In addition the normality test in line with the Engel and Granger (EG) method of cointegration test suggests that residuals from the above regression of the interest rate on output gap and inflation gap are non-stationary and hence this is a spurious regression.

What about estimating the interest rule in terms of the reduced autoregressive second order difference equation equivalent to that given in equation (5)? This gives reasonable results as:

$$i_t = 1.630 + 0.582 i_{t-1} + 0.244 i_{t-2}$$

t-ratios (2.71) (6.42) (6.69)

r-square = 0.62 Durbin-Watson = 2.0104

All coefficients of the reduced form equation of interest for the UK have expected signs. It is however, difficult to retrieve the structural parameters of the original model from the estimates of the reduced form equation.

Alternative is to use a recursive estimation method where the output gap is estimated as a function of the lagged interest rate and then the inflation gap estimated on the lagged output gap and finally the interest rate rule equation estimated with the predicted values of the output gap and inflation gaps. The output gap is influenced by the interest rate, and the inflation gap is determined by the output gap and then that is determined by the interest rate. The recursive simultaneous equation estimation from UK time series that removes the simultaneity bias looks as following:

Interest rate: i = 4.969(y-y*) -5.182 (p-p*)
(7.74) (-7.27)

Output gap: y-y* = 0.08i + 0.504 (p-p*)
(7.75) (5.21)

Inflation: p-p* = -0.071i + 0.421 (y-y*)
(-7.27) (5.21)

System R-Square = 0.8637

The result of the simultaneous equation model has better overall fit even that of the results from the autoregressive model given above. Now the model explains about 86 percent of variation in the interest rate.

The above model can be estimated following Johansen and Juselius (1990) procedure for a cointegrated VAR model. The validity of this approach is based on the rank of the cointegration matrix of the structural coefficients that is crucial for determining the number of cointegration vectors in the model. Consider a VAR model for above three variables.

$$Y_t = A_1 Y_{t-1} + \varepsilon_t$$

where Y_t is vector of interest rate, output gap and inflation gap and ε_t is the vector of normally and identically distributed random error terms. By subtracting Y_{t-1} from both sides

$$\Delta Y_t = (A_1 - I)Y_{t-1} + \varepsilon_t$$

$$\Delta Y_t = \Pi Y_{t-1} + \varepsilon_t \quad \text{where } \Pi = (A_1 - I)$$

Here Π is the matrix of parameters showing the total long run relationship among variables. By using the cointegration procedure this matrix can further be decomposed into adjustment coefficients (α) and cointegrating vectors (β) as $\Pi = \alpha\beta'$. The matrix β denotes the long run steady state relationship among variables and α is the dynamic process of adjustment towards that equilibrium. The estimation on interest rate, output gap and inflation gap for the UK for 1972:2 to 1999:4 obtained using the PcGive (Doornik and Hendry (2001)) yields following results.

$$\Pi = \begin{bmatrix} -0.03654 & -0.12011 & 0.18569 \\ 0.02982 & -0.24185 & -0.08453 \\ -0.09433 & -0.07224 & -0.53655 \end{bmatrix}$$

$$\alpha = \begin{bmatrix} 0.01810 & 0.09100 & 0.01089 \\ 0.01667 & -0.00346 & -0.00208 \\ -0.00793 & -0.20723 & 0.00692 \end{bmatrix}$$

$$\beta = \begin{bmatrix} 1.0000 & 0.19498 & -6.6460 \\ -13.850 & 1.0000 & 3.6355 \\ -4.3680 & 2.7897 & 1.0000 \end{bmatrix}$$

The number of co-integrating vectors in the Johansen procedure is determined by $\lambda_{trace(r)} = -T\sum_{i=r+1}^{n}\ln\left(1-\hat{\lambda}_i\right)$ and $\lambda_{\max(r,r+1)} = -T\ln\left(1-\hat{\lambda}_{r+1}\right)$ statistics, where λ_i denotes the eigenvalues of the characteristic matrix $\Pi = \left(A_1 - I\right)$ and r is an indicator for a reduced rank in (k-r) for k number of explanatory variables. The calculated values of these statistics are compared with the theoretical critical values from Johansen and Juselius (1990) to ascertain the number of cointegrating ranks as following.

Table 2

Cointegration test results

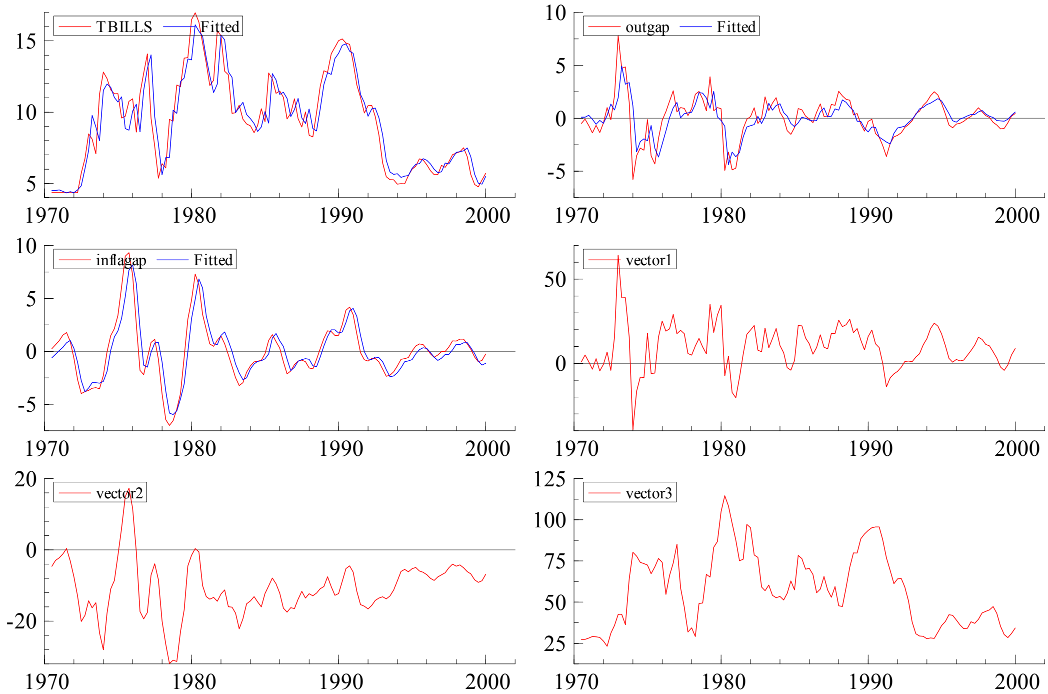
rank: H_0	Trace test [Prob]	Max test [Prob]	Tracetest (T-nm)	Max test (T-nm)
$r = 0$	56.86 [0.000]**	34.38 [0.000]**	55.43 [0.000]**	33.52 [0.000]**
$r \leq 1$	22.48 [0.003]**	12.68 [0.087]	21.91 [0.004]**	12.36 [0.097]
$r \leq 2$	9.80 [0.002]**	9.80 [0.002]**	9.55 [0.002]**	9.55 [0.002]**

These cointegration results are comparable to those found in other applied works such as Cheung and Westerman (2002), Yamada (2002), Brooks and Skinner (2000),Camarero, Ordonez and Tamarit (2002) and Silvapulle and Hewarathna (2002), Valente (2003), Mills and Wood (2002).

The order of the rank of Π suggests the number of cointegrating vectors in β . Above $\lambda_{trace(r)}$ and $\lambda_{\max(r,r+1)}$ tests suggest that at least there are two cointegrating vectors in the above model. The long run relation among these variables is shown by a very good fit of the predicted and actual series of above three variables.

The fit of the predicted and the actual interest rate is almost perfect as shown in the figures 4.

Figure 4: Prediction from A VAR Model: Actual, Fitted and Cointegrating Vectors.



The model estimated above can be used to analyse the impacts of shocks to each of the above equations in terms of incremental and cumulative impulse responses as shown in Figures 5 and Figure 6.

A unique shock to the interest rate by one standard unit reduces the output gap immediately with a lagged response in the rates of inflation; a similar shock to the output equation reduces the interest rate immediately and has lagged response in the rate of inflation rate as shown by graphs in the second row; an unit shock to inflation reduces the interest rate immediately and has lagged response in output gap as shown by graphs in row 3. Though the model converges to the steady state over periods, each of these shocks has its own patterns of impacts. The cumulative shocks corresponding to each of three unit shocks on treasury bills rate, output and inflation gaps in Figure 5 are shown by cumulative response graphs in respective positions in Figure 6. Dynamic forecasts along with their confidence bands are shown in Figure 7.

Figure 5: Impulse Response Analysis

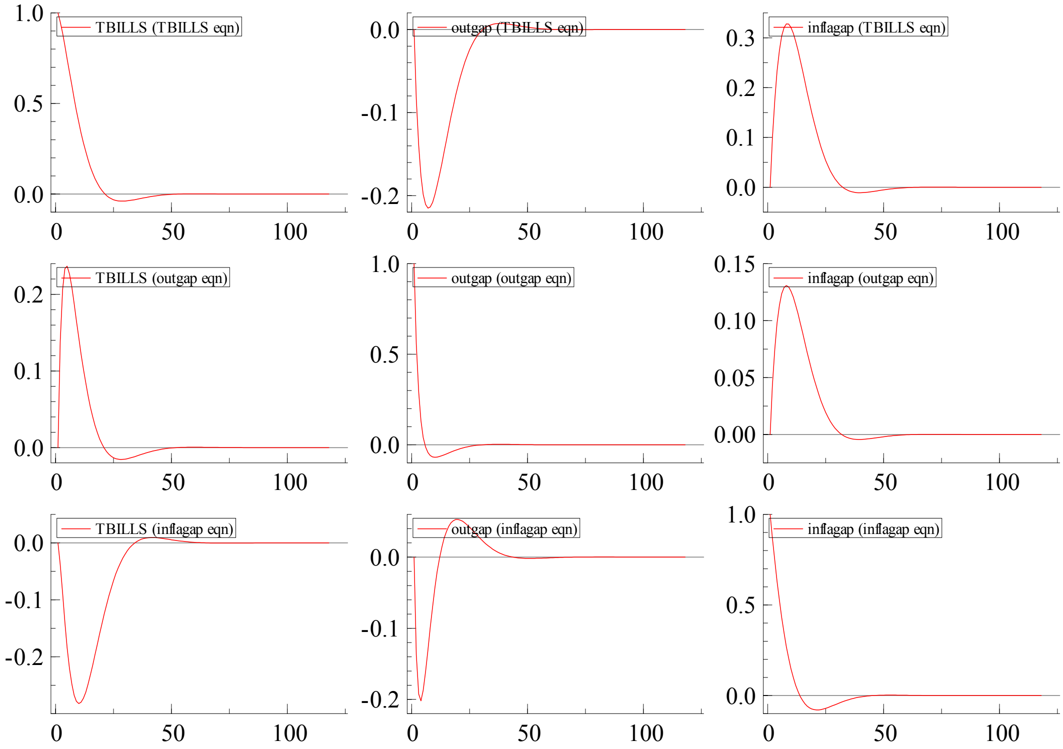
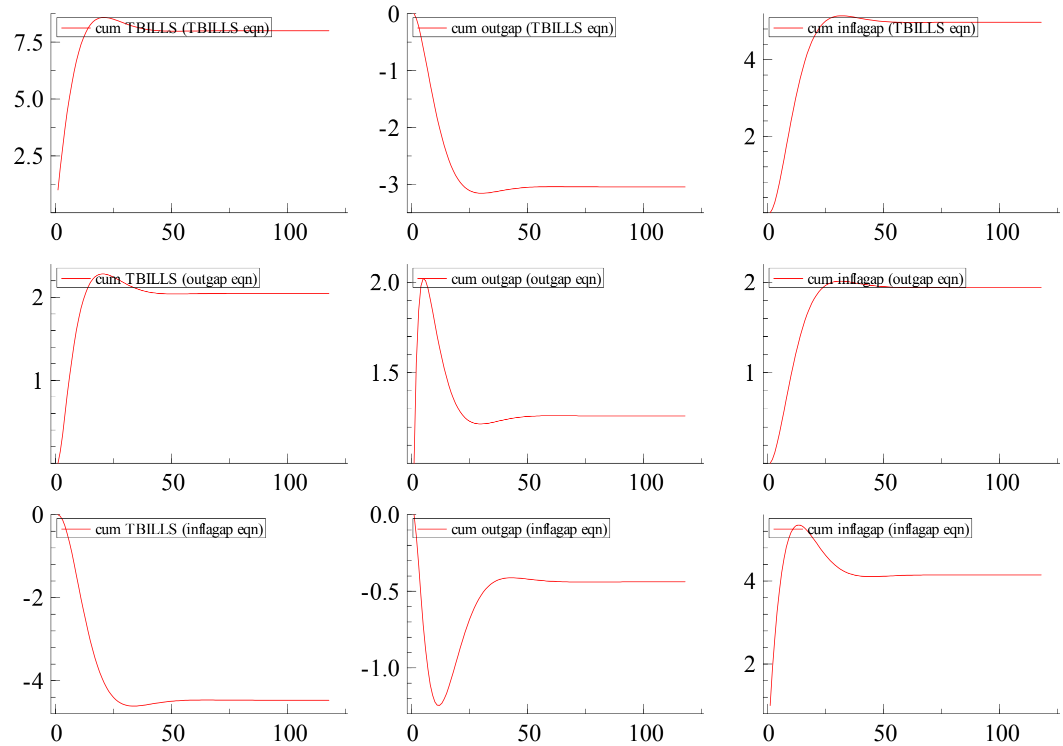
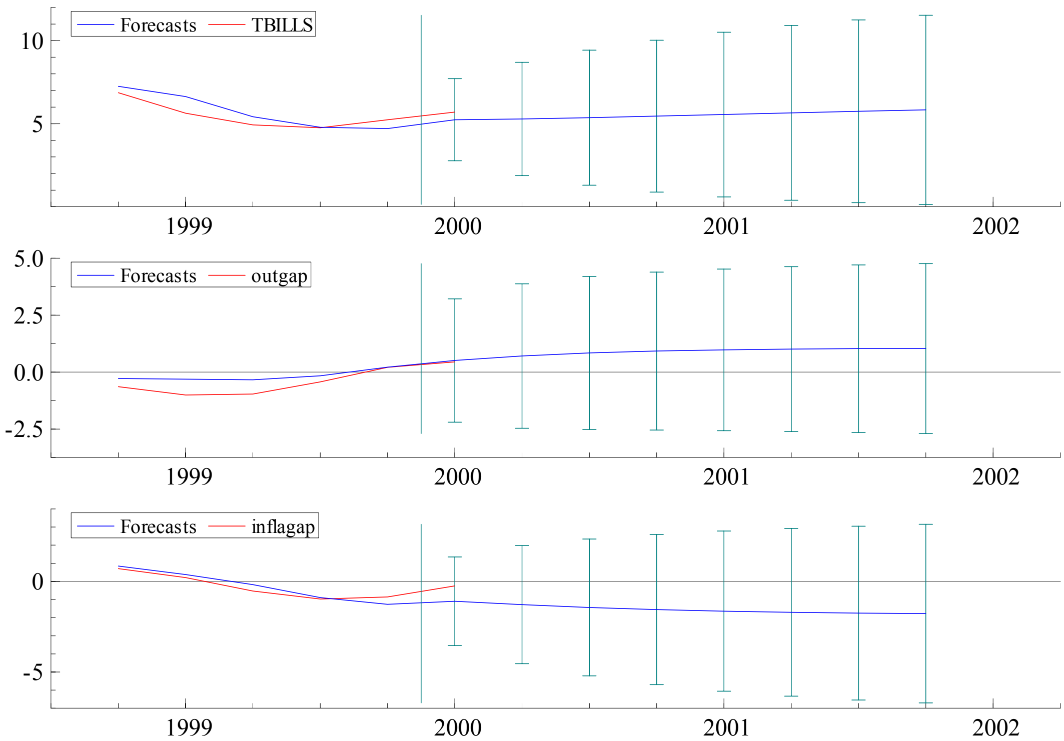


Figure 6: Cumulative Impulse Response Analysis



Studying the time profiles of these shocks it becomes obvious that it may take from 4 to 24 quarters for economy to realise the impact of a shock to the interest rate. The above shocks can further be divided in real shocks to the output and the nominal sector shocks in terms of the interest rate. More detailed estimates for various sub-periods between 1973-2000 can be found in Nelson (2000) or in Castelnouvo (2003).

Figure 7
Dynamic Forecasts of Interest rate, output-gap and inflation gap



The estimation of the interest rule model for one economy can be extended to a group of economies taken together. An attempt is made here to test it for five major industrial economies France, Germany, Japan, UK and the USA using the annual data set on growth rates of output, inflation and interest rates obtained from the World Bank (2002). Three steps are involved in applying this interest determination model to five major industrial economies. First step involves estimation of the current output gap as a function of the actual interest rates in the previous period relative to a trend interest rate, and the estimation of current inflation gap as a function of output gap in the previous period. These predicted series of output and inflation gaps are used to estimate model generated interest rate for each period in the second step. A comparison is made between the series of the actual interest rates to those predicted by the model in the third stage. Then the quality of predictions of the model are judged using test statistics and studying whether model based prediction can track actual interest rates well and decompose the sources of changes in the interest rate into the real or supply side factors as represented by the output gap and the demand side factors as represented by the inflation gaps.

Table 3
Test of Interest Determination Rule for Five Major Economies

	Output gap	Inflation gap	Constant	R^2
France	-6.641 (-14.778)	0.670 (1.341)	5.900 (1.341)	0.766
Germany	-10.732 (-15.187)	4.335 (4.953)	5.339 (11.898)	0.752
Japan	-6.775 (-6.554)	-1.794 (-7.061)	-1.312 (-3.487)	0.641
UK	-2.941 (-5.885)	1.006 (2.848)	7.416 (10.203)	0.574
USA	-1.794 (-7.061)	0.360 (0.408)	5.337 (18.955)	0.696

Estimates from a 3SLS method, values in the parenthesis represent *t*-statistics.

Explanatory power of this model in analysing the behaviour of the interest rate in each economy is quite remarkable as shown by significant t-values for coefficients and higher values of *R*-square statistics. Sizes of the coefficients of output gap vary substantially across these countries reflecting the link between the interest rate and growth rate of the economy comparable to those found in other studies (Cheung and Westerman (2002), Yamada (2002)). These output gap coefficients are significant for each of the above countries at one percent level of significance as shown by the t-statistics. These economies reduce interest rate whenever actual output growth rate is below the trend growth rate and raise it whenever the actual growth rate is above the trend growth rate in order to avoid inflationary consequences. There is dissimilarity however, regarding the link between the interest rate and inflation gap among these countries both is terms of size of the coefficients and their significance. All countries except Japan have expected sign of the coefficient on the inflation gap but that is not significant for the US. Despite this the predictive power of each equation remarkably suggests for existence of interest rate rule among these economies during the study period.

When we study the interdependence in the interest rate determination among G5 major economies treating them as one by pooling cross section and time series data for entire 1978-2000 period, it generates following result.

$$i_t = 6.25 - 0.29\left(y_t - y_t^*\right) + 0.115\left(\pi_t - \pi_t^*\right)$$

t-ratios (0.80) (-3.30) (1.33)

$R^2 = 0.43$ F = 5.5; N=100

From economic point of view this result is not very sensible. In theory the interest rate should rise when output is above its trend but here estimated coefficient has a negative sign showing a reverse result. The coefficient on inflation gap has expected positive sign but it is not significant at 5 percent level of significance. These results do not support the hypothesis of interest rate determination rule at aggregate level by G5 countries for this period though it is supposed to be so in the literature (Asimakopoulos, Goddard and Siriopoulos (2000), Lee (2002), Butter and Jenson (2004), Ghazali and Ramlee (2003), Buch (2004)). Each of G5 countries were acting independently in determining its own interest rate.

Analyes on how the interest is determined and how it affects other economies requires more detailed specification of demand, production, portfolio allocation and trade structure of the monetary economy in line with Tobin (1969), Altig, Carlstrom and

Lansing (1995), Corsetti and Pesenti (2001) and Vickers (1998). Such modelling is subject for further study but beyond the scope of this paper.

V. Conclusion

Analytical solution for interest rate rules in a three equation model is found using a second order-difference equation technique in terms of model parameters. Those parameters were estimated using the quarterly time series data on treasury bills rate, growth rate of output and inflation rates for UK, the annual time series during the last three decades for Germany, France, Japan, UK and the US. The evidence suggests existence of an interest rule. This empirical model is then applied for impulse response analysis and forecasting.

Acknowledgements: Author appreciates comments and suggestions received from editor of this Applied Financial Economics Journal and participants of the Ecomod Conference 2006 in Hong Kong. Earlier version of this paper was published as a Research Memorandum from the Centre for Economic Policy of the Hull University Business School. Correspondence address: Business School University of Hull, Cottingham Road, HU6 7RX, UK. e-mail: K.R.Bhattarai@hull.ac.uk. Phone 44-1482-463207

.

References:

Alesina A, L. H. Summers (1993) Central Bank Independence and Macroeconomic Performance: Some Comparative Evidence *Journal of Money, Credit and Banking*, 25: 2: 151-162, May.

Altig D E, C.T. Carlstrom and K.L. Lansing (1995) *Computable General Equilibrium Models and Monetary Policy Advice*, Journal of Money Credit and Banking, 27: 4:1472-1493: Nov.

Asimakopoulos I, J. Goddard and C. Siriopoulos (2000) Interdependence between the US and major European equity markets: evidence from spectral analysis. *Applied Financial Economics*, Feb, Vol. 10 Issue 1, p41-47.

Bacchetta P. and F. Ballabriga (2000) The impact of monetary policy and banks' balance sheets: some international evidence. *Applied Financial Economics*, Feb2000, Vol. 10 Issue 1, p15-26.

Ball L.and D. Romer (1990) Real Rigidities and the Non-Neutrality of Money, *Review of Economic Studies*, 57:183-203.

Barro R.J. and D. B. Gordon (1983) Rules, Discretion and Reputation in a Model of Monetary Policy, *Journal of Monetary Economics*, 12: 101-121, North-Holland.

Barro R.J. and D. B. Gordon (1983) A Positive Theory of Monetary Policy in a Natural Rate Model, *Journal of Political Economy*, vol. 91:4: 589-610.

Benigno, P. (2002) A Simple Approach to International Monetary Policy Coordination, *Journal of International Economics*, 57:1: 177-96, June.

Bernanke B. S. and F.S. Mishkin (1997) Inflation Targeting: A New Framework for Monetary Policy, *Journal of Economic Perspectives*, vol. II:2:97-116, Spring.

Berument H. and M. M. Jelashi (2002) Fisher hypothesis a multi-country analysis, *Applied Economics*, 34 , 1645-1655.

Bhattarai K R (2003) Interest Determination Rule four UK and Other Four Major Industrial Economies, *Research Memorandum*, no. 42 Business School, University of Hull.

Brooks C. and F. Skinner (2000) What will be the risk-free rate and benchmark yield curve following European monetary union? *Applied Financial Economics*, Feb, Vol. 10 Issue 1, p59-69

Buch, C. M. (2004) Cross-border banking and transmission mechanisms in Europe: evidence from German data. *Applied Financial Economics*, Nov, Vol. 14 Issue 16, p1137-1149.

Camarero M. , J. Ordonez and C.R. Tamarit (2002) Monetary transmission in Spain: a structural cointegrated VAR approach, *Applied Economics*, 34: 2201-2212

Castelnouvo E. (2003) Taylor rules, omitted variables, and the interest rate smoothing in the US, *Economic Letters*, 81, 55-59.

Cheung Y.W. and F. Westerman (2002) Output dynamics in G7 countries: stochastic trends and cyclical movements, *Applied Economics*, 34, 2239-2247.

Corsetti, G and P.Pesenti; (2001) Welfare and Macroeconomic Interdependence, *Quarterly Journal of Economics*, May, v. 116, iss. 2, pp. 421-45

Doornik J A and D.F. Hendry (2003) *PC-Give Volume I-III*, GiveWin Timberlake Consultants Limited, London.

Driffil J. (1988) Macroeconomic Policy Games with Incomplete Information: A Survey, *European Economic Review*, 32 (2-3) 513-41.

Ellis C. and S. Price (2003) The impact of price competitiveness on UK producer price behaviour, Working paper no. 178, Bank of England.

Engle R E and C.W.J. Granger (1987) Co-integration and Error Correction: Representation, Estimation and Testing. *Econometrica,* vol. 55, No. 2, pp. 251-276.

Ferris, J.S. and J.A. Galbraith (2003) Indirect convertibility as a money rule for inflation targeting *Applied Financial Economics*, Oct, Vol. 13 Issue 10, p753, 9p;

Fisher, S. (1977) Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule, *Journal of Political Economy*, 85:1:191-205, February.

Friedman, M (1968) The Role of Monetary Policy, *American Economic Review*, LVIII 58:1:1-17, March .

Gali J and Gertler M (1999) Inflation dynamics: a structural econometric analysis, *Journal of Monetary Economics*, 44(3) 195-222.

Gerlack-Kristen P. (2005) Too little too late, interest rate setting and the cost of consensus, *Economics Letters* 88, 376-381.

Ghazali, N.A. and S. Ramlee (2003) A long memory test of the long-run Fisher effect in the G7 countries. *Applied Financial Economics*, Oct, Vol. 13 Issue 10, p763, 7p;

Goodhart C. (1989) The Conduct of Monetary Policy, *Economic Journal*, 99: pp. 293-346, June.

Hanson J A (1980) The Short Run Relation Between Growth and Inflation in Latin America: A Quasi-Rational or Consistent Expectations Approach, *The American Economic Review*, 70:5: 972-989, December.

Hicks, J. R. (1937) Mr. Keynes and the "Classics": A Suggested Interpretations, *Econometrica*, 5:1:147-159.
HM Treasury (2002) "UK Model of Central Bank Independence: An Assessment" in *Reforming Britain's Economic and Financial Policy*, Palgrave pp. 85-109.http://www.fsa.gov.uk/

Holly S and M Weale Eds.(2000) *Econometric Modelling: Techniques and Applications,* pp.69-93, the Cambridge University Press.

Johansen S. (1988) Statistical Analysis of Cointegration Vectors, *Journal of Economic Dynamics and Control* 12 231-254, North Holland.

Keynes J.M. (1936) *The General Theory of Employment, Interest and Money*, MacMillan and Cambridge University Press.

Kydland, F. E. and E.C. Prescott (1977) Rules Rather than Discretion: The Inconsistency of Optimal Plans, *Journal of Political Economy* 85: 3: 473-491.

Laidler D and M Parkin (1975) Inflation: A Survey, *The Economic Journal*, 85: 340: 741-809 December.

Lee J E (2002) Real interest rate in regional economic blocks, *Applied Economics*, 34:859-864

Lockwood, B; Miller, M; Zhang, L (1998) Designing Monetary Policy When Unemployment Persists *Economica*, August, 65: 259:pp. 327-45

Mankiw N.G. (1987) The Optimal Collection of Seigniorage, *Journal of Monetary Economics*, 20, 327-341, North Holland.
Mills Terrence C and Geoffrey E Wood (2002) Wages and prices in the UK, *Applied Economics*, 34:2143-2149

MPC Bank of England (www.bankofengland.co.uk) *The Transmission Mechanism of Monetary Policy*.

Nelson E. (2000) UK monetary policy 1972-97: a guide using Taylor rules, *Bank of England Working Paper no. 120*, London.

Nickell, S. (1990), Inflation and the UK Labour Market *Oxford Review of Economic Policy* 6(4) Winter.

Nordhaus W. D. (1995) Policy Games: Co-ordination and Independence in Monetary and Fiscal Policeis, *Brookings Papers on Economic Activity* 2:1994: 139-216.

Phillips, A. W., (1958) The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957, *Economica*, pp.283-299.

Phelps E. S. (1968) *Money* wage dynamics and labour market equilibrium, *Journal of Political Economy*, 76: 678-711.

Sargent, T. J. (1986) *Rational Expectation and Inflation*, Harper and Row Publishers, New York.

Silvapulle Param and R. Hewarathna (2002) Robust estimation and inflation forecasting *Applied Economics,* 34:2277-2282.

Staikouras, Sotiris K.. (2004) The information content of interest rate futures and time-varying risk premia *Applied Financial Economics*, Jul, Vol. 14 Issue 11, p761-771.

Sugo T and Y. Teranishi (2005)Optimal monetary policy rule under the non-negativity constraint on nominal interest rates *Economic Letters* 85: 95-100.

Taylor M P (1987) On the long run solution to dynamic econometric equations under rational expectation, *Economic Journal*, 97:385:215-218.

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

Tobin, J (1969), A general Equilibrium Approach to Monetary Theory, *Journal of Money Credit and Banking*, pp. 15-29.

Valente G. (2003) Monetary policy rules and regime shifts,*Applied Financial Economics*, Jul, Vol. 13 Issue 7, p525, 11p.

Vickers J (1999), Inflation Targeting in the UK, *Bank of England Quarterly Bulletin*, pp. 368-375.

Wetherilt, A. V. (2003) Money market operations and short-term interest rate volatility in the United Kingdom *Applied Financial Economics*, Oct, Vol. 13 Issue 10, p701, 19p;

Woodford M. (2001) The Taylor Rule and Optional Monetary Policy, *American Economic Review* 91:2:232-237.

World Bank (2002) *World Development Indicators: a CD-Rom*, Washington DC.
Yamada H. (2002) Real interest rate equalisation: some evidence from three major world financial markets *Applied Economics*, 34:2143-2149

Appendix

Summary of recent applied studies on the determination and interdependence in the interest rates and their impact among economies

Authors	Economic issues	Method	Summary	Journal
Asimakopoulos, Goddard and Siriopoulos(2000)	US and major European equity markets	spectral analysis	Lead-lag relation in stock returns in EU and US	AE
Bacchetta and Ballabriga(2000)	The impact of monetary policy and banks' balance sheets: some international evidence.	VAR	Strong relation between the Interest and output in the US and 13 EU economies	AFE
Brooks and Skinner(2000)	What will be the risk-free rate and benchmark yield curve following European monetary union?	Linear factor model	UK 3-month yield curve best approximates others in EU	AFE
Berument and Jelashi (2002)	Fisher hypothesis a multi-country analysis	ADF, OLS, ARCH-LM	Support for Fisher hypothesis for 13 of 26 countries	AE
Mills and Wood (2002)	Wages and prices in the UK	VECM	Wage growth does not predict inflation	AE
Silvapulle and Hewarathna (2002)	Robust estimation and inflation forecasting	ECM	Support Fisher effect on inflation for Australia	AE
Camarero, Ordonez and Tamarit (2002)	Monetary transmission in Spain	S-CVAR	Support for endogenous policy reaction of monetary policy	AE
Cheung and Westerman (2002)	Output dynamics in G7 countries: stochastic trends and cyclical movements	VAR-Co integration	Existence of common business cycles among G7 countries	AE
Lee (2002)	Real interest rate in regional economic blocks,	VEC, ARIMA	Long run relation in real interest rates of APEC, EU and the US	AE
Castelnouvo (2003)	Taylor rules, omitted variables, and the interest rate smoothing in the US	OLS in first differences	Test of forward looking Taylor rule in the US	EL
Yamada (2002)	Real interest rate equalisation: some evidence from three major world financial markets	VAR cointegration	Departure from long-run real interest rate equalisation is not very large	AE
Ferris and Galbraith(2003)	Indirect convertibility as a money rule for inflation targeting	Relative price concept	How indirect convertibility brings price stability(fixing a basket/ unit of money)	AFE
Valente (2003)	Monetary policy rules and regime shifts	MS-VAR	Time varying parameter and Markov Switching VAR model for policy rule	AFE
Ghazali and Ramlee (2003)	A long memory test of the long-run Fisher effect in the G7 countries	ARIMA, ARFIMA	Long run relation between interest rate and inflation in G7 countries.	.AFE
Wetherilt (2003)	Money market operations and short-term interest rate volatility in the United Kingdom	GARCH and VECM	Reduction in the volatility of market rates along with that in repo rates in uk	AFE
Buch (2004)	Cross-border banking and transmission mechanisms in Europe: evidence from German data.	Credit data analysis	Activities of commercial banks cause transmission of shocks across countries	AFE
Staikouras(2004)	The information content of interest rate futures and time-varying risk premia	VAR cointegration	Tests speculative efficiency hypothesis and supports price discovery hypothesis	AFE
Butter and Jenson (2004)	An empirical analysis of German long term interest rate	ARIMA, ECM	Four theories of interest rate explain German short term rate	AFE
Gerlack-Kristen (2005)	Too little too late, interest rate setting and the cost of consensus	Vote and simulation	Majority vote better than consensus in setting policy	EL
Sugo and Teranishi (2005)	Optimal monetary policy rule under the non-negativity constraint on nominal interest rates	Constrained optimisation	Policy rule optimal even in non-negative constraint on int rate	EL

AE =Applied Economics, AFE =Applied Financial Economics, EL =Economics Letters.