
An empirical study of interest rate determination rules

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This paper finds empirical support for a 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, the UK and the US. The results confirm that such rules implicitly exist during the period of analysis.

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; Laidler and Parkin, 1975; Kydland and Prescott, 1977; Taylor, 1987; Nickell, 1990; Taylor, 1993; Gali and Gertler, 1999). 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 the public fears that the policymakers 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 coordination at national and international levels. The 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 policymakers and initiated a rule-based monetary policy aimed at achieving 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 policymakers. 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 Bernanke and Mishkin (1997) and MPC Bank of England (1999). 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 optimization in more elaborate general equilibrium models though more detailed analysis of consequences of the interest rates by a central bank is often carried out using more comprehensive econometric and general equilibrium models, as discussed in Altig *et al.* (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's (1993) model fits to the interest rate series of the UK and five major industrial economies over the past three decades. It complements applied economic studies on this topic 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 the Fisher hypothesis (Berument and Jelashi, 2002; Silvapulle and Hewarathna, 2002). The model discussed in this paper neither directly derives the interest rate rules using optimizing 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 a single equation or simultaneous equations or panel data or VAR-cointegration models generate results that are comparable to findings seen in studies by Asimakopoulou *et al.* (2000), Bacchetta and Ballabriga (2000), Brooks and Skinner (2000), Camarero *et al.* (2002), Lee (2002), Mills and Wood (2002), Castelnouvo (2003), Ferris and Galbraith (2003), Ghazali and Ramlee (2003), Valente (2003), Wetherilt (2003), Buch (2004), Staikouras (2004). Some details on the issues, methods and major findings of these various studies are given in the Appendix. The 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 the 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 an interest rate determination rule similar to that of Taylor (1993) in Section II. A brief discussion of the dataset used for study is in Section III. The empirical relevance of this model is tested with quarterly macroeconomic time series data for the UK and annual data for five major industrial economies during last three decades in Section IV. 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. The first equation states the current output gap ($y_t - y_t^*$), 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 ($i_{t-1} - i_t^*$). This relationship is expected to be a 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:

$$y_t - y_t^* = -d(i_{t-1} - i_t^*) \quad d > 0 \quad (1)$$

where y_t and y_t^* are actual and natural levels 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:

$$\pi_t = \pi_t^* + c(y_{t-1} - y_t^*) \quad c > 0 \quad (2)$$

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. An 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 the target inflation rate is treated as the expected rate of inflation. A simple interest rate rule is derived by combining Equations 1 and 2 to show how the policymakers like to reduce the interest rate when both output and inflation rates are higher relative to their natural rates as:

$$i_t = i_t^* + a(y_t - y_t^*) + b(\pi_t - \pi_t^*) \quad a > 0; b > 0 \quad (3)$$

If the output gap from Equation 1 and the inflation rate gap from Equation 2 are substituted in the interest rate rule in Equation 3 it generates an autoregressive reduced form single equation of

interest that can explain the cycles of interest rate in terms of reduced form parameters as:

$$\begin{aligned} i_t &= i_t^* - ad(i_{t-1} - i_{t-1}^*) - bcd(i_{t-2} - i_{t-2}^*) \\ i_t + adi_{t-1} + bcdi_{t-2} &= i_t^* + adi_{t-1}^* + bcdi_{t-2}^* \end{aligned} \quad (4)$$

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 $\beta_0 = (i_t^* + adi_{t-1}^* + bcdi_{t-2}^*)$, and $\beta_1 = ad$ and $\beta_2 = bcd$. Then Equation 4 can be written as:

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

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

$$\bar{i} = \frac{i_t^* + adi_{t-1}^* + bcdi_{t-2}^*}{1 + \beta_1 + \beta_2} \quad \text{or} \quad \bar{i} = \frac{i_t^* + adi_{t-1}^* + bcdi_{t-2}^*}{1 + ad + bcd}$$

in terms of the original model parameters with flexible targets i_{t-2}^* , i_{t-1}^* and i_t^* and as

$$\bar{i} = \frac{i_t^*(1 + ad + bcd)}{1 + ad + bcd} \quad \text{with fixed targets } i_t^*. \quad (6)$$

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.

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

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

- real and distinct root, when $\beta_1^2 - 4\beta_2 > 0$, guarantees convergence to the steady state;
- real and equal roots case, $\beta_1^2 - 4\beta_2 = 0$, generates repeated cycles; and
- 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:

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

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 $\lambda_1^t = (-\beta_1 + \sqrt{\beta_1^2 - 4\beta_2}/2)$ and $\lambda_2^t = (-\beta_1 - \sqrt{\beta_1^2 - 4\beta_2}/2)$.

Therefore the general solution Equation 8 can be written as:

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

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

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

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, 1983a, b; Sargent, 1986; Mankiw, 1987; Driffil, 1988; Goodhart, 1989; Ball and Romer, 1990; Alesina and Summers, 1993; Dornbush and Fisher, 1993; Nordhaus, 1995; Lockwood *et al.*, 1998; Vickers, 1999; Nelson, 2000; Corsetti and Pesenti, 2001; Benigno, 2002; Ellis and Price, 2003).

III. Dataset

Interest rates have changed significantly over the years as shown in Figs 1a–c. In general they were low and helped to generate an unprecedented rate of economic growth in major industrial economies till

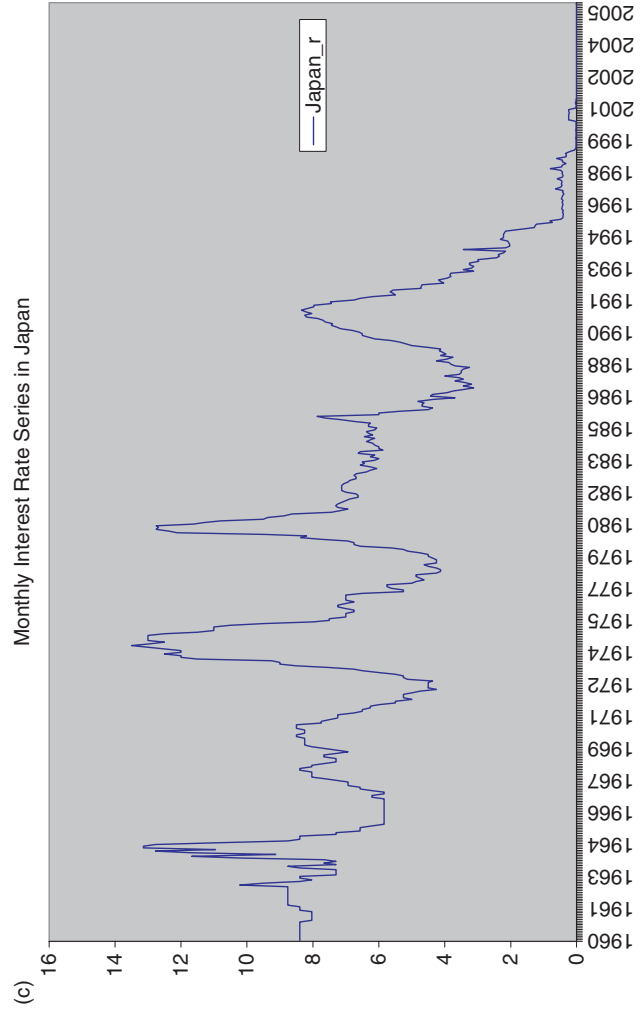
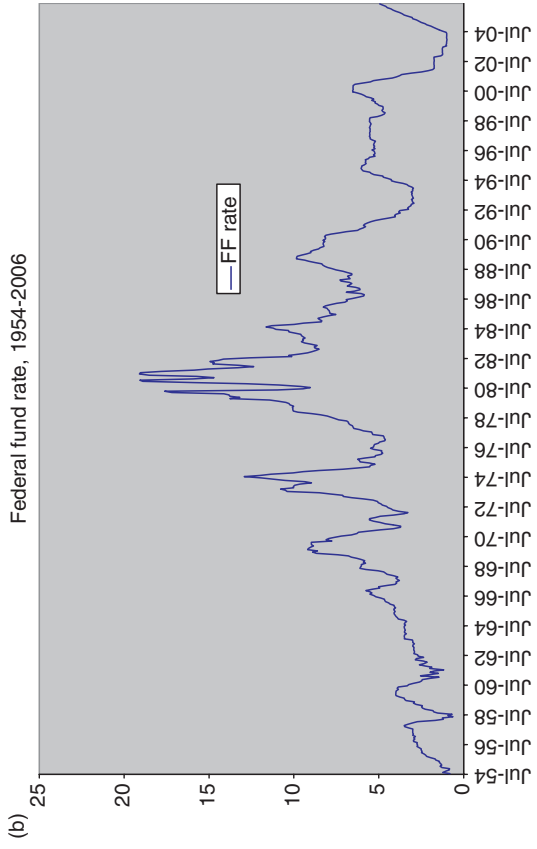
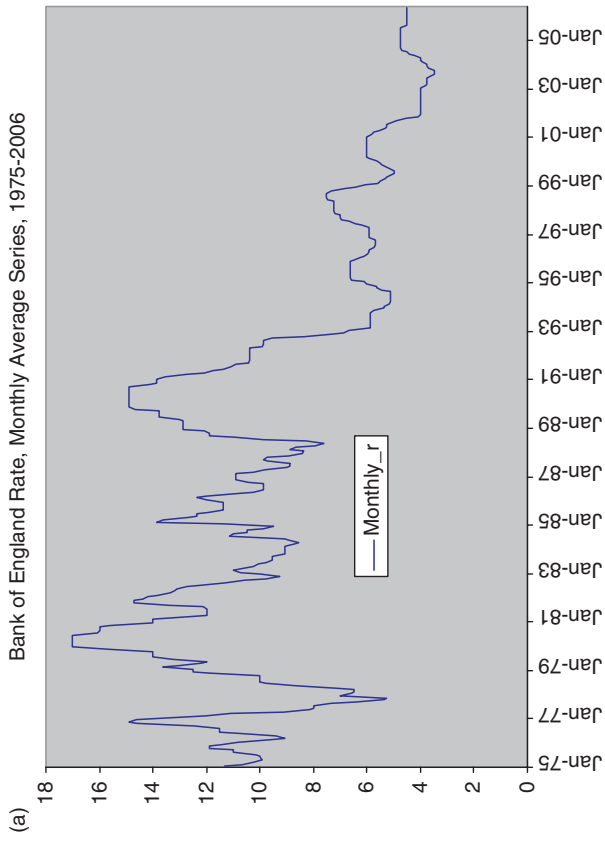


Fig. 1. Monthly basic interest series in the UK, USA and Japan

the late 1960s; then increased and varied significantly and unpredictably in the 1970s and 1980s characterizing economic problems and have started changing systematically in a predictable manner as many western economies adopted a rule-based policy of determining these rates after mid-1990. Interest rates have become a major tool for stabilizing prices and the markets' activities more in recent years.

Quarterly fluctuations in the series for the retail price index, the growth rate of the real GDP and the Treasury bill rates, which represent the whole varieties of interest rates, from 1970:q2 to 1999:q4 are as presented in Fig. 2.

The fluctuations in the rate of interest, inflation and the growth of output were more serious in the 1980s than in 1990. The UK economy has been stabilized and moving more towards its natural rate after 1995 particularly after the adoption of the inflation targeting rule in 1997 (see Nelson, 2000 for more division between sub-periods). A 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 the US from 1978 to 2000 as shown in Fig. 3. The quarterly time series shown in Fig. 2 and the annual series in Fig. 3 are used for estimation of the interest rule model explained in the previous sections.

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 effects 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 homoskedastic and have no autocorrelation and there is no multi-collinearity among the explanatory variables.

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

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

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

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

Unit root tests suggest 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.

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.

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

$t(32.2)$ (-1.1) (2.84)
(SE)(0.29) (0.13) (0.181)

Normality test : $\chi^2(2) = 11.279[0.0036]**$

The interest rate rises with an increase in inflation and the coefficient is significant. The coefficient in the output gap does not have the expected positive sign and it is also statistically insignificant. The above result also suggests that the 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 those of Berument and Jelashi (2002) and Silvapulle and Hewarathna (2002).

In addition the normality test in line with the Engle and Granger (EG) 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.

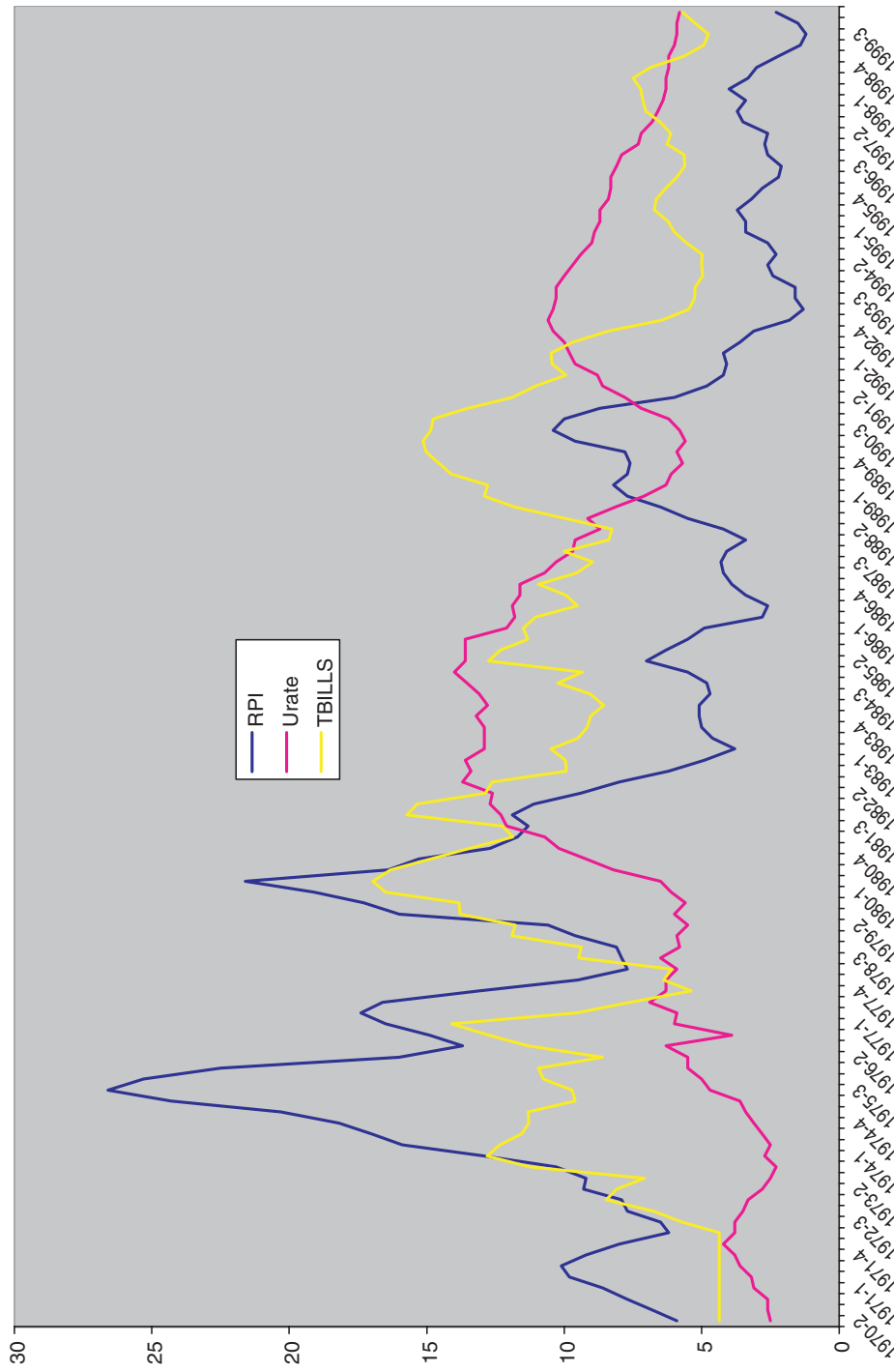
What about estimating the interest rate rule in terms of the reduced autoregressive second-order difference equation equivalent to that given in Equation 5? This gives reasonable results as:

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

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,



Source: These series were obtained from the macro time series data archive in Essex, available at www.data-archive.ac.uk

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

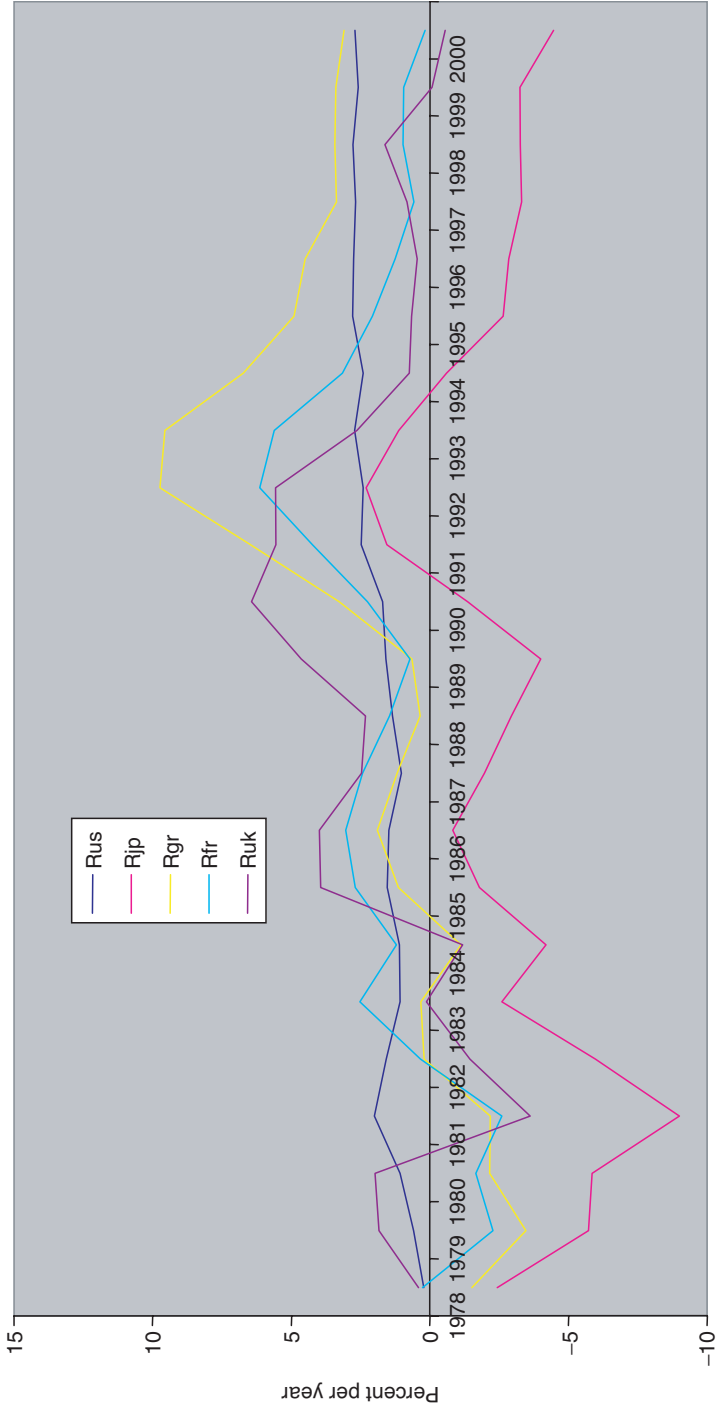


Fig. 3. Real interest rates in major industrial economies

difficult to retrieve the structural parameters of the original model from the estimates of the reduced form equation.

The 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 gap. 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 follows:

$$\text{Interest rate: } i = \underset{(7.74)}{4.969}(y - y^*) - \underset{(-7.27)}{5.182}(p - p^*)$$

$$\text{Output gap: } y - y^* = \underset{(7.75)}{0.08}i + \underset{(5.21)}{0.504}(p - p^*)$$

$$\text{Inflation: } p - p^* = \underset{(-7.27)}{-0.071}i + \underset{(5.21)}{0.421}(y - y^*)$$

System R-Square = 0.8637

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

The above model can be estimated following the 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 the above three variables.

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

where Y_t is the 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 between 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 between 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 PC-Give (Doornik and Hendry, 2001) yields the 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 cointegrating vectors in the Johansen procedure is determined by

$$\lambda_{trace(r)} = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i) \text{ and}$$

$$\lambda_{\max(r, r+1)} = -T \ln(1 - \hat{\lambda}_{r+1}) \text{ statistics}$$

where λ_i denotes the eigenvalues of the characteristic matrix $\Pi = (A_1 - I)$ 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 shown in Table 2.

The cointegration results (Table 2) are comparable to those found in other applied works such as Brooks and Skinner (2000), Camarero *et al.* (2002), Cheung and Westerman (2002), Mills and Wood (2002), Silvapulle and Hewarathna (2002), Yamada (2002), Valente (2003).

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.

Table 1. Stationarity of variables in the model

	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

Note: ADF tests ($T=116$, Constant; 5% = -2.89 1% = -3.49).

The long-run relationship between these variables is shown by a very good fit of the predicted and actual series of the above three variables.

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

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 Figs 5 and 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 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 the graphs in row 3 of Figs. 5 and 6. Though the model converges to the steady state over periods, each of these shocks has its own pattern of impacts. The cumulative shocks corresponding to each of three unit shocks on Treasury bills rate, output and inflation gaps in Fig. 5 are shown by cumulative response graphs in respective positions in Fig. 6. Dynamic forecasts along with their confidence bands are shown in Fig. 7.

Studying the time profiles of these shocks it becomes obvious that it may take from 4 to 24 quarters for an economy to realize the impact of a shock to the interest rate. The above shocks can further be divided into real shocks to the output and the nominal sector shocks in terms of the interest rate.

Table 2. Cointegration test results

Rank: H0	Trace test (Prob.)	Max. test (Prob.)	Trace test (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)**

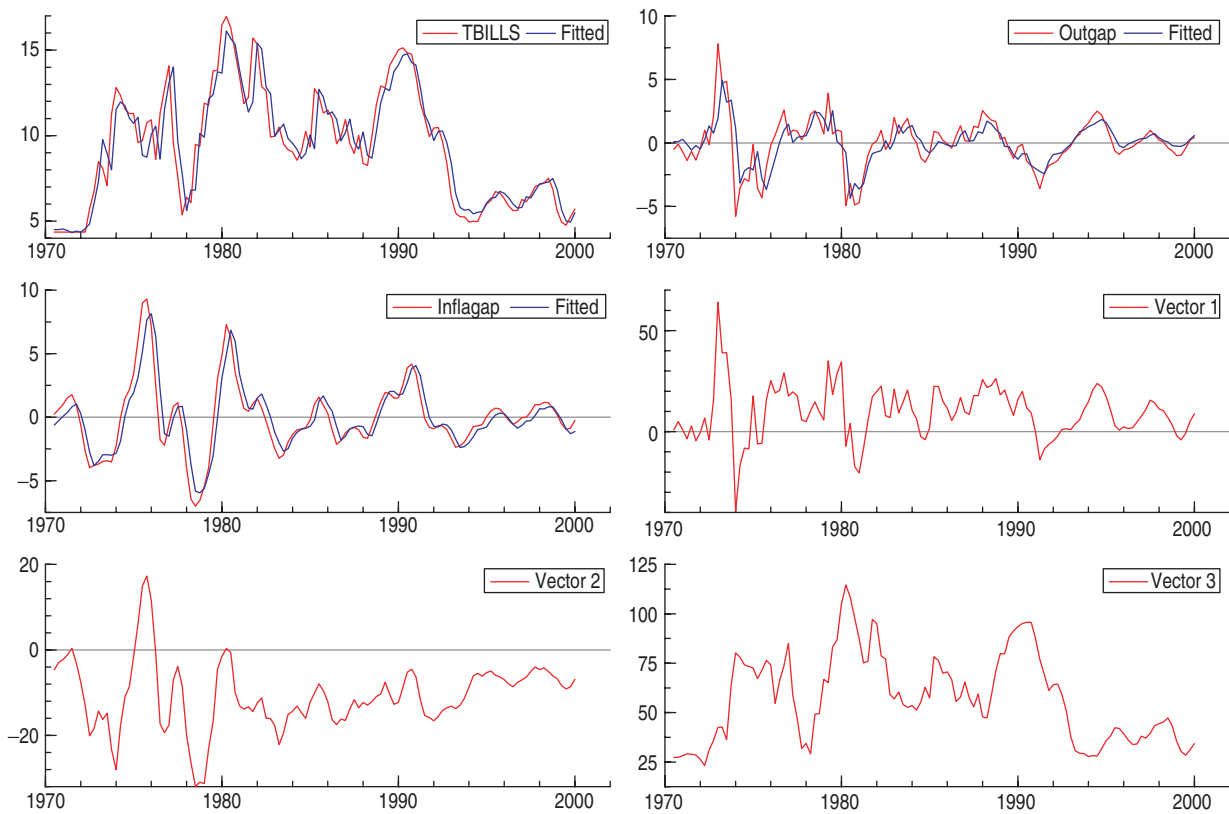


Fig. 4. Prediction from a VAR model: actual, fitted and cointegrating vectors

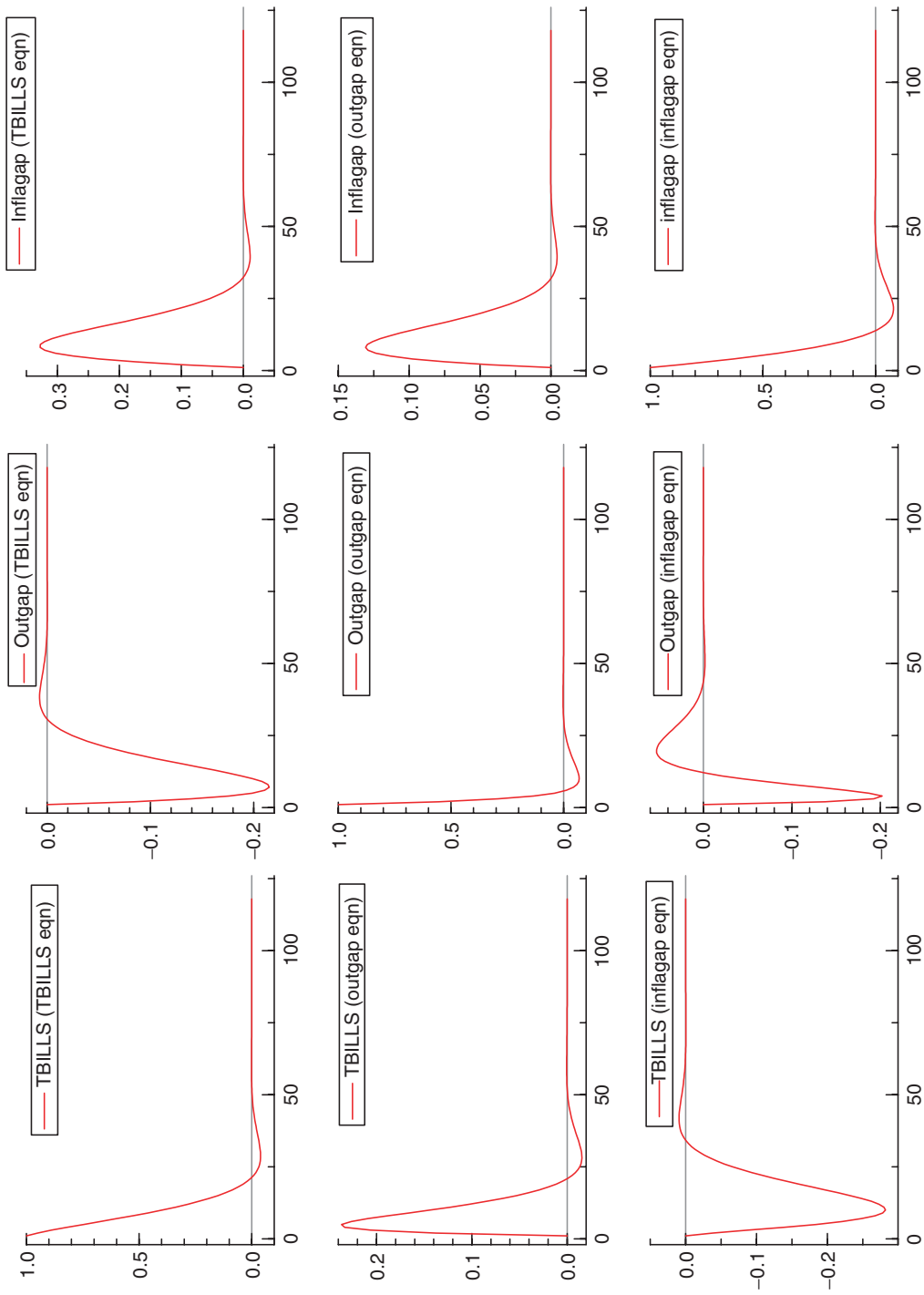


Fig. 5. Impulse response analysis

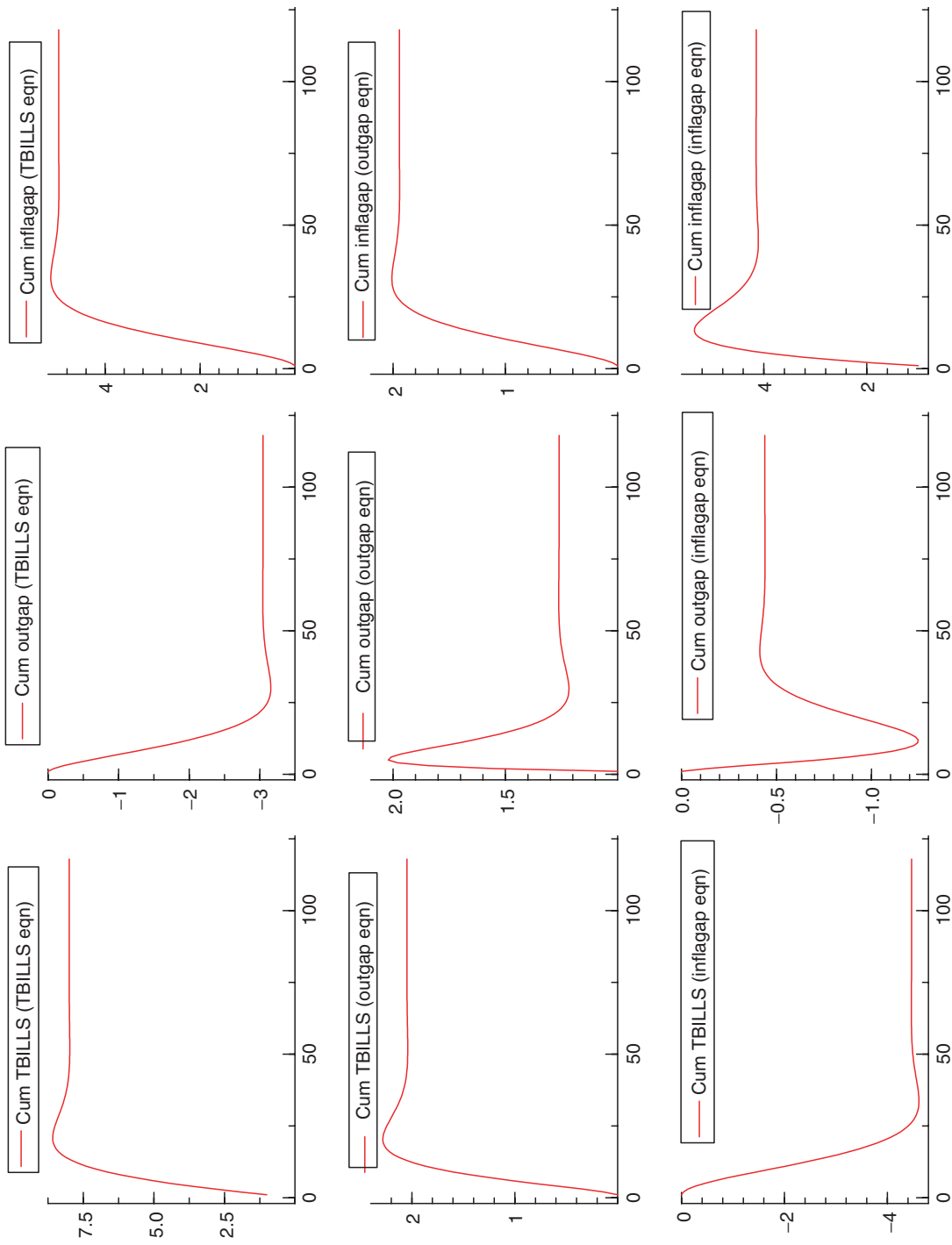


Fig. 6. Cumulative impulse response analysis

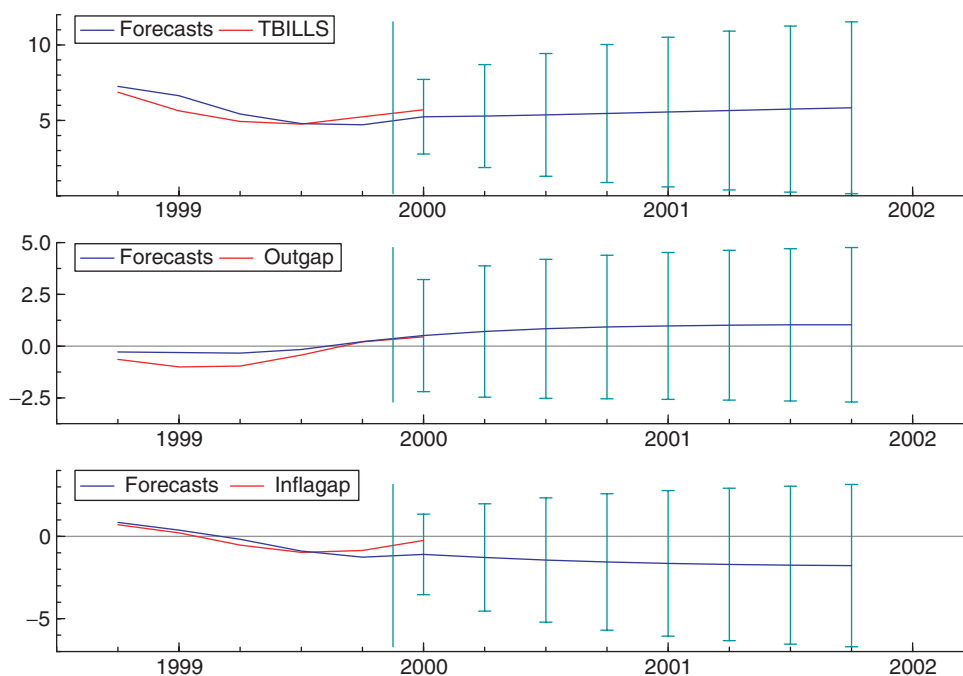


Fig. 7. Dynamic forecasts of Interest rate, output gap and inflation gap

More detailed estimates for various sub-periods between 1973 and 2000 can be found in Nelson (2000) or in Castelnuovo (2003).

The estimation of the interest rate rule model for one economy can be extended to a group of economies taken together. An attempt is made in Table 3 to test it for five major industrial economies France, Germany, Japan, the UK and the USA using the annual dataset 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. The 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 estimation of the current inflation gap as a function of the output gap in the previous period. These predicted series of output and inflation gaps are used to estimate model generated interest rates 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 a 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.

The explanatory power of this model in analysing the behaviour of the interest rate in each economy is

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

Note: Estimates from a 3SLS method; values in parentheses represent t -statistics.

quite remarkable as shown by significant t -values for coefficients and higher values of R -square statistics. The 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 1% level of significance as shown by the t -statistics. These economies reduce the interest rate whenever the 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 in terms of both the size of the coefficients and their significance. All countries except Japan have the 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 suggests the presence of an interest rate rule among these economies during the study period.

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

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

t-ratios (0.80) (−3.30) (1.33)

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

From an 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 the estimated coefficient has a negative sign showing a reverse result. The coefficient on inflation gap has the expected positive sign but it is not significant at 5% level of significance. These results do not support the hypothesis of an interest rate determination rule at aggregate level by the G5 countries for this period, contrary to the literature (Asimakopoulos *et al.*, 2000; Lee, 2002; Ghazali and Ramlee, 2003; Buch, 2004; Butter and Jenson, 2004; Bhattarai, 2003). Each of the G5 countries was acting independently in determining its own interest rate.

Analysis on how the interest rate 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 *et al.* (1995), Vickers (1998), Corsetti and Pesenti (2001). Such modelling is a subject for further study but beyond the scope of this paper.

V. Conclusion

An 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 rates, the growth rate of output and inflation rates for the UK, the annual time series during the last three

decades for Germany, France, Japan, the UK and the US. The evidence suggests the existence of an interest rate rule. This empirical model is then applied for impulse response analysis and forecasting.

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Appendix

Table 4. Summary of recent applied studies on the determination and interdependence in interest rates and their impact on economies

Authors	Economic issues	Method	Summary	Journal
Asimakopoulou <i>et al.</i> (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 rate 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 for Fisher effect on inflation for Australia	AE
Camarero <i>et al.</i> (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 cointegration	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
Castelhovo (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 equalization: some evidence from three major world financial markets	VAR cointegration	Departure from long-run real interest rate equalization 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	AFE
Ghazali and Ramlie (2003)	A long memory test of the long-run Fisher effect in the G7 countries	ARIMA, ARFIMA	Switching VAR model for policy rule 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 optimization	Policy rule optimal even in non-negative constraint on interest rate	EL

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