WORKING PAPER No. 47b
July, 1995

INTEREST RATE DETERMINATION IN THE ECONOMETRIC MODEL KOSMOS

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Svensk resumé på sid 21.

CONTENTS

INTRODUCTION

KOSMOS includes two basic interest rates: the money market rate and the bond rate. The (short term) money market rate is postulated to be a policy variable and thus exogenous to the model. As an alternative, the short rate can be determined by a Central-Bank reaction function which is introduced below.

Given the short rate, the long-term (bond) rate is most conveniently determined from the yield curve, which describes the term structure of interest rates, i.e. the relationship between the yields on securities which differ only in regard of their term to maturity. The three main theories of term structure are (cf. Malkiel [1987] and the references therein) the expectations, liquidity preference and hedging (in particular: preferred habitat) theories.

The expectations hypothesis in its classical form assumes that agents are risk-neutral and that - as a result of their actions - expected holding period yields on assets of different maturities are equalised. Under these assumptions, the yields on bonds of different maturities depend on expectations about future short-term rates. Consequently, an upward-sloping yield curve can be explained by expectations of rising rates.

The liquidity-preference theory also postulates expected yield equalisation, but the agents are assumed to be risk averse. Since investors prefer short-term issues in order to minimize the variability of the money value of their portfolios, a liquidity premium is needed to induce them to hold long-term paper. Then, even if interest rates are expected to be constant, the yield curve should be upward sloping due to risk premia increasing with maturity.

The hedging theory in its extreme form assumes that agents are infinitely risk averse in the sense that they are willing to hold only those securities whose term to maturity strictly corresponds to the agents' preferences (partly determined by institutional factors, e.g. in the case of a life insurance company). Expectations are in this case irrelevant and the shape of the yield curve is determined by demand and supply in each part of the segmented market. The preferred habitat theory (cf. Modigliani and Sutch [1966]) combines elements of all the three above theories, postulating expected yield equalisation and positive *or negative* term premia reflecting the mismatch between the primary (i.e. non-arbitrage) supply of and demand for funds in each habitat (maturity).

Since, in the early seventies, a general consensus emerged that (usually positive) term premia existed, the term 'expectations model' was given a new connotation. Nowadays, it usually denotes the composite hypothesis of rational expectations and time invariant term premia (cf. Melino [1988]). A significant research effort was dedicated to testing the validity of this hypothesis and of its implications, often referred to as the efficient markets theory (cf. Melino [1988], Shiller [1990] and the references therein). Melino [1988, pp. 358-359] summarises the results of these tests as indicating that "term premia do vary, that holding premia on long bonds tend to be positively correlated with the long-short spread, and that they account for a substantial part of the variation in yield curves at the short end of the spectrum".

Despite these results, indicating a clear rejection of the expectations theory, the latter reappears constantly in policy discussions. This is probably due to the absence of an appealing alternative. According to Shiller [1990, p. 670], "empirical work on the term structure has produced consensus on little more than that the rational expectations model, while perhaps containing an element of truth, can be rejected. There is no consensus on why term premia vary. There does not seem even to be agreement on how to describe the correlation of the term premia with other variables."

Empirical work on the term structure of the interest rates was to a large extent directed towards assessing the validity of competing hypotheses rather than modelling the determination of a specific rate of interest. There are generally two approaches to term structure modelling, labelled by Cuthbertson [1988] the reduced form and structural approaches. The latter posits estimation of a supply and a demand function for the financial asset in question (or of a complete set of asset demand and supply functions). The interest rate equation is then obtained from the market equilibrium identity (demand = supply) by "inverting" it such that the interest rate is on the left-hand side.

According to the reduced form approach, the relation between the long and the short rates is estimated directly. This is equivalent to imposing implicit restrictions on the demand and supply functions. Cuthbertson [1988] notes that there is no well-defined (equilibrium) demand functions in the expectations and liquidity-preference hypotheses, since the investors there are assumed to be "plungers", always ready to go for the largest expected return (given the holding period).

Below, we are going to employ the reduced form approach to estimate three models: the expectations model, the preferred habitat model and the loanable funds model of interest rate determination (cf. Mehra [1994] and Sargent [1969]), described below. The latter is originally not a term-structure model but in the present version shows a similarity to this class of models. The loanable funds model is the preferred one, since it gives the best fit and - which is equally important - ties the bond rate directly to economic fundamentals.

The outline of the paper is as follows. The theoretical models considered for bond rate determination are specified in the next section. Data problems and data definitions are discussed next. Estimation results from quarterly data are presented and briefly discussed in the subsequent section, which starts with the assumptions about the expectations formation mechanism. In the following section, a semiannual bond rate function is derived from the quarterly estimates. These empirical results are followed by a brief section on the treatment of expectations in model simulations. Finally, a mechanism for the determination of the short-term rate of interest is postulated in the last section, which deals with the central bank reaction function.

THEORETICAL MODELS

Below, we outline three simple theoretical models of determination of the bond rate to be estimated in the subsequent section.

The *expectations model* assumes that the long rate of interest is an average of the present and expected future short rates:

$$\text{(S.1)} \qquad RL = (RS + \Sigma\, RS^{e}_{+j})/T\,,$$

where

- RL - long rate of interest,
- RS - short rate of interest,
- RS^{e}_{+j} - expected short rate of interest j periods ahead,
- T - the term of RL,

and the summation is defined for $j = 1,2,...,T-1$.

Assuming that the expected changes in inflation rate are the main source of variability in the expectations about the future short rates (i.e. that the real rate is expected to be constant and, consequently, that the nominal rate is expected to fully reflect the variation in the inflation rate), we can replace the expected short rate with expected inflation:

(S.2) $$RL = (T * RSR + INF + \Sigma INF^e_{+j})/T \quad \text{or}$$

(S.2') $$RL - RSR = (INF + \Sigma INF^e_{+j})/T,$$

where

RSR - real short-term rate of interest,

INF - current inflation rate,

INF^e_{+j} - expected rate of inflation j periods ahead.

Our *preferred habitat* equation is derived from a simple portfolio choice model, which makes the distinction between bonds, money (short-term assets) and (net) foreign assets. It is assumed that the choice between domestic and foreign investment is made first. Consequently, the demand for bonds depends on the domestic long rate and the current and expected domestic short rates. It is also proportional to the total financial wealth invested locally. Assuming a constant expected real rate, as in (S.2), we obtain:

(S.3) $$B/W = g_1 [RL - (RS + \Sigma RS^e_{+j})/T] = g_1 \{ RL - [RS + D(INF^e)] \},$$

where

B - stock of bonds,

W - total financial wealth denominated in local currency,

INF^e - expected (average) rate of inflation,

$D(INF^e)$ - expected change in inflation rate,

g_1 - constant coefficient.

Upon the assumptions of exogenous supply of bonds and market equilibrium, we further get:

(S.4) $$RL - RS = (1/g_1) B/W + D(INF^e).$$

In terms of equation (S.2), we have (remembering that the sum below includes only T-1 terms):

$$INF^e = \Sigma INF^e_{+j}/T$$

$$D(INF^e) = INF^e - g_2 INF, \quad g_2 = (T-1)/T.$$

When equation (S.3) is written in the exponential form:

(S.3') $B/W = \{ (1 + RL)/[1 + RS + D(INF^e)] \}^{g_1}$,

we obtain the logarithmic form of (S.4) estimated below:

(S.4') $RL - RS = (1/g_1) \log(B/W) + D(INF^e)$.

The third model is a modification of the *loanable funds model* adapted by Mehra [1994] from Sargent [1969]. The nominal bond rate is within the framework of the model seen as a sum of three components: i) the (equilibrium) real rate, ii) the effect of monetary policy on the real rate and iii) inflationary expectations:

(S.5) $RL = RER + (RLR - RER) + (RL - RLR)$,

where

RL - nominal rate of interest,
RER - equilibrium real rate,
RLR - market real rate.

The equilibrium rate satisfies *ex ante* the economy's financial savings identity, i.e. it equates the desired savings with the sum of investment, government budget deficit and the current account surplus. Mehra [1994] introduced here only budget deficit, in our case, however, the current account appears to be equally important, since the largest part of our sample covers the period of currency peg, when persistent imbalance on the external account could be observed.

The following investment and savings functions are postulated, in order to give a simplified summary of the way these aggregates depend on economic fundamentals:

(S.6) $INV/GDP = a_1 + a_2 D\%(GDP) - a_3 RER$,

(S.7) $S/GDP = b_1 + b_2 RER$,

where

INV - real investment,
GDP - real income,
S - real savings,
D%(X) - percentage change in X.

The investment function includes an accelerator mechanism coupled with real interest rate effects. Also the savings function includes the real rate.

The equilibrium rate satisfies the identity:

(S.8) $\quad S - INV = GDEF + CurrB,$

where

GDEF - real government budget deficit,
CurrB - real current account balance.

Substituting (S.6) and (S.7) into (S.8) and solving for RER we obtain:

(S.9) $RER = [\,(a_1 - b_1) + a_2\, D\%(GDP) + (GDEF + CurrB)/GDP\,]/(a_3 + b_2).$

Thus, according to our model, the budget deficit and the current account surplus as well as accelerated growth of real output increase the demand for funds and push up the equilibrium interest rate.

The second component of the bond rate in (S.5) is the deviation of the market real rate from the equilibrium real rate, here interpreted as a result of monetary policy. Through open market operations the Central Bank affects the supply of money and, as a consequence, the money market rate. In the short run, changes in the nominal short rate of interest are directly translated into changes in the corresponding real rate. The effects of the Central Bank actions are here represented by the real money market rate. An increase in the latter can be expected, *ceteris paribus*, to affect the bond rate in the same direction.

(S.10) $\quad RLR - RER = k_4\, RSR.$

The third component of the bond rate in (S.5) is the difference between the nominal and the (market) real rates. This difference is by definition due to anticipated inflation. Since the latter variable cannot be measured directly, we express the difference between the nominal and the real rates as a multiple of our indicator of the expected rate of inflation:

(S.11) $\quad RL - RLR = k_5\, INF^e,$

where

INF^e - expected inflation rate.

Substituting (S.9), (S.10) and (S.11) into (S.5) and introducing new symbols for the coefficients in (S.9) we obtain:

$$\text{(S.12)}\quad RL = k_1 + k_2\,D\%(GDP) + k_3\,(GDEF+CurrB)/GDP + k_4\,RSR + k_5\,INF^e\,.$$

According to our model, the bond rate depends on the real growth rate, the relation of the budget deficit and the current account balance to GDP, inflationary expectations and the real money-market rate.

Equations (S.2'), (S.4') and (S.12) constitute three long-term relations corresponding to the three models described above. The actual bond-rate equations will be estimated in the error-correction form, to allow for gradual portfolio adjustment and information lags.

DATA PROBLEMS AND DATA DEFINITIONS

Estimation of the bond rate equations was made difficult by the fact that the period covered by our data includes a process of gradual deregulation and transformation of the Swedish financial sector. On September 22, 1983, the liquidity ratio requirement, forcing banks to invest in priority (low-interest) housing and government bonds, was abolished. On September 20, 1984, a similar requirement from the insurance companies and the National Pension Fund (*AP-Fonden*) was limited to comprise only the purchase from the issuing agent. The requirement was abolished altogether in December 1986. On May 13, 1985, the recommended average bank lending rate was taken away. Finally, on November 21, 1985, the bank lending regulation was abolished and the Central Bank interest rate scale was introduced. Furthermore, on June 1, 1989, exchange controls were abolished. Some years later, on November 19, 1992, a long period of basket peg for the Swedish krona came to an end and the currency was floated.

Since the deregulatory measures listed above significantly changed the choice possibilities of the agents and thus, potentially, their behaviour, we have decided to exclude the period prior to 1986 from our sample. (The abolition of exchange controls was given here less importance, due to the limited effectiveness of the legislation in the final period.) This left us with 18 semiannual observation - far too little to draw any significant conclusions about the behaviour to be modelled. Consequently, and analogously to the case of the exchange rate equation, the bond rate equation was estimated on quarterly data and than transformed into the semiannual form (see below).

The thirty six quarterly observations at our disposal are in our opinion still not sufficient as a stable base for statistical inference. Furthermore, and most importantly, the period under study (1986-94) is exceptionally ill-suited for any attempts to unveil stable behavioural patterns. Our ambition in estimating the bond rate equation was therefore, as in the case of the exchange rate, to obtain reasonable reaction patterns rather than to identify stable long-run relations.

The bond rate (RL) is represented by the effective rate on five-year government bonds (percentage points, p.a.). The money-market (short-term) rate (RS) is the (discount) rate on three-month treasury notes (percentage points, p.a.). The real rate of interest (RSR) is defined as the short rate adjusted for the percentage change in the price level over the four quarters ending in the current one. The annualised rate of inflation during the current quarter (as opposed to the four-quarter number) was judged to show too much volatility. The price level is defined as the implicit deflator for private consumption expenditure. The development of the interest rates is illustrated in Chart X.1.

The supply of bonds (B) is represented by the total stock of bonds denominated in SEK, owned by both residents and non-residents. The resident-owned stock was computed from the Financial Accounts (*Finansräkenskaper*), while the non-resident owned stock is based on the current account data from the Riksbank. The SEK financial wealth (W) is approximated by the sum of bonds and (short term) certificates, the latter stock being defined and computed analogously to the stock of bonds.

Real income in the loanable funds model (GDP) is defined as the real GDP. The ratio of the sum of budget deficit and current account surplus to GDP was computed using the variables in nominal terms. The variables included in the ratio were expressed as four-term moving averages (with three lagged terms) to eliminate seasonal variation and better reflect the way this ratio is generally perceived. The budget deficit is here defined as government borrowing requirement. Its ratio to the GDP is illustrated in Chart 2.

Quarterly long-term-bond interest rate equation

Four expectation formation mechanisms for the inflation rate were considered: static expectations, adaptive expectations, rational expectations and a backward-looking

Chart X.1 Nominal long (solid line) and short (dashed line) rates
and real short rates of interest (dotted)

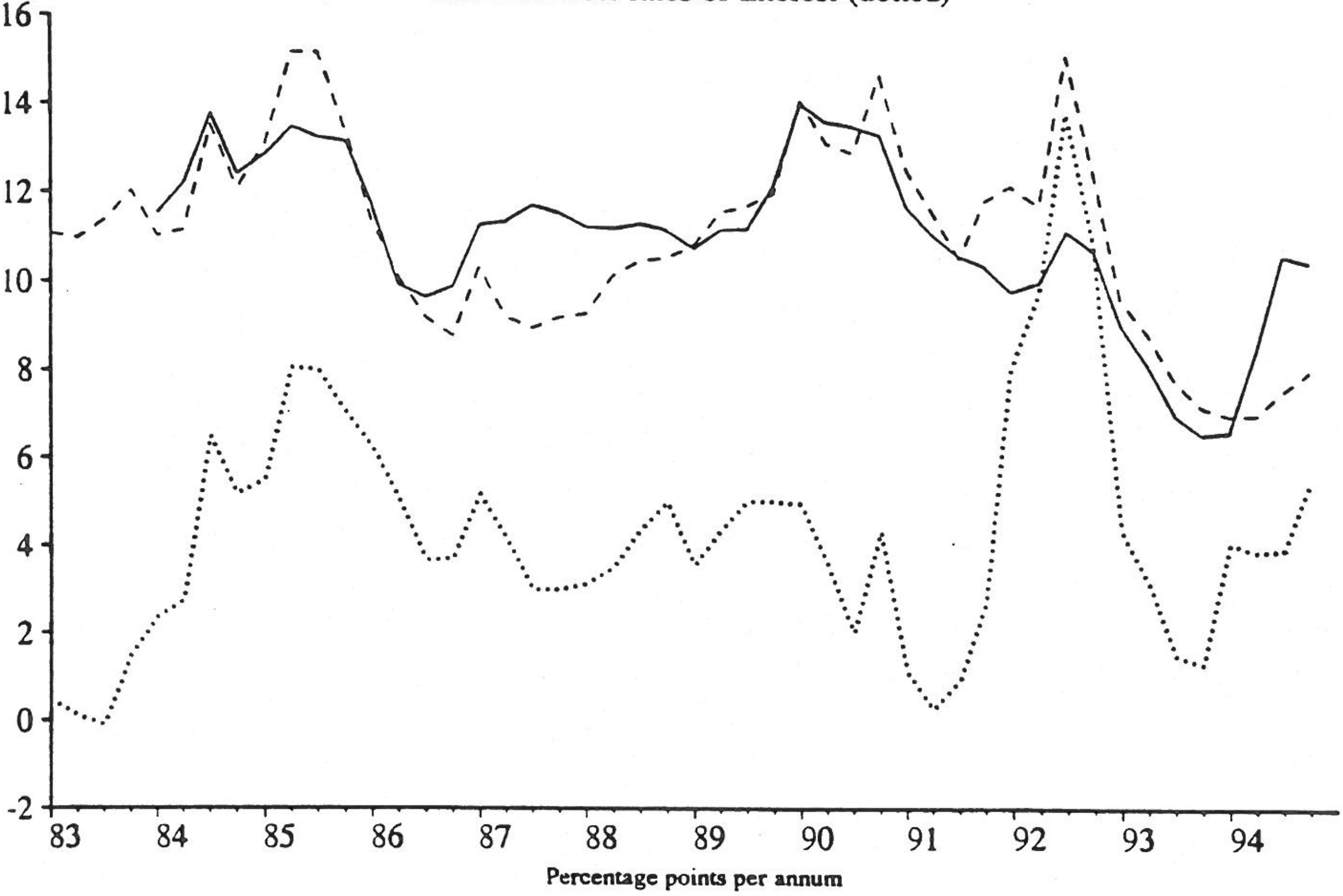
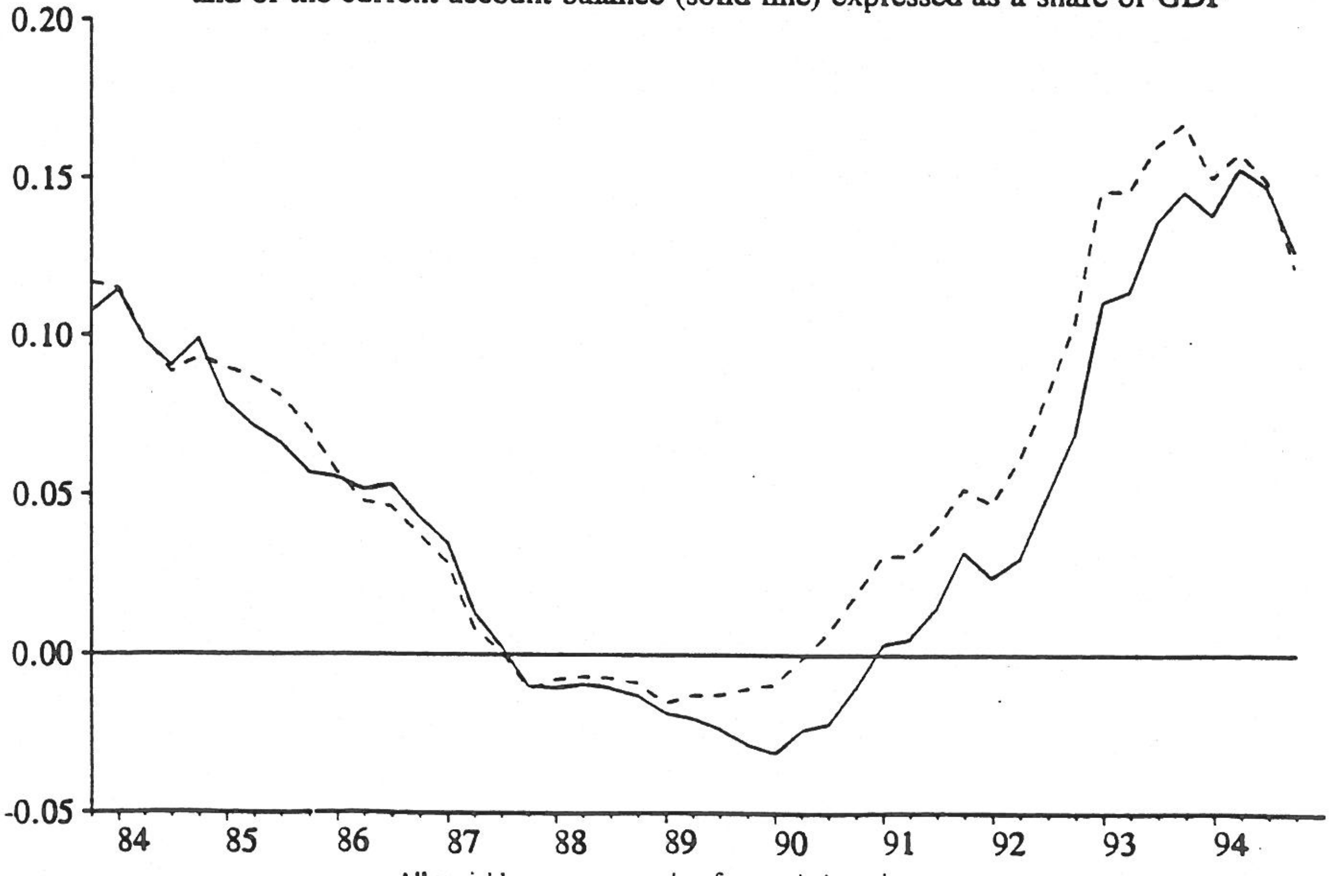


Chart X.2 Government borrowing requirement (dashed line) and the sum of the former
and of the current account balance (solid line) expressed as a share of GDP



All variables are expressed as four-period moving averages.

approach where a separate expectations equation was introduced based on an inverted money demand relation. The first of the above approaches gave by all standards the best results. In particular, rational expectations - with lead values of actual inflation substituted for the expected values - resulted in erroneous timing of most turning points.

Below, we assume that inflationary expectations are static (above a minimal level) as long as the government debt is constant. When the government debt is increasing, expected inflation accelerates. The minimum expected inflation level depends on the average level of the government debt.

In the estimated equations, the government debt is divided by the nominal GDP, the latter being expressed as four-term moving average (analogously to the denominator in the ratio of the sum of budget deficit and current account surplus to GDP, described above). Preliminary estimation indicated that the government debt ratio has the greatest explanatory power when it is lagged by two quarters. This appears to correspond well to the apparent information lag observed in the press in the discussion on the financial investors' confidence in the Swedish economy.

The assumed expectations formation mechanism is formalised as:

(S.13) $INF^e = \Sigma\, INF^e_{+j}/T = v_1 + v_2\, INF + v_3\, (GDEBT/GDP)_{-2},$

where

GDEBT - total government debt,
GDEBT/GDP - ratio of government debt to (seasonally adjusted) GDP ,
v_i - constant coefficients ($i = 1, 2, 3$).

Consequently, in equations (S.2') and (S.4'), respectively,

(S.14) $(INF + \Sigma\, INF^e_{+j})/T = h_1 + h_2\, INF + h_3\, (GDEBT/GDP)_{-2},$

(S.15) $D(INF^e) = INF^e - g_2\, INF = z_1 + z_2\, INF + z_3 (GDEBT/GDP)_{-2},$

where

h_i, z_i - constant coefficients ($i = 1, 2, 3$).

Dickey-Pantula tests (cf. Dickey and Pantula [1987]) indicate the following variables to be I(1): RL, RS, INF, D%(GDP) and (GDEF+CurrB)/GDP. The latter variable is "accepted" as I(1) only at 10% level. The first differences of the above variables as well as the real rate of interest (RSR) and the ratios of the bond stock to financial wealth (B/W) and of government debt to GDP (GDEBT/GDP) are according to the test results I(0). It should, however, be noted that the development of the three latter variables is not entirely typical of stationary series, as each of them exhibits a deep trough or (in the case of the real rate) a peak, during the period under study. In view of this, and since unit root tests based on eight years (35 observations) are not reliable, the three variables RSR, B/W and GDEBT/GDP will be treated below as non-stationary, until further evidence is obtained.

Below, we first report OLS estimation results for equations (S.2'), (S.4') and (S.12), respectively. While analysing the equations, it should be borne in mind that all the variables except log(B/W) are expressed in percentage points per annum.

(S.16)

```
RL - RSR

 =    1.28194 * INF + 0.12600 * 100*(GDEBT/GDPLma)_-2 + 6.25354
     (16.8222)          (6.62382)                          (37.0970)

Sum Sq      33.7590   Std Err      1.0114   LHS Mean    6.2535
R Sq         0.8984   R Bar Sq     0.8923   F  2, 33  145.962
D.W.( 1)     0.8205   D.W.( 4)     1.9107   Est. per. 1986:1-94:4
```

where

INF - year-on-year (i.e. between quarter t and quarter t-4) percentage change in the implicit deflator for consumer expenditure,

RSR = RS - INF ,

GDPLma = $(GDPL + GDPL_{-1} + GDPL_{-2} + GDPL_{-3})$,

GDPL - current-price gross domestic product,

RL and RS are defined in the preceding section

and both INF and (GDEBT/GDPma) are expressed as deviations from their sample means (amounting to 6.1299 and 0.5835, respectively).

Since both explanatory variables in the expectations equation (S.16) are expressed as deviations from their sample means, the equation implies an average expected inflation (RL - RSR) of 6.25% per annum (when the two variables are equal to their sample means). When the two variables are equal to zero, the equation implies a negative expected inflation rate. This is also the case in the next equation, which - as explained below - is very similar to (S.16), but where the explanatory variables are not expressed as deviations from the mean.

(S.17)

$$\dot{RL} - RS$$

$$= \underset{(2.84927)}{0.24282} * INF + \underset{(2.71197)}{0.09791} * 100*(GDEBT/GDPLma)_{-2}$$

$$+ \underset{(0.87199)}{3.81913} * \log(B/W) - \underset{(2.06278)}{6.35270}$$

Sum Sq	29.9743	Std Err	1.0347	LHS Mean	-0.0659
R Sq	0.5140	R Bar Sq	0.4619	F 3, 28	9.8717
D.W.(1)	0.8069	D.W.(4)	1.5866	Est. per.	1986:1-93:4

where

B/W - share of bonds in the stock of bonds and (short-term) certificates defined in the preceding section.

The preferred habitat equation, (S.17), was estimated over a shorter period, due to lack of data on financial stocks. Inclusion of the change in the current inflation rate instead of its level did not improve the fit of the equation. The contribution of the supply term, log(B/W), to the equation's explanatory power is negligible by all standards; consequently the preferred habitat equation reduces to the expectations equation (this can be seen when INF is moved from the dependent variable to the right-hand side of the equation). We can conclude that the supply term carries the same information as the inflation rate and the government debt. This might explain why Taylor [1992], who included *only* the supply term, obtained "encouraging" results in his equation for the U.K.

(S.18)

$$RL - INF$$

$$= \underset{(21.1930)}{0.84606} * RSR + \underset{(6.18138)}{0.46384} * D\%(GDP) + \underset{(2.49313)}{0.07113} * (DEFma/GDPLma)$$

Sum Sq	34.8082	Std Err	1.022	LHS Mean	4.5127	Res Mean	0.097
R Sq	0.8278	R Bar Sq	0.8173	F 3, 33	52.8624	%RMSE	53.88
D.W.(1)	1.1332	D.W.(4)	2.2806	Est. per.	1986:1-94:4		

where

$D\%(GDP)$ - year-on-year (i.e. between quarter t and quarter t-4) percentage change in real GDP,

GDP - real gross domestic product,

$DEFma = 100 * (DEF + DEF_{-1} + DEF_{-2} + DEF_{-3})$,

DEF - sum of the government borrowing requirement and the current account surplus, $DEF = GDEF + CurrB$.

In the loanable-funds equation, (S.18), the government debt variable was excluded, as it largely carried the same information as the budget deficit. The coefficient of the (expected) inflation was set to one (it was 1.02 in free estimation). This specification is desirable for theoretical reasons, since it ensures that the Fisher equation is satisfied in the model (the remaining explanatory variables being supposed to affect the real rate). The intercept in the equation was set to zero, as its contribution to the fit was negligible. This allowed us, at the same time, to obtain a positive coefficient for the DEFma/GDPLma term.

Neither of the above long-run relations passed the augmented Dickey-Fuller cointegration test. However, given the character of the sample period, mentioned above, we are inclined to take an agnostic view of the longer-term validity of the postulated models.

Since our non-financial variables summarise information which in reality is available only gradually or with a time lag and, furthermore, since adjustment to interest-rate changes may be gradual, the three equations were also estimated in the error-correction form. The short-run bond rate equation was then estimated together with the long-run relation using the so called ADL approach. The OLS results were as follows:

(S.19)

$$D(RL - RSR) = \underset{(12.2756)}{1.22349} * D(INF) - \underset{(3.55003)}{0.42517} * (RL_{-1} - RSR_{-1})$$

$$+ \underset{(2.94608)}{0.50027} * INF_{-1} + \underset{(3.21834)}{0.06286} * 100*(GDEBT/GDPLma)_{-2} - \underset{(2.67815)}{4.01694}$$

Sum Sq	18.9601	Std Err	0.7821	LHS Mean	-0.0306
R Sq	0.8485	R Bar Sq	0.8290	F 4, 31	43.4145
D.W.(1)	2.2645	D.W.(4)	2.2872	Est. per,	1986:1-94:4

where

$$D(X) = X - X_{-1}.$$

(S.20)

$$D(RL - RS)$$

$$= \underset{(1.64741)}{0.18492} * D(INF) - \underset{(2.94745)}{0.40416} * (RL_{-1} - RS_{-1})$$

$$+ \underset{(0.67547)}{0.05513} * INF_{-1} + \underset{(1.57830)}{0.04418} * 100*(GDEBT/GDPLma)_{-2}$$

$$+ \underset{(0.40363)}{1.41625} * \log(B/W)_{-1} - \underset{(1.05308)}{2.57883}$$

Sum Sq	17.4693	Std Err	0.8044	LHS Mean	-0.0031
R Sq	0.3184	R Bar Sq	0.1922	F 5, 27	2.5231
D.W.(1)	2.3239	D.W.(4)	2.1768	Est. per,	1986:1-94:1

The expectations and preferred-habitat equations in the error-correction form are generally rather similar to their long-run counterparts. However, their adjustment towards equilibrium is far from instantaneous, the adjustment coefficients being around 0.4. The long-run solutions to equations (S.19) and (S.20) do not pass the augmented Dickey-Fuller cointegration test.

The fit of equations (S.19) and (S.20) is illustrated in Charts X.3 and X.4, respectively. It should be noted that the actual values in the charts show the respective dependent variables (which in this case differ) rather than the bond rate.

(S.21)

$$D(RL)$$

$$= \underset{(5.67720)}{0.72623} * D(INF) + \underset{(6.26820)}{0.54608} * D(RSR)$$

$$- \underset{(3.05144)}{0.32921} * (RL_{-1} - INF_{-1}) + \underset{(2.68253)}{0.25328} * RSR_{-1}$$

$$+ \underset{(3.62020)}{0.23605} * D\%(GDP)_{-1} + \underset{(3.25823)}{0.06424} * (DEFma/GDPLma)_{-1}$$

Sum Sq	10.349	Std Err	0.5846	LHS Mean	-0.074	Res Mean	-0.05
R Sq	0.6588	R Bar Sq	0.6019	F 6, 30	9.6543	%RMSE	308.39
D.W.(1)	1.5867	D.W.(4)	2.1057			Est. per.	1986:1-94:4

Chart X.3 Actual (solid line) and fitted (dashed line) values for the expectations theory equation

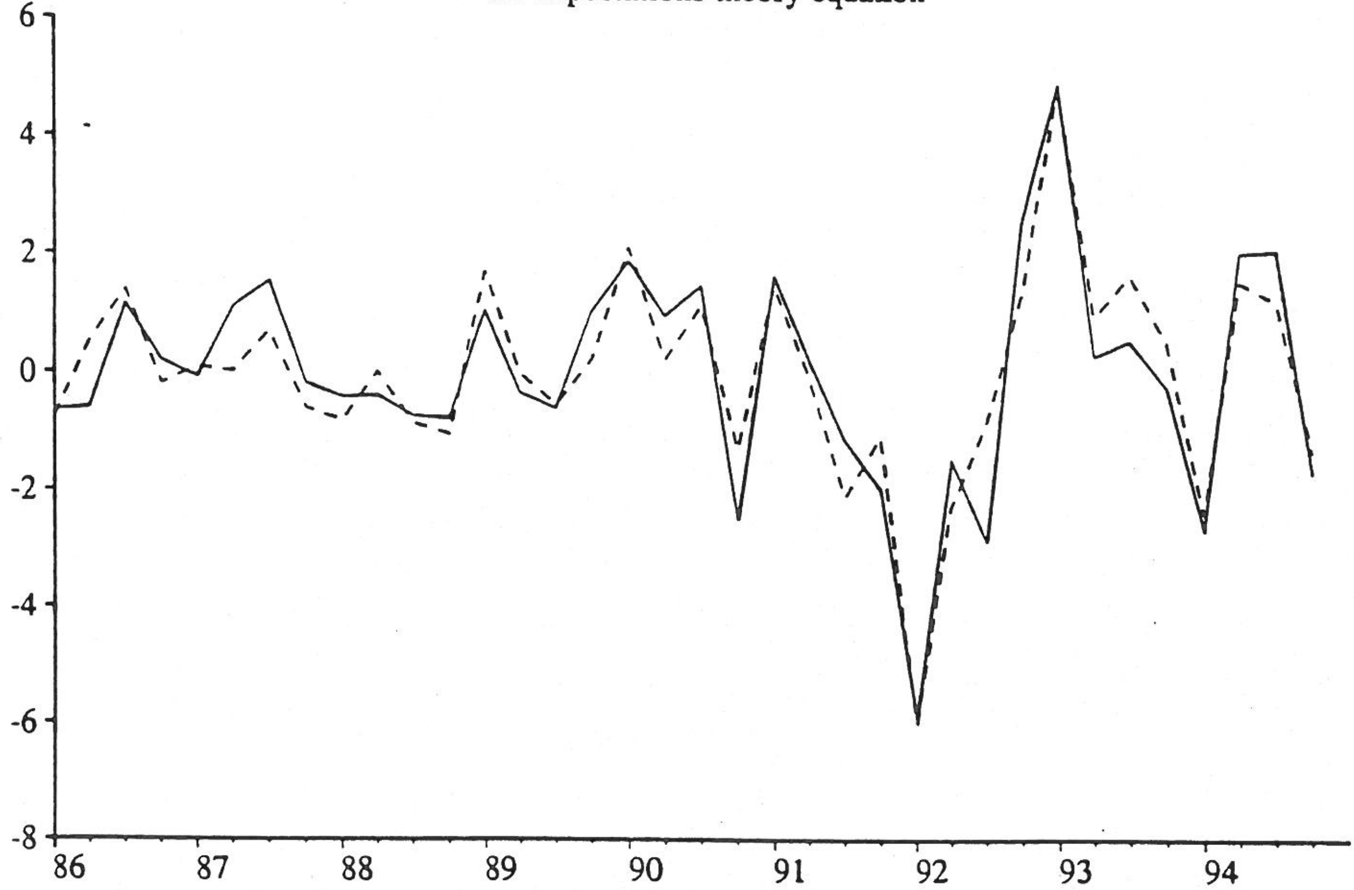
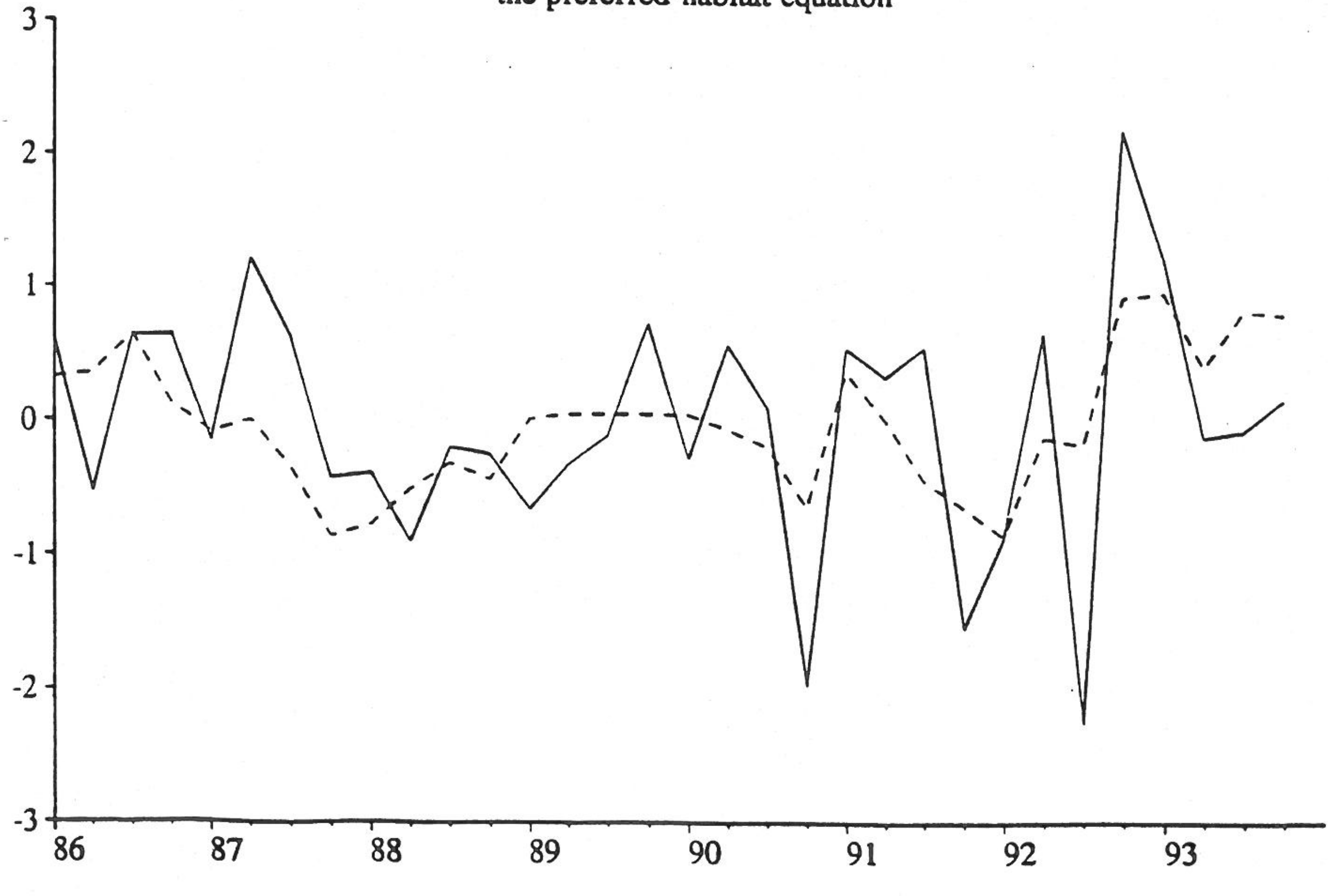


Chart X.4 Actual (solid line) and fitted (dashed line) values for the preferred-habitat equation



The fit of equation (S.21) is illustrated in Chart X.5 (again, with the actual values showing the dependent variable rather than the bond rate). The equation implies the following long-run solution to the loanable funds model:

(S.22)

$$RL = INF + 0.769\ RSR + 0.717\ D\%(GDP) + 0.195\ (DEFma/GDPLma)\ .$$

This long-run solution passes the augmented Dickey-Fuller test at 5% level, the test statistic being -4.19.

According to equation (S.22), in the long run approximately 75% of the effects of monetary policy (as shown by the real rate) are passed on to the bond rate. An increase of the long-run real growth by one percentage point gives rise to an increase of the bond rate by around 0.7 percentage point. An increase of the long-term government borrowing requirement or the current account surplus by one percentage point in terms of the GDP, results in the bond rate 0.2 percentage point higher than it otherwise would be. Finally, the expected long-run inflation is fully passed on to the bond rate.

The ex post forecasts for the level of the bond rate, derived from the fitted values of the estimated equations, are compared in Chart 6. Only the expectations and loanable-funds equations are shown, since the preferred-habitat equation reduces to the former. As can be seen from the chart, the loanable funds equations appears to trace the bond rate somewhat better than the expectations equation. Other factors in favour of this model are the better statistical properties of the implied long-run solution and the fact that it directly ties the bond rate to economic fundamentals. Thus, equation (S.21) is the preferred one.

Semiannual long-term-bond interest rate equation

The semiannual bond rate equation was obtained analogously to the half-yearly exchange rate equation (cf. the section on the semiannual exchange rate equation). The quarterly equation was summed for two consecutive periods and then adapted to allow for the definition of semiannual data and the length of the time period.

Changes in quarterly variables became, after summation, changes over two quarters and were - after semiannual averages had been substituted for quarterly data - interpreted as semiannual changes lagged by 0.25 half-year.

Chart X.5 Actual (solid line) and fitted (dashed line) values for the loanable-funds equation

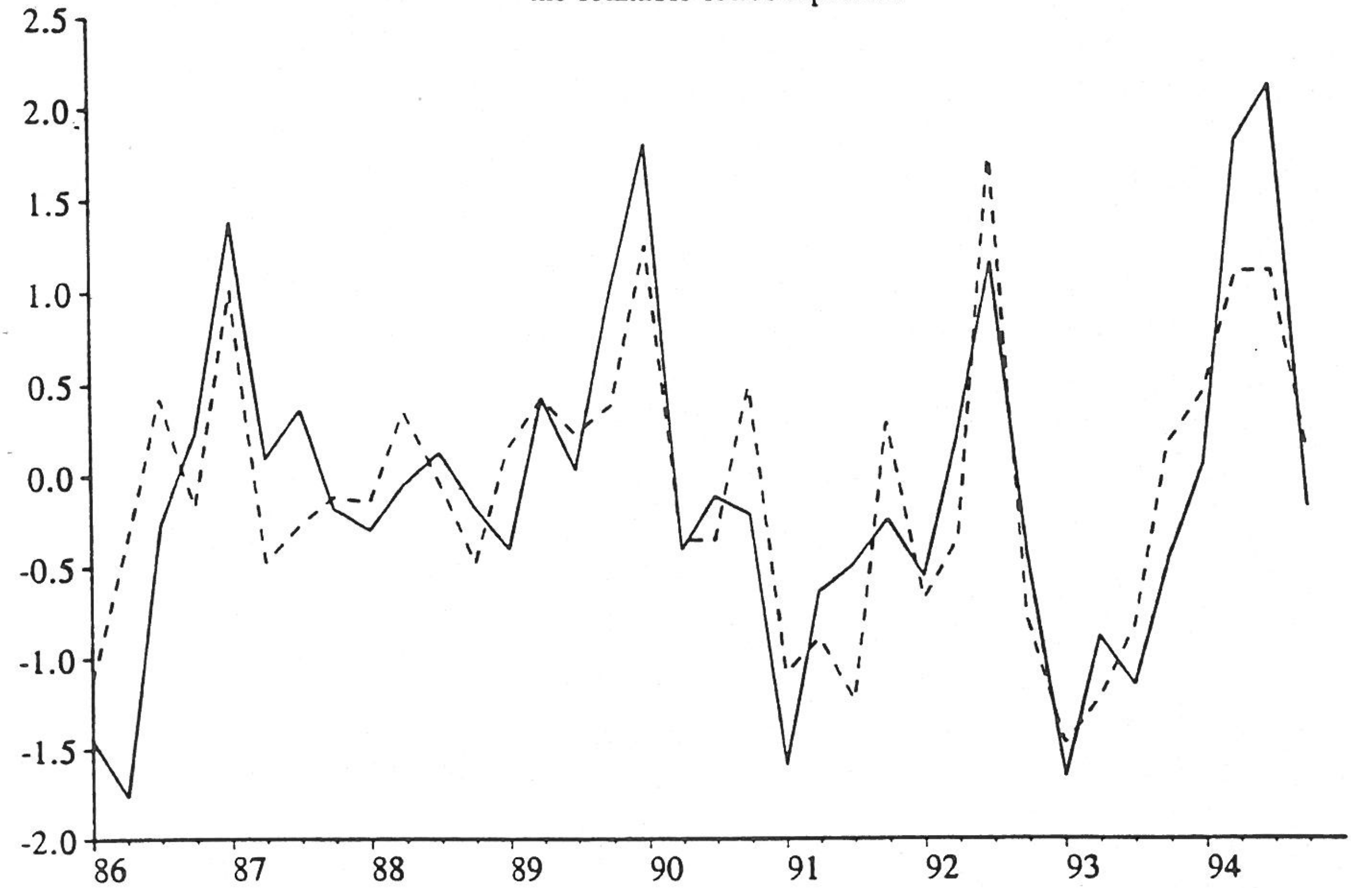
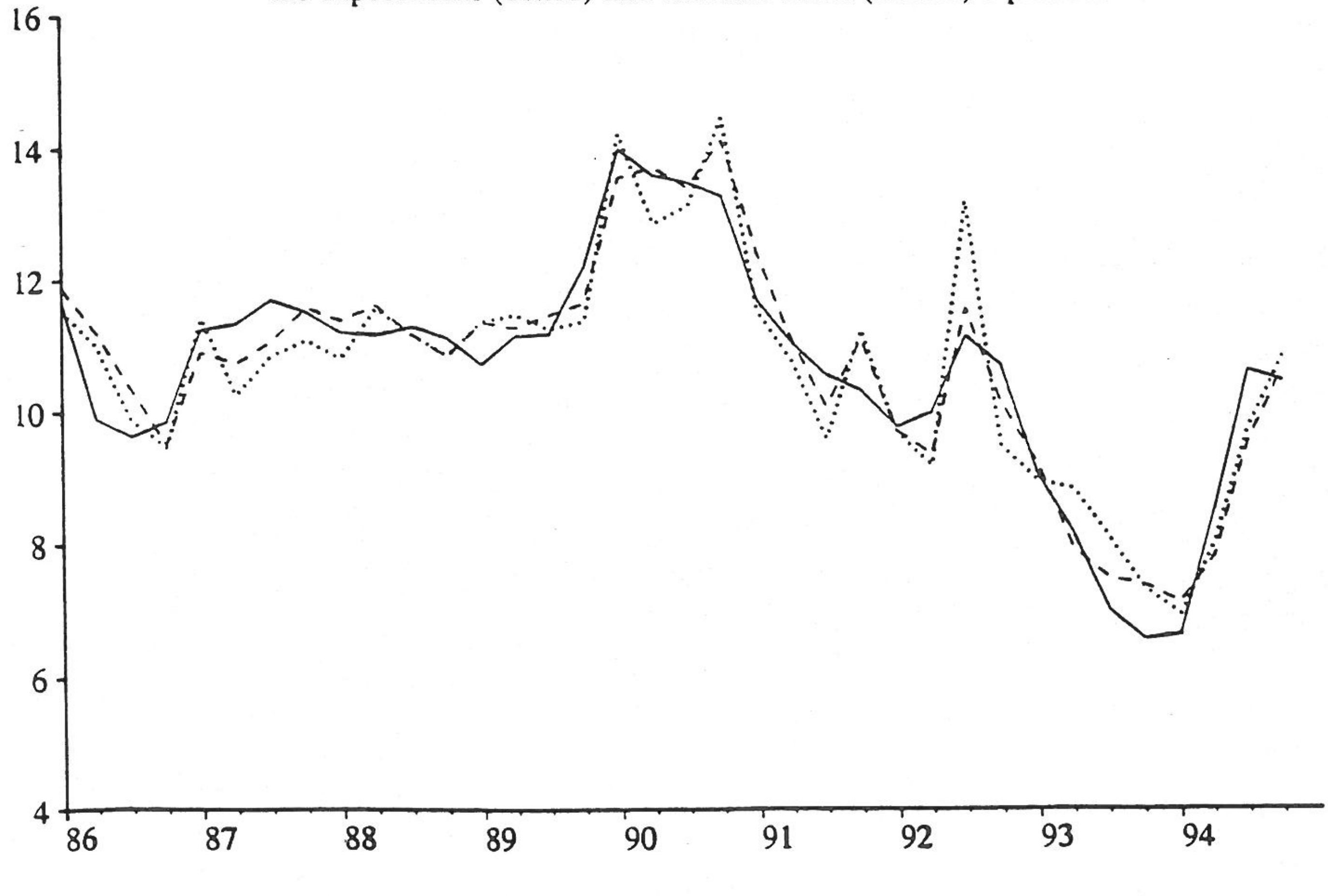


Chart X.6 Long interest rate level (solid line) and its fitted values derived from the expectations (dotted) and loanable-funds (dashed) equations



Semiannual averages were multiplied by 2, to obtain sums of two quarters. The year-on-year percentage change in GDP (i.e. D%(GDP)) was replaced by the corresponding value based on semiannual data, both providing an annual rate of change. Four-quarter moving averages in DEFma/GDPLma were, in the half-yearly equation, substituted by two-term ones, to retain an annual ratio. The two latter variables were multiplied by 2, as an approximation of the sum of their two consecutive quarterly values, required by the semiannual equation. Finally, the lags were adjusted to approximate the lag structure of the sum of two quarterly equations (including the lag introduced by the semiannual definition of the dependent variable).

The half-yearly equation had the following general form:

(S.23)

$$D(RL) = k_1\, D(INF) + k_2\, D(RSR) + 2\, k_3\, (RL_{-1} - INF_{-1}) + 2\, k_4\, RSR_{-1} + 2\, k_5\, D\%(GDP)_{-1} + 2\, k_6\, (DEFma/GDPLma)_{-1}\,,$$

where all variable names refer to semiannual aggregates and the coefficients k_i ($i=1,2,...,6$) are equal to the corresponding coefficients in the quarterly equation (S.21).

In the above semiannual approximation of the quarterly equation (S.21), the coefficient k_3 does not allow for the fact that the lagged quarterly bond-rate values, which in aggregation are added together, depend on each other through the quarterly error-correction mechanism. The ex-post predictions from equation (S.23), using the coefficients from equation (S.21), are illustrated in Chart X.7 .

Treatment of expectations in simulations

The sample period at our disposal is too short and too turbulent to make inference about the expectations formation mechanism. Nevertheless, the assumption of static expectations appears to work relatively well in the present context, where our attempts to employ rational expectations and rather sophisticated backward-looking schemes failed. Mehra [1994] also reports satisfactory results with static expectations.

Meanwhile, even if expectations generally were not formed in a rational manner (in the sense of being on average correct), it is obvious that the agents would react to information about the future. For example, legislative changes announced in advance may affect financial markets before the legislation comes into effect.

Chart x.7 Actual half-yearly values for the change in bond rate (solid line) and the ex-post predictions from the derived semiannual equation (dashed line)

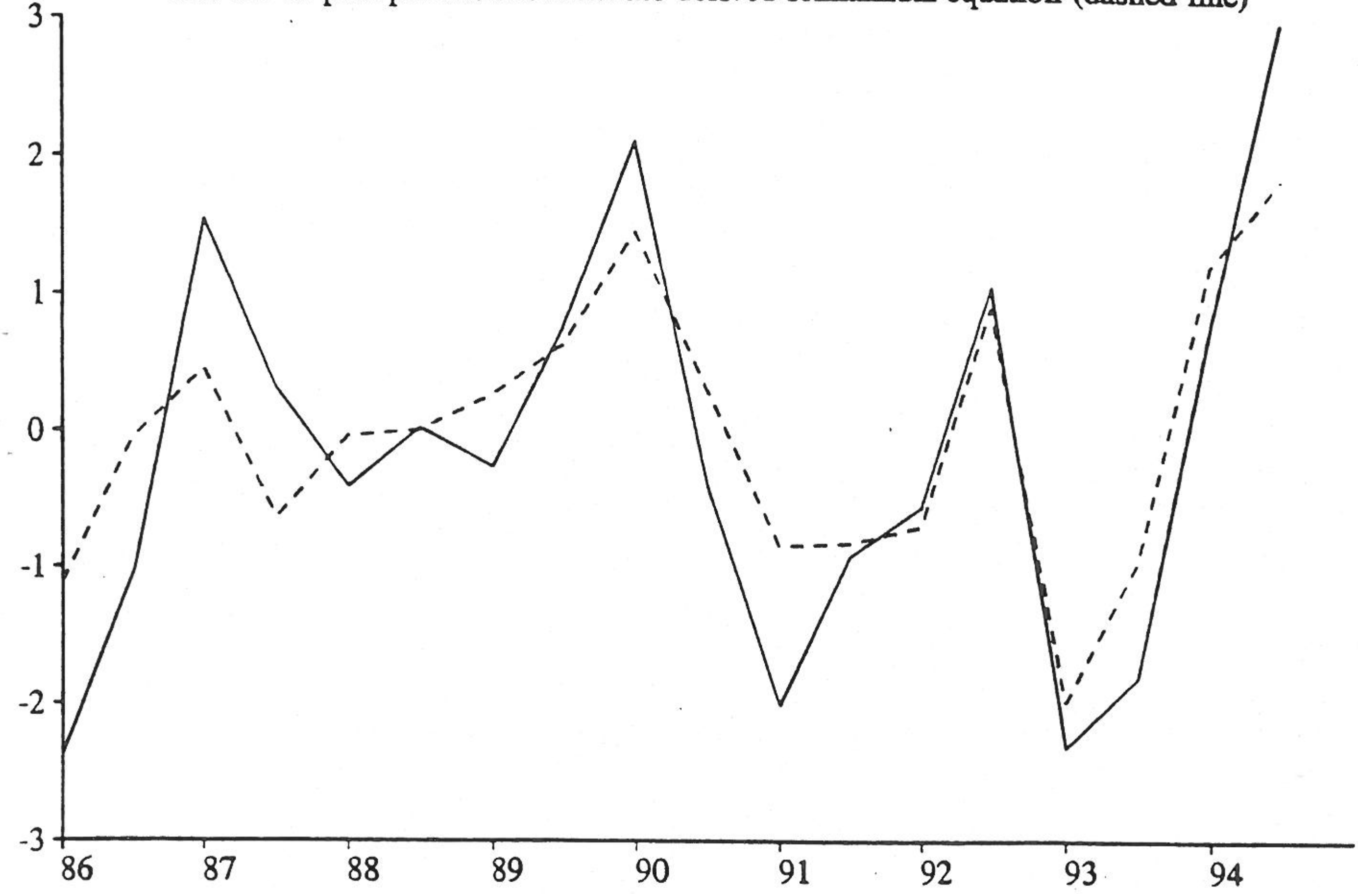
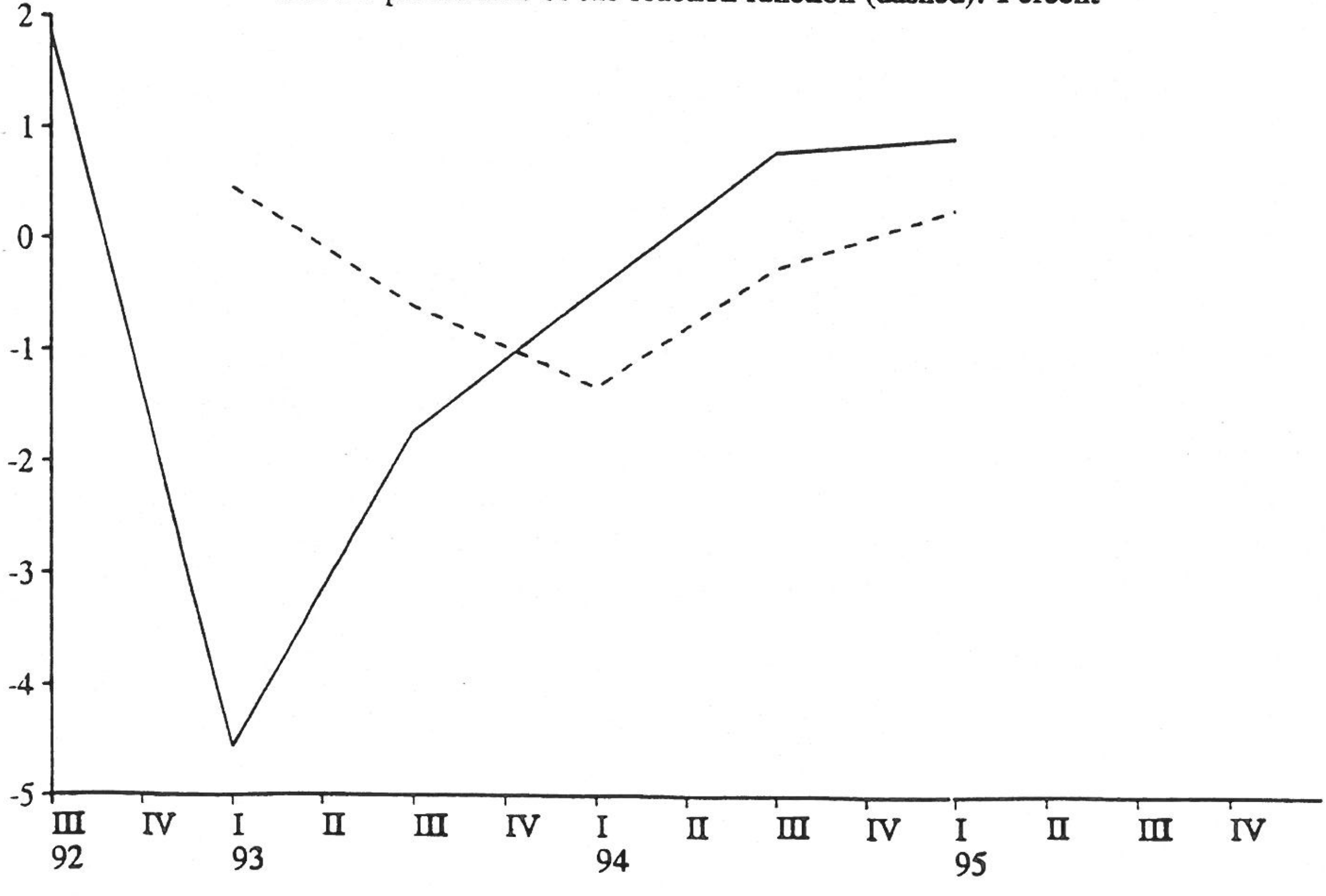


Chart X.8 Actual changes in the money-market rate (solid line) and the predictions of the reaction function (dashed). Percent



The expectations variable is explicitly specified in equation (S.12) and - consequently - in equation (S.21). This paves the way for employment of any kind of expectations formation mechanism in simulations (including the so called model consistent expectations). In particular, static expectations can be modified to allow for any deviations due to information about the future. However, until more definite results about the actual expectations formation mechanism have emerged, such adjustments have to be introduced on a more or less *ad hoc* basis.

Determination of the (short-term) money-market interest rate

The (short term) money market rate of interest is here considered to be a policy parameter, which is exogenous to the model. It is assumed that this rate is controlled by the Central Bank. This is an approximation, since the short rate in the model is represented by the three-month treasury note rate, while the Central Bank in actual fact controls the two-weeks rate. The correlation between the two rates is, however, very high.

For the purposes of simulation, a Central-Bank reaction function is postulated below. This function should ensure a reasonable path for the short rate in all cases when the development of the interest rate cannot be uniquely determined in advance.

As the introduction of the floating exchange rate entailed new policy rules on the part of the Central Bank, data shortage currently makes econometric estimation of the reaction function rather meaningless (cf. the discussion of data problems in the chapter on exchange rate determination). However, even if data *were* available, experience from other countries indicates that we hardly could expect to estimate a simple function which adequately describes the behaviour of the Central Bank (cf. Easton [1985]).

It is postulated that the Central Bank primarily adjusts the short rate of interest in accordance with the changes in the corresponding foreign rate, here represented by the three-month Eurorate for the Deutsche Mark. In addition, the distance between the Swedish and the German rates is adjusted in response to the changes in the expected rate of inflation. Furthermore, adjustments are made as long as the *level* of the expected inflation rate differs from the Central Bank target, currently announced to be 2 per cent per year (we neglect here the band of 1 percentage point on both sides of the target). Finally, it is postulated that (much smaller) adjustments are made as long as the effective exchange rate differs from the equilibrium rate:

(S.24)

$$D(RS) = D(RSG) + 0.2\ D(INF^e) + 0.2\ (INF^e - 2) + 0.02\ (vx_{-1} - vxe_{-1})/(vxe_{-1}),$$

where

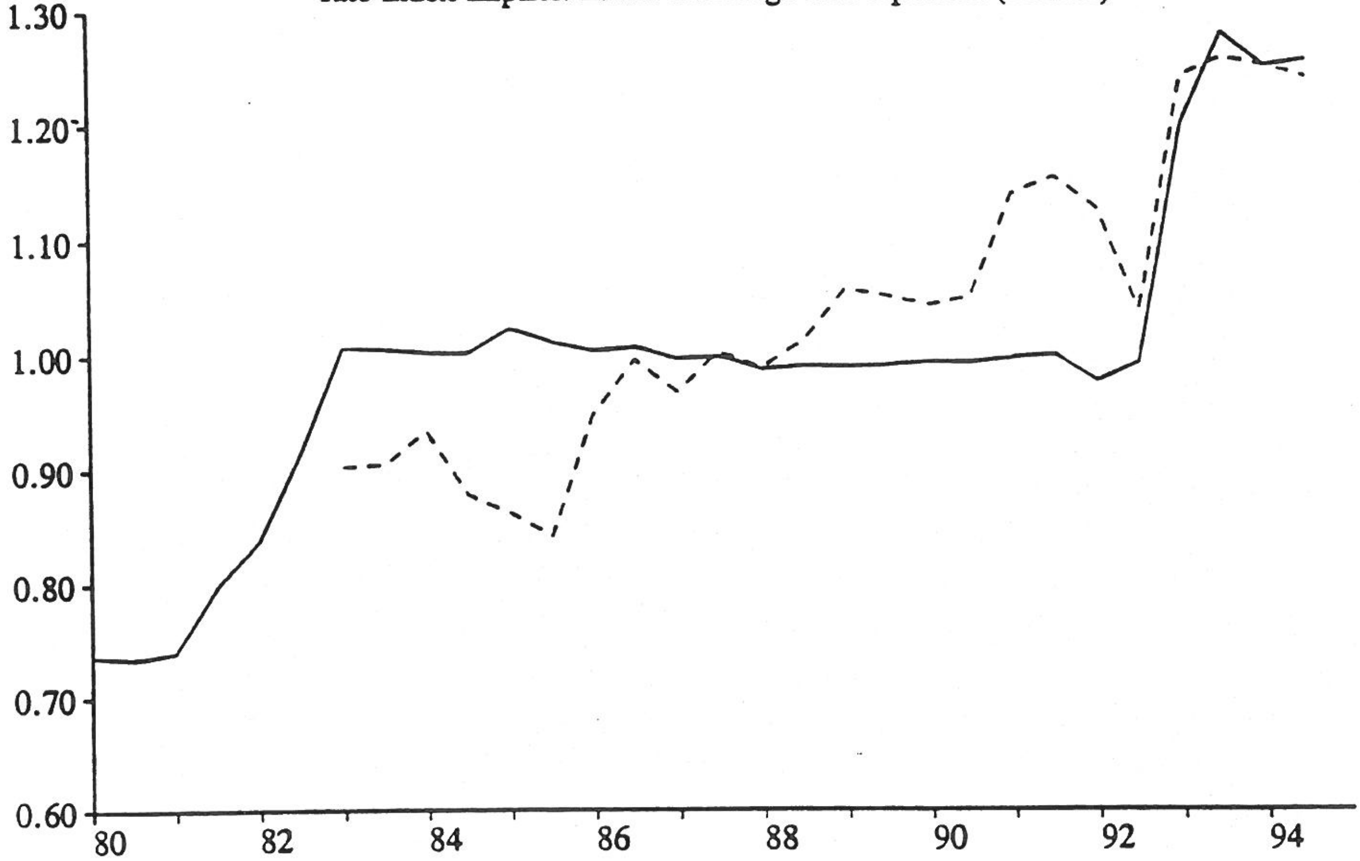
RSG - German money-market rate (Euro-Deutschmark rate),
vx - effective exchange rate,
vxe - equilibrium exchange rate,
$D(X) = X - X_{-1}$,
and all the variable names refer to semiannual aggregates.

Assuming - as above - static expectations, the expected (annual) inflation rate is defined in terms of semiannual aggregates as the sum of the current and directly preceding semiannual percentage changes in the implicit deflator for consumer expenditure. An alternative would be to take the year-on-year percentage change for the current half-year. The (monthly) equilibrium exchange rate is given by equation (Y.12') in the chapter on exchange rate determination. The semiannual equilibrium rate is computed, in accordance with the method employed above, by directly applying equation (Y.12') to semiannual data. The equilibrium exchange rate, thus computed, is shown together with the actual rate in Chart X.9.

The coefficients in equation (S.24) were chosen *ad hoc*, such that the result would not deviate too much from the actual development of the money-market rate in 1993-94 (cf. Chart X.8).

According to the postulated reaction function, the short-term rate follows the changes in the German money-market rate. The rate is also increased by 0.2 percentage points each time the inflation rate accelerates by one percentage point. In addition, the short rate is increased by another 0.2 percentage points when the inflation rate exceeds the 2 per cent target by one percentage point (i.e. when the inflation rate is 3%). This addition is made every half-year as long as the inflation rate remains above the target. Finally, still another increase by 0.2 percentage points per half-year is introduced when the local currency is undervalued by 10%, compared to the equilibrium exchange rate (recall that the exchange rate is expressed in SEK per unit of foreign currency). The latter effect is lagged by one period, mainly to limit the simultaneity of the model.

Chart X.9 Actual effective exchange rate index (solid line) and the equilibrium exchange rate index implicit in the exchange rate equation (dashed)



The exchange rate index is expressed in SEK/foreign currency.

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EKVATION FÖR OBLIGATIONSRÄNTA

SVENSK SAMMANFATTNING

Ränteekvationen utgår från en real jämviktsränta, som bestäms på den gemensamma marknaden för alla lån. Den långa marknadsräntan avviker sedan från den reala jämviktsräntan på grund av två faktorer: centralbankens interventioner på penningmarknaden samt inflationsförväntningar.

Jämviktsräntans bestämningsfaktorer erhölls från ekonomins finansiella sparandeidentitet under antagandena att sparandets andel av BNP är en funktion av realräntan samt att investeringarnas andel av BNP beror på realräntan och BNPs tillväxttakt. Penningpolitikens effekter antogs vara proportionella till den korta realräntan, eftersom det är den som påverkas av Riksbankens interventioner på penningmarknaden.

Efter substitution erhöll man ett långsiktssamband där den långa räntan förklaras av real BNP-tillväxttakt, kort realränta, inflationsförväntningar samt summan av budgetunderskott och bytesbalanssaldo i relation till BNP. Ekvationen skattades på kvartalsdata och transformerades sedan till en approximativ halvårsform.

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