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Economics Department
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From Policy Rate to Market Rates: An Empirical Analysis of Finnish Monetary Transmission

SUOMEN PANKIN KESKUSTELUALOITTEITA • FINLANDS BANKS DISKUSSIONUNDERLAG

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Abstract

In this paper we analyse the empirical relevance of the mechanisms through which the Bank of Finland's actions are transmitted to the Finnish economy. We concentrate on the first stage of the monetary policy transmission mechanism; namely, the effect of the Bank's actions on domestic market interest rates and the exchange rate. The questions we analyse include: What is the impact of a change in the Bank of Finland's one month tender rate on interest rates of longer maturities and on the exchange rate? How do Finnish interest rates and the exchange rate react to turmoil in foreign money and bond markets? To what extent can recent developments in Finnish interest rates be attributed to the Bank of Finland's policies?

We find that the effect of a monetary policy shock is limited to the short end of the yield curve. Changes in the Bank of Finland's tender rate seem to signal the future path of short rates for a period of 1–2 years. On the other hand, Finnish bond rates appear to follow closely circumstances in the international financial market and do not seem to react systematically to changes in the Bank of Finland's tender rate. We find that monetary policy has contributed little to the large swings in Finnish bond rates experienced over the last few years. Most of the variation in bond rates can be attributed to changes in international long rates and changes in the perceived overall credibility of the Finnish economy.

Key words: monetary policy transmission, VAR-models, Finland

Tiivistelmä

Tutkimuksessa analysoidaan empiirisesti Suomen Pankin huutokauppakoron muutosten välittymistä Suomen talouteen. Työssä keskitytään välittymismekanismin ensimmäiseen vaiheeseen, eli Suomen Pankin toimien vaikutukseen markkinakorkoihin ja markan valuuttakurssiin. Tutkimuksessa haetaan vastausta muun muassa seuraaviin kysymyksiin: Miten muutokset Suomen Pankin huutokauppakorossa välittyvät pitemmän maturiteetin korkoihin? Miten Suomen markkinakorot ja valuuttakurssi reagoivat ulkomaisten korkojen muutoksiin? Miltä osin markkinakorkojen viime vuosien kehitys on seurausta Suomen Pankin toimista?

Tutkimuksen mukaan Suomen Pankin operaatioiden vaikutukset rajoittuvat korkokäyrän lyhyeen päähän. Muutokset huutokauppakorossa näyttävät välittävän informaatiota tulevien lyhyiden korkojen tasosta noin 12 vuoden tähtäimellä. Toisaalta Suomen pitkät korot näyttävät seuraavan läheisesti tapahtumia kansainvälisillä rahoitusmarkkinoilla, eivätkä reagoi systemaattisesti muutoksiin huutokauppakorossa. Tulosten mukaan rahapolitiikan välitön merkitys pitkien korkojen viime vuosien jyrkissä vaihteluissa on ollut vähäinen. Vaihtelut ovat ollet seurausta pääasiassa muutoksista kansainvälisissä pitkissä koroissa sekä Suomen talouden tilaa kohtaan tunnetussa luottamuksessa.

Asiasanat: rahapolitiikan transmissio, VAR-mallit, Suomi

Contents

1 Introduction

The mandate of the Bank of Finland is to safeguard the value of the Finnish markka. To fulfill this mandate, the Bank of Finland, as with all central banks in countries with liberal financial markets, is armed with an array of imprecise instruments. Under the current regime, the Bank of Finland only has control over very short-term interest rates. As one moves towards bonds with longer maturities, the influence of the Bank of Finland diminishes. Long-term yields and the floating exchange rate of the markka are determined by the market's expectations of the future performance of the economy and the future economic policies, both in Finland and abroad.

In this paper we try to shed some light on the empirical relevance of the mechanisms through which the Bank of Finland's actions are transmitted within the Finnish economy. We concentrate on the first stage of the monetary policy transmission mechanism; namely, the effect of the Bank's actions on domestic market interest rates and the exchange rate. The questions we analyze include the following: What is the impact of a change in the Bank of Finland's one month tender rate on interest rates of longer maturities and on the exchange rate? How do Finnish interest rates and the exchange rate react to turmoil in foreign money and bond markets? To what extent can the recent developments in Finnish interest rates be attributed to the Bank of Finland's policies?

The analytical tool we employ is a variant of the popular structural vector autoregression (VAR), or more precisely a structural vector-error-correction approach. Ideally, the analysis of the transmission mechanism of monetary policy would be conducted within the framework of a fully specified dynamic macroeconomic model capable of producing plausible policy simulations and forecasts. However, policy actions are transmitted to the financial markets through various mechanisms, many of which depend heavily on expectations. The structural macroeconomic description of these mechanisms would be highly complicated and, in the fully structural form, possibly not identifiable.

Our analysis indicates that monetary policy shocks, defined as innovations to the Bank of Finland's tender rate, have a statistically significant effect only at the short end of the yield curve. Bond rates and the exchange rate do not seem to react systematically to changes in policy rates; rather they seem to be affected mainly by international bond rates and the overall credibility of Finnish economic policy.

When interpreting the results, two remarks should be kept in mind. First, the model analyzes the effects of monetary policy *shocks*, it does not deal with the effects of monetary policy strategies. That is, the model takes the monetary policy regime as given and assumes that monetary policy actions are not interpreted as changes in the regime. Second, the model is constructed for analyzing monetary policy effects, not for forecasting purposes. This is reflected in various choices concerning the modeling strategy.

The outline of this paper is as follows. Section two reviews the literature on the analysis of monetary policy transmission using VAR models. We specifically focus on the identification of monetary policy shocks. In section three we construct an econometric model which we use to address questions concerning the monetary policy transmission mechanism in Finland. In section four we analyze the effects of domestic monetary policy shocks and foreign shocks on the Finnish yield curve and exchange rate. Section five concludes the paper.

2 Monetary policy transmission using Vector Autoregression (VAR) methods

2.1 Measuring shocks to monetary policy

Central to an analysis of the effects of monetary policy changes is the identification of monetary policy shocks. The ideal measure of monetary policy would be one that is under the direct control of the central bank, evolves according to the decisions of policy makers, and is, in the short-run, unaffected by changes in the demand for money. Generally, two classes of candidates for such a measure have been considered in the literature (mainly on US data).

1. Innovations in a measure of liquidity targeted by the central bank.
2. Innovations in an interest rate predetermined by the central bank.

The choice between these candidates depends on the strategy and operating procedures of the central bank.

The first approach is appropriate if the central bank's policy is best described as some variant of the monetarist approach. In other words, if the central bank's operating target is some measure of liquidity and its open market operations are aimed at keeping this measure at the level set by the bank (thus allowing the interest rate to adjust to balance supply and demand), then monetary policy shocks are best measured by innovations to that particular measure of liquidity. Often the choice of the correct measure of liquidity is not obvious. In the case of the US Federal Reserve, several alternatives have been used. Eichenbaum (1992) used innovations in total reserves to characterise changes in the stance of monetary policy in the United States. In another approach that has gained some popularity, Strongin (1992) measured monetary policy by changes in non-borrowed reserves relative to total reserves.

Another branch of work has focused on short-term interest rates to identify monetary policy shocks (Sims 1992, Bernanke and Blinder 1992, and Bernanke and Mihov 1995). Bernanke and Blinder chose the Federal Funds rate as an appropriate measure of monetary policy arguing that while it is not the marginal interest rate for the banking system, it is the rate that the Federal Reserve holds as predetermined over their frequency of interest (one month). They point out that although the Federal Funds rate is not strictly exogenous, it should be exogenous in the short-run so that its innovations can be interpreted as monetary policy shocks.

2.2 Empirical identification of Finnish monetary policy shocks

Our estimation period starts at the announcement of inflation target by the Bank of Finland. During that period, the Bank has used short interest rates as its operative target. Interventions in the currency market have been infrequent and targeted to reduce short term fluctuations. In that sense, the monetary policy regime has been stable during the estimation period.

However, in December 1994, the Bank of Finland changed its operating procedure in open market operations. Up to that point, open market operations had been managed, to keep 1-month and 3-month HELIBOR rates inside corridors set by the board of the Bank of Finland. The boundaries of these corridors were not communicated to the general public. During that period, changes in short rates usually took place gradually rather than in discreet steps, and it was difficult for the market to separate within-band rate movements from shifts in the corridor.

Since December 1994, the Bank of Finland has set only the 1-month tender rate. The Bank operates solely at this maturity and market operations are conducted on a fixed-rate basis to keep the tender rate at the level set by the board. The tender rate is changed infrequently, and always after an explicit decision by the board. The typical change is 25 or 50 basis points. The goals of the new procedure were greater transparency in Bank policy and clearer signalling of monetary policy.

Such a recent change in the operating procedure creates problems for the empirical measurement of monetary policy. Under the current operating procedure, the choice of the measure is rather straightforward. The present method of monetary policy formulation of the Bank resembles closely that of the US Federal Reserve. Since monetary policy actions are executed directly through changes in the 1-month tender rate, innovations to that rate should provide an acceptable measure of monetary policy shocks. However, during 1993 and most of 1994, when monetary policy was executed through market operations in both 1-month and 3-month maturities, the situation was different. The nature of the change is clearly observable in Figure 1. Up to December 1994, the 1-month tender rate fluctuates in small steps in a rather continuous manner, while in the latter part of the period (up to week 22 of 1996), the tender rate changes only 8 times.

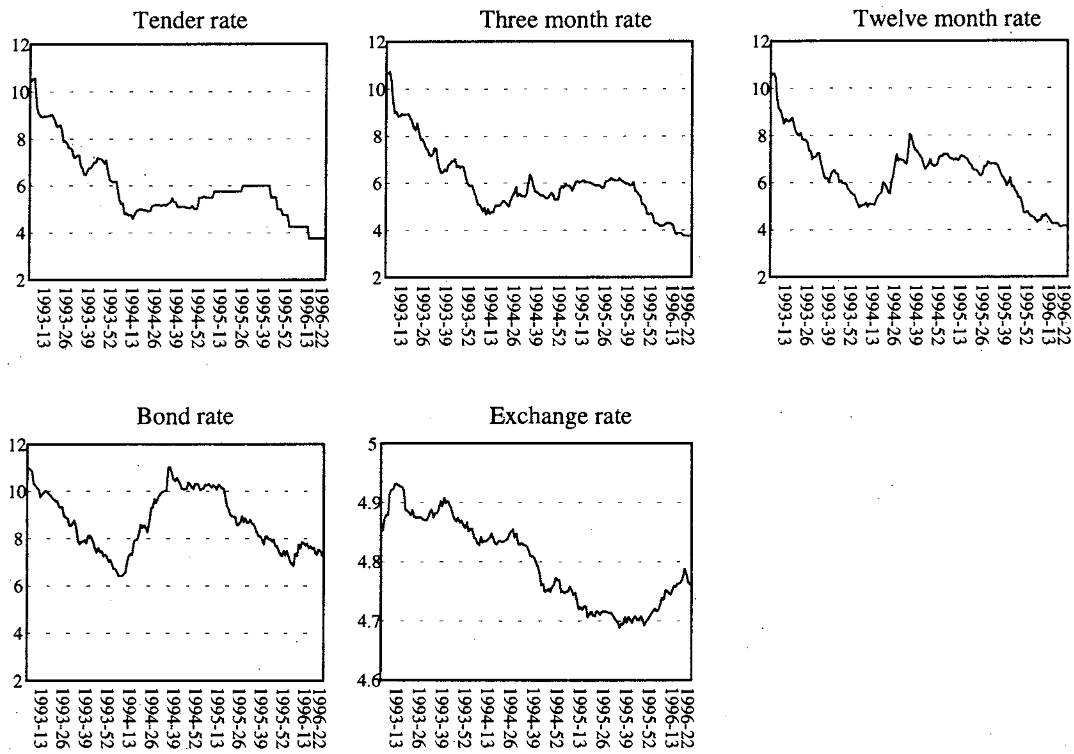
We decided to follow the approach of Bernanke and Blinder and chose to measure Finnish monetary policy shocks by innovations to the 1-month tender rate. There is really no better choice available: monetary aggregates play a secondary role in the setting of Finnish monetary policy, and fluctuations of monetary aggregates mainly reflect changes in money demand. We expected the structural break to cause problems mainly in the estimated relationship between the 1-month and the 3-month rates, and anticipated our results would suffer from two kinds of bias. First, during the earlier part of the estimation period the Bank of Finland intervened actively in the 3-month maturity, so monetary shocks may not be fully captured by innovations to the 1-month rate. Second, that part of the (within-band) variation in the 1-month rate during the first part of the estimation period which was caused by market situations, will be erroneously interpreted as monetary policy shocks. Nevertheless we did not expect this problem to cause major trouble in measuring the transmission of policy shocks from the short end of the yield curve to the long end. We return to these expectations later in section 4 where we test for a structural break in the model.

Finally, changes in the tender rate in the latter part of the estimation period have not been normally distributed. Instead, the distribution resembles a discrete distribution with most of the probability mass on zero and discrete probabilities on round number such as 25 basis points, 50 basis points, etc. Then, a normal VAR model is not the optimal tool for analysing such a phenomenon. In principle, one could think about a system including both some variation of a probit model for the probability of a change in the tender rate and another model for the expected size of the change. Implementing such a model in a dynamic multivariate system is, however, not an realistic option.

3 Model and estimation

3.1 The data

Figure 1. **Endogenous variables**



The data used in this analysis is the Friday mid-point values for the period starting in 1993:5 and extending to 1996:22, giving a total of 174 weekly observations. The beginning of the period coincides with the announcement of the inflation target by the Bank of Finland. The model has five endogenous variables. The interest rate used as a measure of monetary policy is the one month tender rate (F1m), set by the Bank of Finland. Short-term Finnish interest rates include the three month (F3m) and twelve month (F12m) HELIBOR interest rates. The bond rate (Fbr) is the yield of the Finnish Government benchmark bond with maturity date in March 2004. This series only extends back to mid-1993, so for the first half of 1993 we chain link the series backwards using the Finnish Government housing fund's benchmark bond maturing in March 2002. The fifth endogenous variable is the log of the Finnish trade weighted exchange rate (Fer). The endogenous variables are plotted in Figure 1.

The exogenous variables include a variety of indicators of international monetary conditions. We use German interest rates as the measure of the international level of interest rates, including foreign short rates such as the German three-month (D3m) and twelve-month (D12m) euromarket rates, and the German bond rate (Dbr), calculated from the German Government bond maturing in July 2002.

We also included several Swedish interest rates in the model. This choice reflects not so much the intrinsic importance of the Swedish financial market to the local market. Rather, the changes in Swedish rates complement German rates as an indicator of the amount of general uncertainty in the European financial market as a whole. A rise in Swedish rates relative to German rates may reflect a rise in uncertainty in the international financial markets which, in turn, generates a "flight-to-quality"; a flow of money out of high-yield fringe countries such as Sweden to low-yield safe havens such as Germany. During the estimation period, Finland has been mostly associated with the former group, so we would expect to find similarities between the behaviour of Finnish and Swedish bond rates. Of course, any statistical correlations between Finnish rates and Swedish rates is not to be interpreted as causality from the latter to the former, but instead as an indication of the similarity with which international investors rate the two countries. Thus, we included the Swedish three-month (S3m) and twelve-month (S12m) STIBOR rates and the Swedish 10-year bond rate (Sbr, from Reuters) as exogenous variables. Further, we include the log of the Swedish trade-weighted exchange rate (Ser).

We also included a measure of the default risk on Finnish Government bonds (drisk). It is calculated as the difference in yields between the Finnish Government deutschmark bond maturing on the 25th of June 2002 with a coupon rate of 8.25 and the German Government bond GBR with a coupon rate of 8.0. Finally, we included a step dummy (sd95w15) for the week 95:15, marking the approval of the sizable spending reduction program by the newly appointed government.

3.2 Stationarity and cointegration properties

Given the high frequency of the data, it is no surprise that conventional unit root tests found non-stationarity in practically all of the time series. Hence, we estimated the model in an error correction form. Formal tests of the cointegration relationships (such as Johansen's Maximum Likelihood method) are plagued by the large number of exogenous variables entering the cointegration space which alter the distributions of the test statistics. We arrived at four cointegration relationships each of which is judged to be stationary by the conventional tests (see Table 1 for Dickey-Fuller tests), performs well in the model estimation, and can be assigned a satisfactory economic interpretation. The cointegration relationships are the following:

$$
\begin{aligned}
ec_1 &= \text{F1m} - \text{F3m} \\
ec_2 &= \text{F3m} - 0.702\ \text{F1m} - 0.298\ \text{F12m} \\
ec_3 &= \text{F12m} - 0.679\ \text{F3m} - 0.474\ \text{Fbr} \\
ec_4 &= \text{Fbr} - 1.03\ \text{Sbr} - 0.86\ (\text{Sbr} - \text{S12m}) + 0.727\ (\text{Sbr}-\text{S3m}) \\
&\quad - 0.317\ \text{Gbr} - 0.923\ (\text{Gbr}-\text{G12m}) + 0.59\ (\text{Gbr}-\text{G3m}) \\
&\quad - 4.69\ \text{Ser} + 1.38\ \text{s95w15}
\end{aligned}
$$

The first cointegrating vector simply reflects the stationarity of the difference between the tender rate and the three-month rate. The second cointegrating vector indicates that in the long-run, the three-month rate is a weighted average of the tender rate and the twelve-month rate. The third equation presents a similar relationship between the three-month rate, the twelve-month rate and the bond rate. This equation is, however, not homogenous of degree one.

Table 1. **Unit root tests (augmented Dickey-Fuller statistics)**

	Lags		
	1	2	3
ec_1 (no constant)	−3.28	−2.59	**−2.51**
ec_2 (constant incl.)	−7.04	−5.21	**−5.39**
ec_3 (constant incl.)	**−2.98**	−3.22	−3.05
ec_4 (constant incl.)	**−7.05**	−6.27	−5.33

Approximate critical values without constant term 5% = −1.94, 1% = −2.58; with constant term 5% = −2.88, 1% = −3.47. Test statistics corresponding to the last significant lag are in bold.

The fourth cointegrating vector is more complicated. Essentially, it relates the Finnish bond rate to the German and Swedish bond rates, but allows the shapes of the foreign yield curves and the performance of currencies to contribute as well. Both the Swedish and German bond rates contribute strongly to the Finnish bond rate in the long-run, the Swedish bond rate with close to a unit coefficient. The trade-weighted exchange rate of the Swedish krona also enters this relationship. This does not imply any direct causality between the two, nor can it be seen as an indication of a lasting cointegrating relation. The motive for this choice is to control for the effects of international currency turmoils on the endogenous variables to avoid biases in the estimated relationships between the endogenous variables. For the period in question, the Swedish exchange appeared to react systematically to situations in currency markets and was therefore judged to be a satisfactory proxy for such effects[1].

Finally, the cointegration vector assigns a 1.38 percentage point long-term reduction in the Finnish bond rate to the deficit reduction package in the spring of 1995, as captured by the dummy variable.

3.3 Identifying the structural error correction model

As discussed in section 2.2, we measure monetary policy shocks by innovations to the 1-month tender rate. By doing this, we effectively assume that monetary policy does not react to situations in the financial markets within the same period. Any contemporaneous correlations between the residual of the equation for the 1-month rate and the residuals of other equations are interpreted as contemporaneous causality from the policy rate to other variables. Given the high (weekly) frequency of our data, we think this is a fair approximation of reality.

We do not seek to identify the contemporaneous structure of the model any further. The part of the residual variation of the four non-policy variables which is not accounted for by the monetary policy shock is left unspecified. We do not have sufficient theoretical or other information for that end, nor it is the primary purpose of this paper which is mainly concerned with the transmission of monetary policy shocks.

[1] The results indicate that during the estimation period, currency market situations which weaken the Swedish exchange rate tend also to increase the Finnish bond rate. We make no statement about whether such a relation will continue to exist in the future. Since the model is intended for policy analysis and not for forecasting purposes, such stability (or the lack thereof) is of little concern.

Hence, the estimated model is of the following form:

$$\Delta x_{1,t} = A_1 \Delta x_{t-1} + B_1 \Delta Z_t + C_1 ec_{t-1} + \varepsilon_{1,t}$$
$$\Delta x_{i,t} = A_i \Delta x_{t-1} + B_i \Delta Z_t + C_i ec_{t-1} + \varepsilon_{i,t} + \theta_i \varepsilon_{1,t}\ ,$$
$$\text{for } i = 2,...,5$$

where x = {F1m, F3m, F12m, Fbr, Fer}, ε is the corresponding vector of residuals, Z is the vector of exogenous variables and ec is the vector of cointegrating vectors. The contemporaneous effect of monetary policy on the non-policy variables is captured by the θ coefficients.

The estimation results are summarized in Table 2 and look typical for this type of regression. The Bank of Finland tender rate seems to be little predicted by anything besides the 3-month money market rate, entering the model in both lagged difference form and in the first error-correction term, it seems to be a quite powerful predictor of changes in the tender rate. This is well in accordance with the expectations hypothesis; ie, if the market correctly uses all available information, then no other variable should have predicting power for the tender rate except the term premium at the short end of the yield curve.

Generally, the error-correction terms explain most variation in the tender rate. At the long end of the yield curve, changes in foreign interest rates are also powerful predictors. Finally, the exchange rate is affected mainly by the cointegrating vector for the bond rate; when there is a downward pressure on the bond rate, the markka tends to appreciate.

Residual cross-correlations generally proved to be high. The residual of the tender rate equation has a correlation coefficient of almost 0.8 with the residual of the 3-month helibor and nearly 0.5 with the residual of 12-month helibor. Generally, residuals for interest rates of adjacent maturities correlate strongly. Overall, the covariance matrix indicates that contemporaneous effects play a large role in the system. Table 2 gives the θ coefficients (with their asymptotic standard errors) for the contemporaneous effects of monetary policy shocks, implied by the covariance matrix.

Model diagnostics are satisfactory except for the normality of the residuals, which is rejected in three of the five residual series. In each case, non-normality arises because of fat-tailed distributions. The normality assumption is severely violated by the Bank of Finland's tender rate which tends to move infrequently and in discrete steps. Tests do not find any systematic form of heteroscedasticity, although the aforementioned non-normality may affect the distribution of the test statistics.

Overall, non-normality of the residuals will have only limited implications for the results of this paper. By using OLS, we lose some efficiency, although OLS still remains the BLU (best linear unbiased) estimator also in this case. Parameter estimates and the standard errors continue to be unbiased. The distribution of the parameter estimates is still asymptotically normal, so the use of a normal distribution for the parameters when simulating system responses is justified. On the other hand, non-normality does have an effect on the asymptotic distribution of the parameter covariance matrix estimate, which will also play a role in the simulations. We will return to this issue later.

Table 2. **Parameter estimates**

OLS estimates from period 93:11 – 96:22

	$\Delta F1m_t$	$\Delta F3m_t$	$\Delta F12m_t$	ΔFbr_t	ΔFer_t
$\Delta F1m_{t-1}$	-0.160 (0.136)	-0.067 (0.141)	-0.137 (0.135)	-0.004 (0.122)	0.006 (0.007)
$\Delta F3m_{t-1}$	0.356 (0.181)	0.124 (0.188)	0.142 (0.179)	0.101 (0.162)	-0.007 (0.010)
$\Delta F12m_{t-1}$	-0.186 (0.129)	-0.012 (0.133)	0.061 (0.128)	-0.106 (0.115)	-0.004 (0.007)
$\Delta Fbrm_{t-1}$	0.108 (0.078)	0.083 (0.080)	0.068 (0.077)	0.060 (0.069)	-0.001 (0.004)
ΔFer_{t-1}	0.567 (1.535)	0.725 (1.587)	0.549 (1.518)	0.069 (1.369)	-0.065 (0.082)
$ec_{1,t-1}$	0.173 (0.059)	0.051 (0.061)	0.037 (0.058)	-0.032 (0.053)	-0.001 (0.003)
$ec_{2,t-1}$	-0.055 (0.166)	-0.579 (0.172)	-0.394 (0.165)	0.203 (0.148)	0.009 (0.009)
$ec_{3,t-1}$	-0.012 (0.067)	-0.112 (0.069)	-0.184 (0.066)	0.074 (0.060)	0.000 (0.004)
$ec_{4,t-1}$	0.049 (0.059)	0.034 (0.061)	-0.054 (0.059)	-0.291 (0.053)	-0.011 (0.003)
$\Delta G3m_t$	0.105 (0.192)	0.030 (0.198)	0.129 (0.190)	0.319 (0.171)	0.010 (0.010)
$\Delta G12m_t$	-0.187 (0.199)	-0.086 (0.206)	-0.173 (0.197)	-0.157 (0.177)	-0.011 (0.011)
ΔGbr_t	0.086 (0.145)	0.312 (0.150)	0.486 (0.143)	0.752 (0.129)	0.003 (0.008)
$\Delta S3m_t$	0.011 (0.142)	0.125 (0.147)	0.043 (0.140)	0.111 (0.126)	-0.002 (0.008)
$\Delta S12m_t$	0.042 (0.147)	0.149 (0.152)	0.244 (0.145)	-0.048 (0.131)	0.000 (0.008)
ΔSbr_t	-0.029 (0.079)	-0.032 (0.082)	0.115 (0.078)	0.499 (0.071)	0.008 (0.004)
$\Delta drisk_t$	0.187 (0.251)	0.326 (0.260)	0.218 (0.248)	0.518 (0.224)	0.009 (0.013)
$\Delta drisk_{t-1}$	-0.048 (0.219)	-0.144 (0.226)	-0.224 (0.217)	0.200 (0.195)	0.003 (0.012)
$\Delta drisk_{t-2}$	0.236 (0.206)	-0.036 (0.213)	-0.235 (0.204)	-0.005 (0.184)	-0.006 (0.011)
$\Delta drisk_{t-3}$	0.000 (0.200)	-0.186 (0.207)	-0.261 (0.198)	0.363 (0.178)	0.005 (0.011)
$\Delta s1995w15_t$	0.007 (0.143)	0.052 (0.147)	0.010 (0.141)	-0.377 (0.127)	-0.022 (0.008)
constant	-1.115 (1.265)	-0.993 (1.308)	0.765 (1.251)	6.347 (1.128)	0.230 (0.068)
θ	1.0 (-)	0.813 (0.049)	0.455 (0.068)	0.221 (0.067)	0.006 (0.003)
R^2	0.206	0.293	0.474	0.673	0.186
σ	0.137	0.142	0.135	0.122	0.007
AR1-7, F(7,140)	1.00	0.26	0.46	0.79	0.64
Normality, $X^2(2)$	26.1	5.4	15.8	2.4	13.9

5% and 1% critical values: F(7,140), 2.08 and 2.77, $X^2(2)$, 5.99 and 9.21.

4 Simulation results

4.1 Responses to monetary policy shocks

We first calculated the dynamic response of the system to a monetary policy shock, ie an innovation in the tender rate. Intuitively, these impulse response functions provide the answer to the question: What happens if at a time when no rate change is anticipated, the Bank of Finland increases its tender rate by one percentage point and follows thereafter the monetary policy reaction function as estimated by the model? In this sentence, the words "when no rate change is anticipated" are quite important: a change in the tender rate is not tantamount to a monetary policy shock of the same size. The size of the shock represented by a rate change depends on whether it is anticipated or not. Although the equation estimated for the tender rate has the worst fit of the four interest rate equations, there are periods for which the expectation of a rate change has been clearly different from zero. For example, in week 43 of 1993, the tender rate was 7.14% while the 3-month market rate was 6.69%, indicating a strong expectation of a downward move in the tender rate. According to the estimated equation, the expectation for the consequent week's tender rate was 6.96%. Hence, in that situation a rate reduction by 50 basis points would have constituted a negative shock of only 31 basis points while a similar move upwards would have been perceived as a 69 basis point positive shock.

Figure 2 plots the impulse response functions of the five endogenous variables together with two standard error bounds. The standard errors are calculated from sets of 1000 draws using the standard Bayesian procedure. For each draw, a sample parameter covariance matrix is first drawn from a Wishart distribution.[2] This covariance matrix then defines the multi-normal distribution from which the coefficient vector is drawn. Cointegrating vectors are kept constant across the simulations.[3]

[2] Because of the non-normality of the residuals (see the previous section), the parameter covariance matrix is not actually Wishart distributed, making the width of the confidence intervals likely to be slightly biased. In any case, the calculated standard errors are wider than what would be obtained using the classically oriented (rather than Bayesian) approach in which the parameter covariance matrix is treated as known.

[3] The simulated distribution of the impulse response functions seems to be well approximated by the normal distribution. We also allowed for the existence of skewness in the distribution by calculating the 2.5% and 97.5% fractiles from the empirical distribution of the draws. These proved to be very close to the two standard error bounds, so we only report the latter.

Figure 2. **Responses to a monetary policy shock**

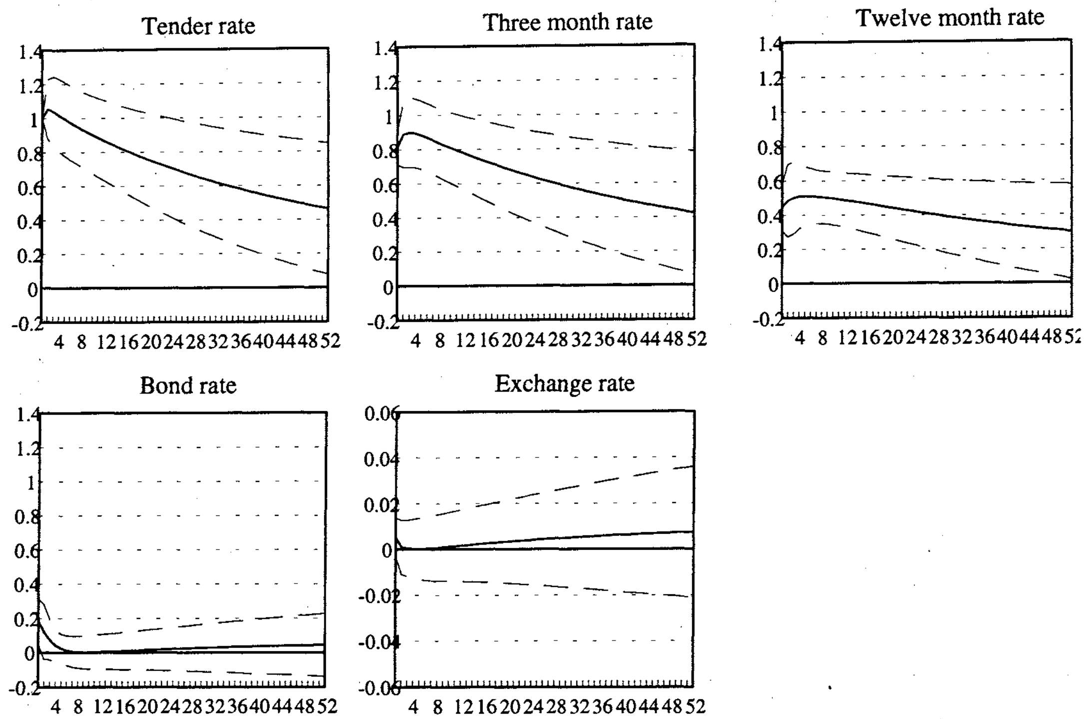


Figure 2 indicates that the responses of the short rates to a monetary policy shock are rather tightly estimated. By definition, the initial response of the tender rate to the shock is one percentage point. The response decays smoothly thereafter, so that within a year approximately half of the initial innovation has disappeared. In other words, the results indicate that a one percentage point increase in the tender rate today increases the expectation of the tender rate after a year by half a percentage point.

The figure shows a similar pattern for the three month and the twelve-month money market rates. As expected, the response of the three month rate is more pronounced with an 80–90 basis point initial response, half of which is still present a year later. For the twelve-month rate the increase is initially about 50 basis points and 30 basis points after a year. The relative sizes of the responses of the three short interest rates are roughly consistent with the expectation hypothesis: ie, the short run response of the 12-month rate is close to what could be expected on the basis of the response of the shorter rates over the course of the year.

The reaction of the bond rate is markedly different from that of the shorter rates. The immediate response of the bond rate to the monetary policy shock is significantly different from zero: a 100-basis-point positive shock to the tender rate increases the bond rate by roughly 20 basis points. This effect then disappears almost immediately. A week after the rate change, the remaining effect on the bond rate is not statistically significant, and after two months, the point estimate of the response drops to almost zero. It is worth noting that the lack of a systematic effect from the policy rate to the bond rate is not an artifact created by the choice of the cointegrating vectors (or more precisely, modelling the bond rate to cointegrate with the foreign rates): the impulse responses are, to all practical purposes, identical when the model is estimated in levels, ie when no restrictions are imposed on the cointegration space. We believe that this result is a consequence of various mechanisms offsetting each other. For example, the simple substitution effect between short maturity assets and long maturity assets indicates a positive effect from short rates to long rates. On the other hand, the "credibility effect" works in the opposite direction: a rate cut may increase the expectation of future inflation and future short rates, thus pushing long rates upwards.

The model finds no statistically significant systematic effect from the policy rate to the exchange rate. Theoretical models would generally predict rate increases, *ceteris paribus,* to induce an appreciation of the currency. Findings of this type are not uncommon in empirical literature. For example, Sims (1992) and Grilli and Roubini (1993) found that positive interest rate innovations lead to a significant depreciation of the currency. Such a finding has actually been common enough that it has been dubbed "the exchange rate puzzle". Grilli and Roubini suggested that these results may be due to models excluding information to which the central bank actually responds. If the exchange rate and the tender rate respond to common underlying causes, the resulting correlation may mask any true causality. In the present context this argument has only limited power. If the expectation hypothesis holds, then the shape of the yield curve, which *is* included in the model, should capture all available information about the future evolution of the tender rate. Hence, the exclusion bias only arises if the common causes behind the tender rate and the exchange rate take place in a frequency shorter than a week.[4]

We offer these possible explanations for the apparent lack causality from monetary policy to exchange rate. First, it is simply likely that the majority of exchange rate movements stem from the real side of the economy and from situations in the international financial markets, and that the contribution of short interest rates is quite small. Extracting this small contribution from the data would require the inclusion of a more complete set of the major determinants. Second, although the markka is floating and the tender rate is not used actively to steer the exchange rate, it may be that the timing of interest rate changes is chosen so as to support the stability of exchange rate. Finally, the financial markets may not simply always follow mainstream theories. Sometimes a rate cut may be interpreted as a sign of confidence by the central bank, which can induce a currency appreciation. Sometimes the logic of the market may have been something like, "a cut in the nominal rate induces a reduction in the real rate, which strengthens the economy so as to warrant an appreciation of the currency". The rationale behind such line of thinking may not be perfect, but there are certain recent episodes in which such reasoning seems to have been at work.

Table 3 summarizes the forcast error decomposition of the endogenous variables. The numbers reinforce the picture conveyed by the impulse response functions. Shocks to the tender rate are an important source of variance at the short end of the yield curve but their contribution is negligible for the bond rate and the exchange rate. In the long-term, shocks to the tender rate account for about 85% of the variation in the 3-month rate but has virtually no contribution to the bond rate.

[4] In addition, the difference between the 3-month and the 1-month rates is not a perfect measure of the rate expectations for the next week.

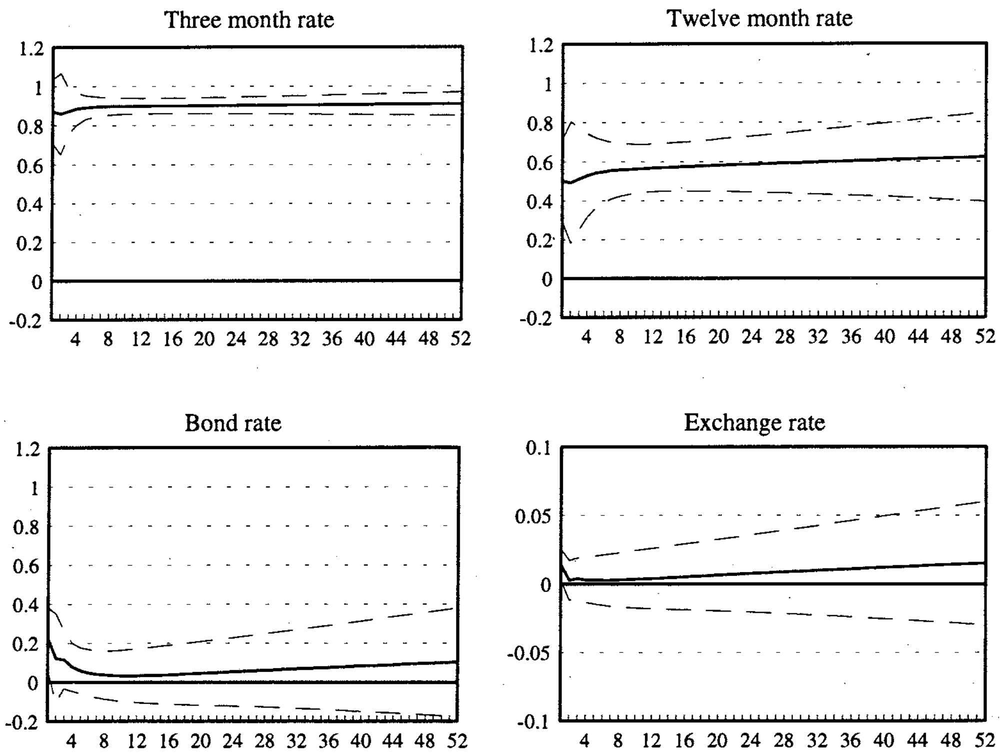
Table 3. **Forecast error decomposition**

			Contributions of					Contributions of	
		σ^2	ε_1	ε_2 to ε_5			σ^2	ε_1	ε_2 to ε_5
F1m	1	0.1284	100	0	F3m	1	0.1325	61.93	38.07
	3	0.2335	95.59	4.41		3	0.2256	72.74	27.26
	5	0.2981	95.04	4.96		5	0.2814	78.77	21.23
	7	0.3469	94.73	5.27		7	0.3241	81.93	18.07
	10	0.4042	94.35	5.65		10	0.3747	84.29	15.71
	15	0.475	93.71	6.29		15	0.4385	85.7	14.3
	20	0.5277	92.99	7.01		20	0.4868	85.87	14.13
	30	0.6031	91.21	8.79		30	0.5573	84.71	15.29
	40	0.656	89.02	10.98		40	0.6082	82.57	17.43
	52	0.7039	85.97	14.03		52	0.6556	79.36	20.64
F12m	1	0.1255	20.89	79.11	Fbr	1	0.1079	5.04	94.96
	3	0.2067	26.34	73.66		3	0.1358	5.13	94.87
	5	0.2439	32.89	67.11		5	0.1479	4.49	95.51
	7	0.2701	38.09	61.91		7	0.1608	3.81	96.19
	10	0.3013	43.71	56.29		10	0.1794	3.06	96.94
	15	0.3431	49.17	50.83		15	0.2067	2.31	97.69
	20	0.378	51.76	48.24		20	0.2303	1.87	98.13
	30	0.4354	52.76	47.24		30	0.2704	1.44	98.56
	40	0.4825	51.39	48.61		40	0.3045	1.29	98.71
	52	0.5308	48.65	51.35		52	0.3403	1.28	98.72
Fer	1	0.007	0.93	99.07					
	3	0.0118	0.34	99.66					
	5	0.0153	0.2	99.8					
	7	0.0182	0.14	99.86					
	10	0.0219	0.1	99.9					
	15	0.0269	0.09	99.91					
	20	0.031	0.12	99.88					
	30	0.0379	0.25	99.75					
	40	0.0435	0.44	99.56					
	52	0.0495	0.69	99.31					

4.2 Permanent increase in the tender rate

When there is discussion of the effects of a change in the policy rate, impulse response functions such as what we calculated above are not what the typical policy maker has in mind. There is little interest in a temporary change in the policy rate that more or less quickly melts away as the system converges back to its equilibrium. Distinguishing questions in such cases can often be conceptually rather simple – like; What happens if the policy rate is cut by one percentage point and kept there for a while? Such innocent questions are notoriously difficult to analyze in a theoretically rigorous manner. In the context of the present model, there are at least three ways to approach this question, none of which is particularly appealing.

Figure 3. **Permanent increase in the tender rate**



The first, and the most straightforward, approach is to treat the tender rate as a random walk, exogenous to all other variables in the model. With such a strategy, the effects of any rate change could be measured by imposing the desired path for the tender rate and simulating with the remaining four equations. The unattractive part of this approach is that the exogeniety of the tender rate is rejected by the model: the slope of the short end of the yield curve does predict movements in the tender rate. A more Bayesian variant of this approach would be to use the joint distribution of the coefficients to calculate the expected values of the coefficients of the other four equations, conditional on all the parameters in the first equation being zero. In practice, the difference between these two approaches is very small.

A second approach would be to calculate a time series of monetary policy shocks which, when fed into the complete model, would first increase the tender rate by 100 basis points and thereafter keep it unchanged. In other words, the convergence of the tender rate would be prevented by continuously feeding in small positive monetary policy shocks. The downside of this approach is that it is internally inconsistent: it involves testing the effects of what essentially constitutes a particular change in the monetary policy reaction function, but at the same time maintaining model parameters which imply a very different reaction function.

A third approach would be to impose more theoretical structure on the model and define the behavioral (invariant) equations governing the endogenous variables. One could then hypothesize a change in the "deep" parameters defining the Bank of Finland's reaction function. Unfortunately for this strategy, the theoretical virtues come at the price of insurmountable practical difficulties.

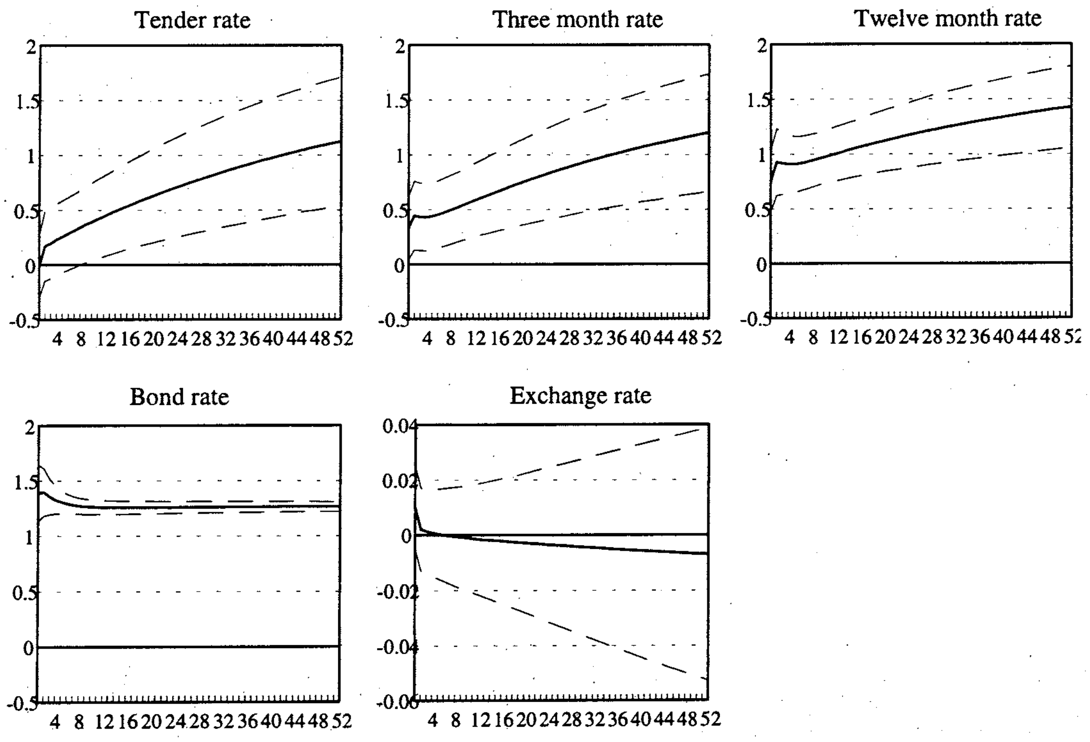
The following results are calculated using the first approach. In effect, we shock the tender rate by 100 basis points and keep it unchanged from then on. The reactions of the other endogenous variables are calculated from the system formed by the remaining four equations. The responses of the four variables with the approximate 95% confidence intervals are plotted in Figure 3.

Overall, the results correspond to the picture conveyed in the previous section. According to the model, the 3-month Helibor response to a 100 basis point increase in the tender rate reaches 90 basis points in about a month and stays close to that level thereafter. The response of the 12-month rate is slightly slower and converges to a little above 50 basis points. Again, neither the bond rate nor the exchange rate show a systematic response to changes in the tender rate.

4.3 Changes in foreign rates

In this section we examine the effects of changes in foreign interest rates on Finnish interest rates and the exchange rate. Since all foreign variables are exogenous in the model, some care must be taken to ensure the plausibility of the scenarios. For example, it would make little sense to study the effect of a one percentage point increase in the German bond rate while at the same time keeping the Swedish rate constant. A change in the financial market sentiment that induces a one percentage point increase in the German bond rate is bound to affect the Swedish rate. It is generally observed that when the bond markets perceive increased general uncertainty, interest rates tend to rise on bonds from non-core members of the European Union, relative to the core countries (eg Germany, France and Benelux). Conversely, when markets perceive a reduction in uncertainty, non-core countries tend to experience greater falls in interest rates than core nations. Specifically, we study the effects of the following two scenarios:

Figure 4. **Worldwide increase in bond rates**

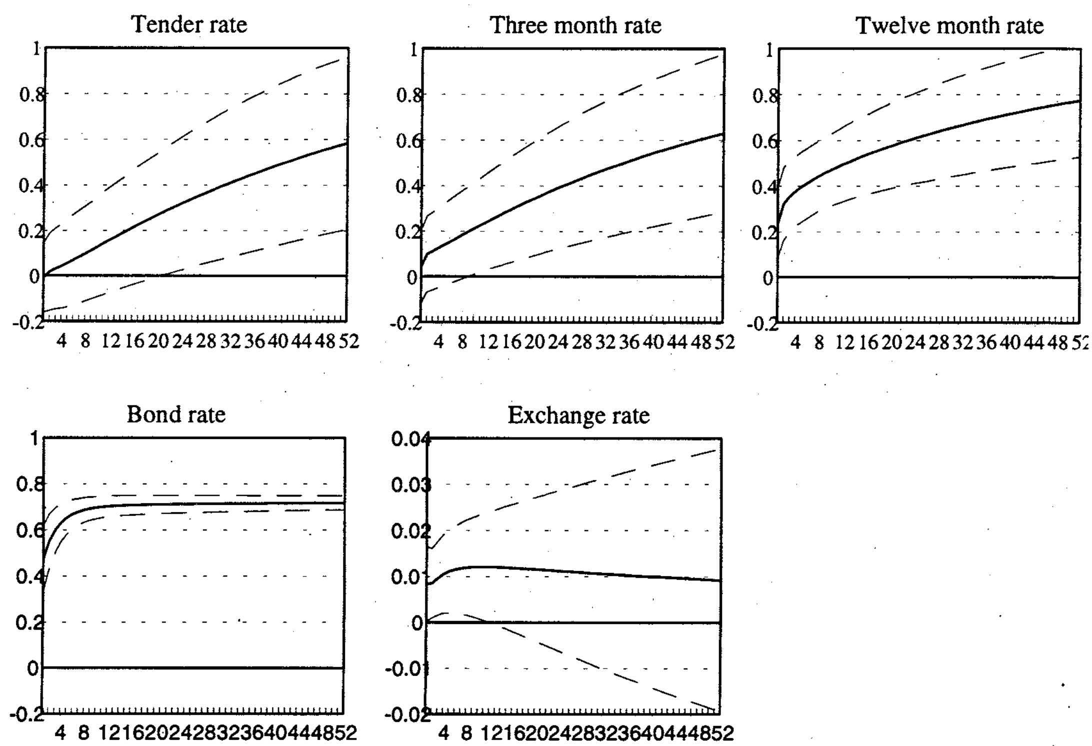


– *Worldwide increase in bond rates*. Financial markets revise their expectations about future monetary policies and long rates increase worldwide. We assume that the German bond rate increases (permanently) by 100 basis points and the 12-month rate by 50 basis points. Rate increases are more pronounced in fringe countries, so that the Swedish bond rate increases by 150 basis points and the 12-month rate by 75 basis points. Short money market rates do not change.

– *Flight-to-quality*. Uncertainty about the international economy and financial markets increases, generating a flow of capital from high-yield countries to safe havens. We assume that the Swedish bond rate increases by 100 basis points and the 12-month rate by 50 basis points while the German rates remain unchanged.

One may think the first scenario as something similar to what happened in the spring of 1994, when the rise in the US Federal Funds rate triggered a worldwide increase in interest rates. In the USA and Germany, bond rates increased by about 2 percentage points, while the effect on countries such as Sweden, Italy, or Finland was close to 4 percentage points. The second scenario resembles the developments in early 1995, when bond rates came down rapidly in Germany and the USA, and stayed high or even increased in the high-yield countries. Figures 4 and 5 plot the responses of the Finnish rates to these episodes. Again, we calculate the 95 percent confidence intervals around our shock responses using a Monte Carlo simulation method with a random sample of 1000 draws.

Figure 5. **Flight-to-quality**



In the case of the worldwide increase in long rates, the yield curve reacts in a quite intuitive manner: bond rate reacts almost immediately by rising about 130 basis points and remaining at that level. Shorter rates response more slowly. The slowest to react is the tender rate, for which the response reaches 50 basis points in roughly a quarter of a year, and tops 100 basis points after about a year. Again, the adjustment in the shape of the yield curve is roughly consistent with the expectation hypothesis. In the long-run, all the responses converge to a level close to 130 basis points. As before, no systematic link is found between foreign interest rates and the exchange rate of the Finnish markka.

The simulated responses to the flight-to-quality episode are qualitatively similar to those of the worldwide increase in bond rates. Finnish rates increase by 50 to 70 basis points in the long-run. Again, the bond rate responds almost immediately, whereas the short rates adjust slowly as the Bank of Finland adjusts its tender rate. Interestingly, the exchange rate, which generally shows very little responsiveness in the simulations throughout the paper, exhibits here a statistically significant response; a flight-to-quality episode seems to induce a small depreciation of the markka. The calculated depreciation is about 1 percentage point and is significantly different from zero for approximately 3 months after the shock.

4.4 What is behind Finnish bond rate movements?

The three years since the beginning of 1993 wittnessed several large and rapid swings in Finnish bond rates. In the beginning of 1993, the yield on the Finnish government 10-year bond was about 11 %. During that year, bond rates came down rapidly, reaching a trough at around 6.5 %, rocketed back to 11 % in 1994, and have since slid downwards to approximately 7 %. In this section, we use our model to offer an idea of the driving forces behind these developments. We do this by decomposing changes in the bond rate during the estimation period into four sources: changes induced by shocks to monetary policy, changes induced by other (non-policy) shocks, effects of foreign exogenous variables (foreign interest rates and the Swedish exchange rate), and effects of domestic exogenous variables (default risk and the credibility dummy).[5]

Figures 6 and 7 illustrate the contributions of the different sources. For each case, the left column plots the actual bond rate together with the simulated bond rate the model predicts would have been realized without the contribution of that element. The right column plots the difference between these two, ie the cumulative effect of the particular element since the beginning of the estimation period.

Figure 6 plots the cumulative effects of monetary policy shocks (upper panels) and the cumulative aggregate effect of other, or "non-policy", shocks (lower panels). For the monetary policy shocks, the results are in line with what can be expected on basis of the results reported above: the difference between the actual and simulated bond rates is almost indistinguishable. The contribution of monetary policy shocks on bond rates seldom exceeds 10 basis points. The effect of the non-policy shocks is somewhat larger, sometimes exceeding 30 basis points. Still, the overall contribution of shocks has been very modest.

[5] In addition to these four elements, the initial conditions cause minor changes in the level of the bond rate.

Figure 6. **Contribution of exogenous variables on the bond rate**

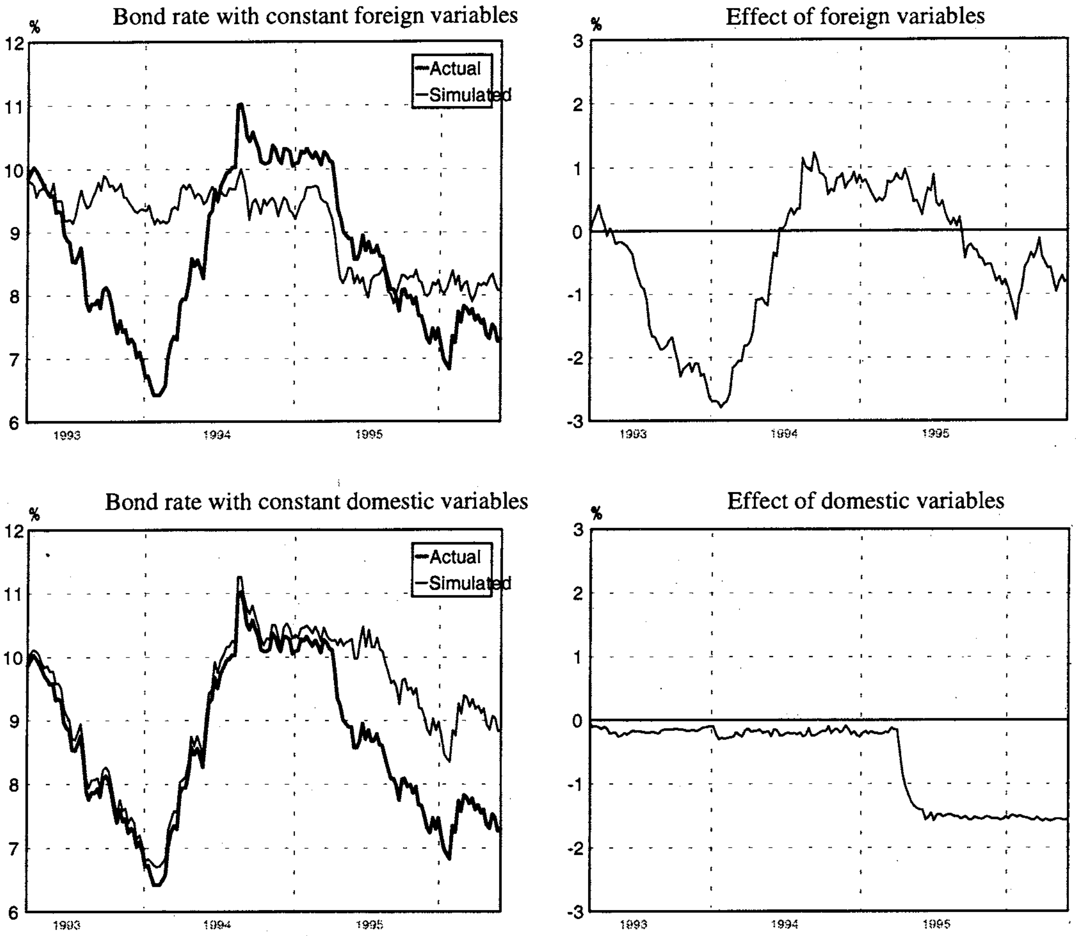
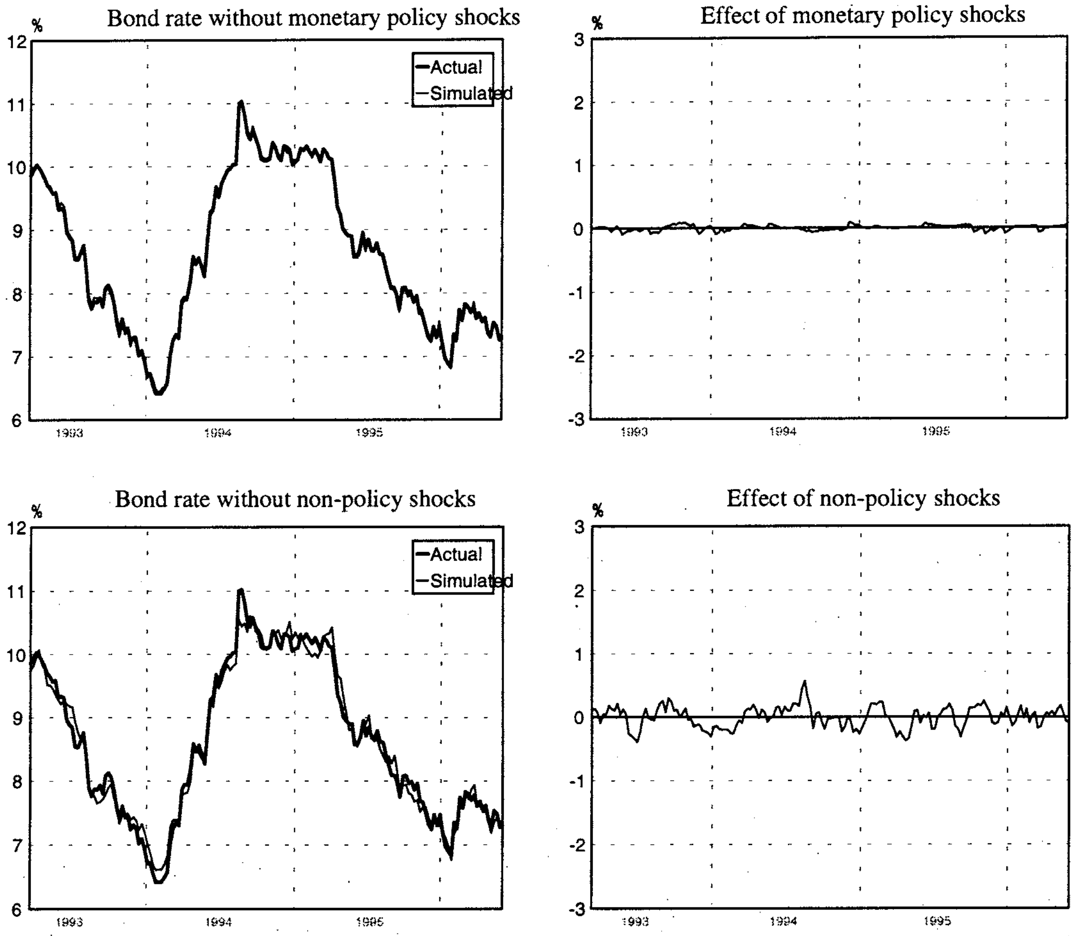


Figure 7 plots the effects induced by changes in exogenous variables. According to the simulations, changes in foreign interest rates (upper panels) seems to have been by far the single most important contributor to the changes in bond rates in recent years. The model attributes the fast drop in bond rates in 1993 and the subsequent increase in 1994 almost entirely to changes in the foreign variables. Also, approximately half of the 3 percentage point reduction in the bond rates during 1995 seems to have been due to foreign effects. The other half is attributed to improved domestic credibility (lower panels). Overall, the results indicate that the recent developments in Finnish bond rates have been dominated by factors other than changes in the Bank of Finland's tender rate.

Figure 7. **Contribution of monetary policy and non-policy shocks on the bond rate**



4.5 Effects of the change of the operating procedure

The change in the Bank of Finland operating procedure in December 1994 constitutes a notable break in the time series properties of Finnish short rates, and it may have profound implications on the results of this paper. In this section we analyze the nature and magnitude of those effects. We divide our estimation period into two subperiods – cut-off point at 1994 week 48 – and estimate the error-correction model separately for each. The cointegrating vectors remain the same for both subsamples.

Although the degrees of freedom still remain plentiful after splitting the estimation period (57 in the smaller of the subsample), this abundance is mostly illusory. Despite the high frequency of the data, most of the variation in the policy rate takes place in a frequency much lower than a week. Hence, subsample parameters are less tightly estimated than those of the full sample, and confidence intervals around the point estimates are considerably wider.

Figure 8. **Subsample responses to a monetary policy shock**
(1993:11–1994:48 dashed line, 1994:49 – 1996:22 solid line)

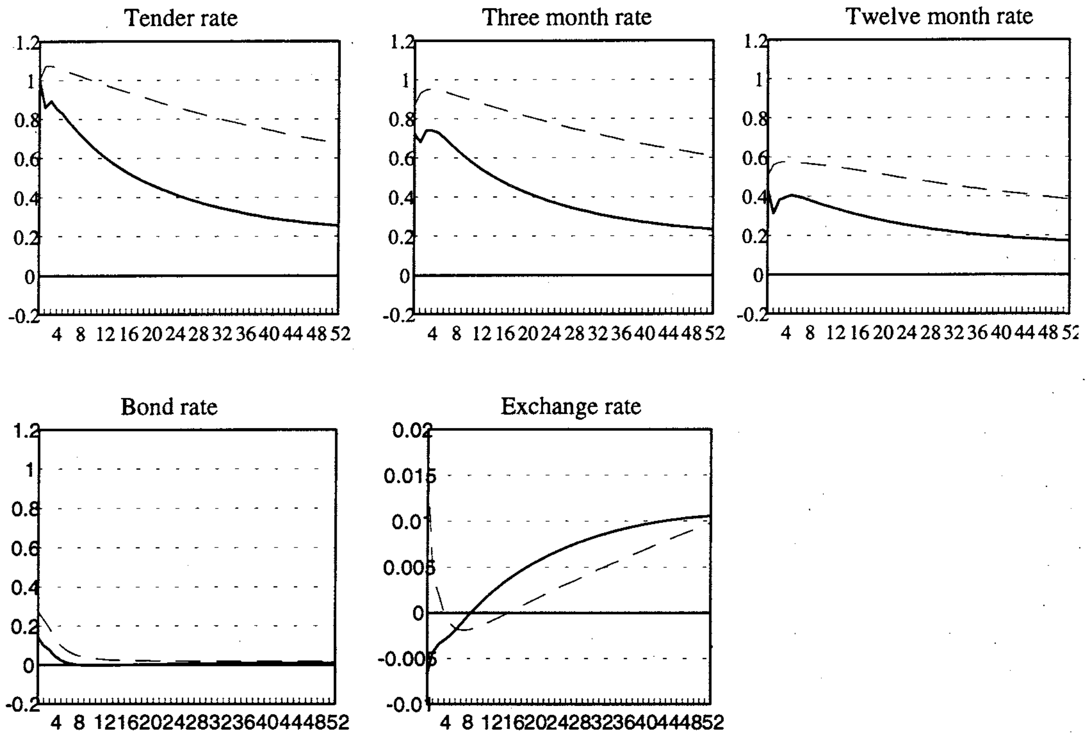
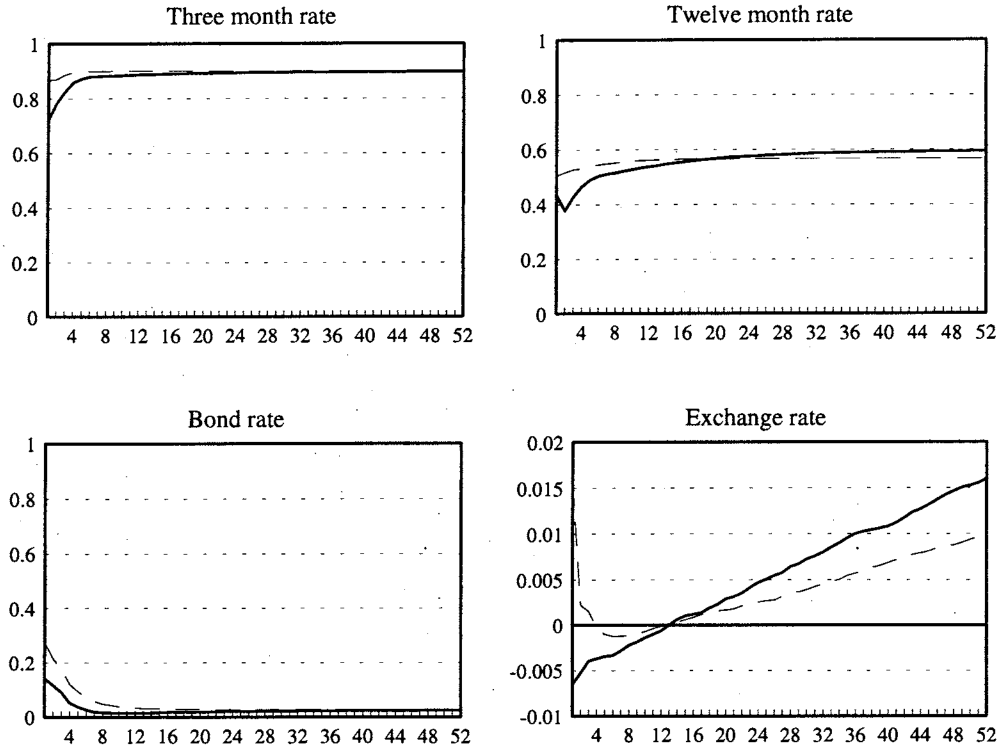


Figure 8 plots the impulse responses of the endogenous variables to a monetary policy shock for each of the subsamples. The dashed lines represent the responses estimated from the first subperiod and the solid line those estimated from the latter. Qualitatively, the impulse responses are quite similar across scenarios. Most notably, the persistence of shocks to the tender rate is estimated to have been higher in the first subperiod. Before December 1994, 75 percent of the shock is still estimated to be present after a year, while in the second subperiod, this percentage is close to 30. However, the confidence intervals are wide and the impulse response estimated from the whole sample fits well within the two standard error bounds for both subperiods. Conventional (asymptotic) tests for a structural break do not point to a significant change in the model parameters.[6]

The difference in the persistence of tender rate response shows up as a similar difference in the responses of other short rates. For both the 3-month rate and the 12-month rate, persistence of the response is estimated higher in the first subperiod. On the other hand, the response of the bond rate is markedly similar for both subperiods: a slight positive reaction, which melts away almost immediately. Further, the response of exchange rate is estimated to be insignificantly different from zero for both subsamples.

[6] Likelihood ratio test produced the test value 124.7 and Lagrange multiplier test the value 109.8 for parameter stability. Both tests are asymptotically chi-squared distributed with 105 degrees of freedom. 5% critical value for the tests is 129.9.

Figure 9. **Subsample responses to a change in the tender rate** (1993:11–1994:48 dashed line, 1994:49 – 1996:22 solid line)



In order to separate the effect of the change in the estimated persistence of the tender rate from any possible change in the causal relation from the tender rate to the other variables, we also run a simulation similar to that of section 4.2 for both subperiods, ie we assume that the tender rate is increased by 100 basis points and kept at that level from then on. As can be seen in figure 9, the responses of the remaining four endogenous variables are very similar for both periods. Short rates react in a manner much like what was estimated for the whole period. Bond rate and exchange rate do not seem to be affected by the tender rate in either subperiod. Hence, the differences in the impulse responses to monetary policy shocks between the subperiods are almost entirely due to the estimated lower persistence of the shocks for the latter period.

We conclude that the change in the Bank of Finland operating procedure in December 1994 did not alter the transmission of monetary policy in a significant way.

5 Conclusions

In this paper, we analyse the effects of Finnish monetary policy actions on money market rates, bond rates and the exchange rate, and study other determinants of Finnish yield curve. We construct a 5-variable error-correction system consisting of four interest rate variables and the exchange rate of the Finnish markka to analyse this problem. We follow a recent branch of work on the US data and define monetary policy shocks as innovations to the Bank of Finland 1-month tender rate.

We find that the effects of monetary policy shocks are limited to the short end of the yield curve. According to the result, changes in Finnish bond rates closely follow circumstances in the international financial market and changes in the overall credibility of the Finnish economy, but do not seem to react systematically to changes in the Bank of Finland's tender rate. This behaviour is markedly different from, for example, what is observed in the US where the bond market seeks to anticipate the moves of the Federal Open Market Committee and watches closely for signs of change in monetary policy trends. We interpret this as an indicator that the financial market perceives the future evolution of Finnish interest rates as largely dependant on international factors.

Our other results generally support this interpretation. For example, we find that the signaling effect of monetary policy shocks is fairly short-lived: innovations to the policy rate have a half-life of only about a year and their effects on short and medium-term money market rates have a similar persistence. With the obtained estimation precision, this means that changes in the policy rate only provide useful information of the future short rates over a horizon of around a year. With such short-lived effects on short rates, the impact of a monetary policy shock on long rates cannot be expected to be large.

We also analyse the causes of the large swings in bond rates in recent years. According to the results, monetary policy has contributed little to these developments. Instead, most of the variation is attributable to changes in the international long rates and changes in the perceived credibility of the Finnish government.

We fail to find a systematic effect from policy rates to the exchange rate of the Finnish markka. Although such a finding is not uncommon in other similar empirical studies, we do not want to emphasize this result too much. This result may be the outcome of our model failing to identify correctly the dependence of monetary policy actions on circumstances in the foreign exchange market. Although the markka is floating and the tender rate is not used actively to steer the exchange rate, it may be that the timing of interest rate changes is chosen so as to support the stability of the exchange rate. If this is the case, then a simultaneity bias affects the results. Also, during the estimation period, exchange rate variation was dominated by few major trends, the likely determinants of which were outside the scope of the model. We suspect that longer time series and the inclusion of a more complete set of exchange rate determinants from the real side of the economy might help better to identify the effect of monetary policy on exchange rate.

Finally, we want to reemphasize the point made in the introduction: throughout the analysis, the monetary policy regime has been taken as given. For example, the result that monetary policy shocks have not affected bond rates during the estimation period does not mean that monetary policy as a whole has not had an effect on bond rates. The monetary policy regime constitutes an integral part of the mechanism through which the effects of exogenous variables are transmitted to endogenous variables. If the monetary policy regime changed, this mechanism would most likely be affected. The results of this paper should be interpreted as relating to monetary policy actions which do not indicate a regime change – in practice, to relatively small changes in the tender rate.

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