Alpo Willman
Bank of Finland Research Department
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17/88

IF THE MARKKA FLOATED: Simulating the BOF4 model with fixed and floating exchange rates*

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ABSTRACT

In this paper the BOF4 model of the Bank of Finland, which is estimated in a fixed exchange rate regime, is transformed into a model with a floating exchange rate. In endogenizing the exchange rate two alternative assumptions about the formation of exchange rate expectations are used, i.e. static and market-specific (MS) rational expectations. We found that under static expectations the adjustment paths of the exchange rate were very volatile when shocks originated from the financial market. In response to real shocks, however, the results were not sensitive with respect to the alternative expectations formation schemes.

In the case of MS-rational expectations the reactions of the exchange rate to real and financial shocks were, also somewhat greater than typically presented in the literature. In addition, the response paths were highly cyclical.

CONTENTS

1 Introduction

The purpose of this paper is to describe how the functioning of the Finnish economy changes, if instead of being fixed the exchange rate is allowed to float. The calculations are based on use of the BOF4 model.[1]

Exchange rate modelling has proven to be one of the most difficult areas in macroeconomics. In the Finnish context extra difficulties in endogenizing the exchange rate are caused by the fact that no data exist on the floating exchange rate regime. Hence, in deriving an equation for the floating exchange rate only data on the fixed exchange rate regime can be used. The main contribution of this paper concerns the way the fixed exchange rate version of the BOF4 model is transformed into a floating exchange rate version.

The paper proceeds as follows. I first shortly review how the exchange rate is edogenized in existing macroeconometric models. Thereafter the solution used in this paper is presented. In the last two sections the simulation results are presented and compared to those obtained with other models.

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[1]BOF4 is an econometric model of the Finnish economy built at the Bank of Finland for forecasting and policy analysis (see BOF4 (1987)). It is a quarterly model consisting of about 300 equations. The theoretical starting point adopted in constructing BOF4 is the neoclassical synthesis, i.e. the short-run properties of the model are Keynesian whereas the long-run asymptotic properties are classical. In these respects it quite closely resembles its predecessor BOF3 (see Tarkka & Willman (1985)).

2 Determination of the flexible exchange rate

Let us examine alternative ways of modelling exchange rates with the help of a simple asset market model of exchange markets.[2] After abstracting some unimportant terms the model can be written as follows:

$$\Delta F_t = a*(\Delta i_t - \Delta i_t^f - (E_t \Delta s_{t+1} - E_{t-1} \Delta s_t)) \qquad (1)$$

$$\Delta R_t = B(s_t,.) + \Delta F_t \qquad (2)$$

where F refers to the net stock of foreign assets held by domestic residents, i is the domestic and i_f the foreign nominal interest rate, s is the logarithm of the exchange rate, R is the stock of foreign reserves and B is the current account balance. Δ and E are the difference and expectations operators, respectively.

Equation 1 is the portfolio-balance equation for the net demand for foreign assets written the difference form and equation 2 is the balance-of-payments identity.

If one wants to use the model in the flexible exchange rate regime, the key question is how to operationalize exchange rate expectations. The simulation properties of the model depend stongly on this solution.

In macroeconometric models the following assumptions are usually made in specifying exchange rate expectations:

a) Static expectations, i.e. $E_t s_{t+1} = s_t$.

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[2]A good review on the treatment of the exchange rate in macroeconomic models of the UK economy can be found in Wallis et. al. (1985).

b) The expected exchange rate is a function of developments in some "long-run fundamentals", i.e. $E_t s_{t+1} = f(Z_t)$, where Z_t represents the vector of the current and past values of the fundamentals.

c) Rational expectations/perfect foresight i.e $E_t s_{t+1} = s_{t+1}$.

In terms of modelling static expectations are technically the simplest assumption. In this case the equations of the model are same both in the floating and fixed exchange rate regimes. The only difference is that in the floating exchange rate regime foreign reserves are exogenized and the exchange rate is solved from the balance-of-payments identity.

Static exchange rate expectations have recently been supported by Branson (1983), who argues that "one robust empirical finding from the 1970s is that the spot exchange rates roughly follow random walks". However, the assumption of static expectations can be criticized for ignoring the available information about the structure of the economy and possible inferences about the expected values of exogenous variables.

An approach in which exchange rate expectations are determined according to past developments in market fundamentals is commonly used in large-scale multi-country models (see Amano (1986), Holtham (1986), Hooper (1986) and Pauly and Petersen (1986)). Estimates for parameters of the function $f(Z_t)$ are obtained in estimating the exchange rate equation. Typically vector Z includes such variables as relative prices and cumulative current account balances. However, the choice of fundamentals is ad hoc (not necessarily consistent with the rest of the model) and expectations are backward looking.

Rational expectations are forward looking and consistent with the structure of the model. Hence they do not involve persistent prediction errors. As with static expectations, so also with rational expectations the model need not to be estimated separately in different exchange rate regimes. Partly due to computational problems and partly due to the very strong informational assumptions contained by rational expectations this expectations formation scheme is not as yet widely applied in large-scale macro-econometric models. For an exception to this see e.g. Budd et al.(1984), Minford, Agenor and Nowell (1986) and Taylor (1988).

We cannot in the present context use the approach in which exchange rate expectations are reduced to the past values of market fundamentals. This is due to the fact that as the Finnish markka has been pegged to a basket of currencies there is no data on a freely floating exchange rate. Hence, no exchange rate equation for the Finnish markka can be estimated directly from the data.

In this paper static expectations are used as one of two alternative expectations formation schemes on which endogenization of the exchange rate is based. Another approach is based on rational expectations modified, however, so that the information set available to agents operating in the foreign exchange market is assumed to be limited.

2.1 The case of static exchange rate expectations

Under static exchange rate expectations and after inserting equation (1) into the balance-of-payments identity (2), the following relation is obtained for the current account:

$$B_t = a(\Delta i_t^f - \Delta i_t) + \Delta R_t \tag{3}$$

Equation (3) defines the demand for net foreign assets in flow form. The supply of net foreign assets is determined from the goods market side of the economy and can be presented as a conventional current account as follows:

$$B_t = T(s_t + p_t^f - p_t, y_t, y_t^f) + I_t \tag{4}$$

where T refers to the trade balance and I to the net interest from abroad. Variables p and p_f are the logs of domestic and foreign price levels and y and y_f are the logs of domestic and foreign real income, respectively. The exchange rate can now be solved from the equilibrium condition that the demand for net foreign assets equals the supply of net foreign assets.

2.2 The case of market-specific (MS) rational expectations

In this section we assume that agents operating in the foreign exchange market are rational within an information set constrained in a market specific way (market specific (MS) rationality). They know the parameter a in equation (1) (the interest sensitivity of the net demand for foreign assets) and the impact effect of the change in the exchange rate on the current account in different monetary policy regimes (i.e. regimes with either the interest rate or the stock of money as the target variable of monetary policy). They do not, however, know the effects of the change in the exchange rate on the other endogenous variables of the model (economy). Under these assumptions the determination of the floating exchange rate is derived.

In the flexible exchange rate regime, foreign reserves are an exogenous intervention variable in the control of the central bank and the exchange rate can be solved from the balance of payments equilibrium condition (2). After substituting equation (1) into (2) we obtain:

$$E_t s_{t+1} - s_t - E_{t-1} s_t + s_{t-1} =$$

$$\Delta i_t - \Delta i_t^f + (1/a)(B_t - \Delta R_t) \tag{5}$$

Assume first that that the monetary authority is targeting the nominal interest rate i. In that case all variables except B on the right hand side of the equation are genuinely exogenous.

We next linearize B around the exchange rate s* balancing the current account, i.e.

$$B_t = \alpha(s_t - s_t^*) \tag{6}$$

Equation (6) shows the size of the change in the exchange rate that would be needed to bring the current account into balance instantaneously with given values of the exogenous variables of the model. It should be noted that s* is independent of s and changes only when some of the exogenous or predeterminend variables changes.

After inserting equation (6) into (5) we obtain the following difference equation:

$$E_t s_{t+1} - (1 + \alpha/a)s_t - E_{t-1}s_t$$

$$= \Delta i_t - \Delta i_t^f - (1/a)\ \Delta R_t - (\alpha/a)s_t^* \tag{7}$$

By using

$$s_t = \mu\ s_{t-1} + \sum_{j=0}^{\infty} \Phi_j E_t Z_{t+j} + \sum_{j=0}^{\infty} \Theta_j E_{t-1} Z_{t+j} \tag{8}$$

as a trial solution, equation (7) can be solved using the method of undetermined coefficients. In (8) variable Z equals the right hand side of equation (7). A solution for Φ_j and Θ_j is obtained as

$$\Phi_j = -\ \mu^{j+1}/(1-\mu)\ ;\ \Theta_j = \mu^{j+2}/(1-\mu)$$

The characteristic root μ can be solved from the relation

$$\mu^2 - (2 + \alpha/a)\mu + 1 = 0 \qquad (9)$$

As can be seen $\mu_1 + \mu_2 = 2+\alpha/a$ and $\mu_1 \mu_2 = 1$. If the Marshall-Lerner condition holds, i.e. $\alpha/a > 0$, then one of the characteristic roots is greater than unity and the other is smaller than unity but greater than zero. Hence equation (7) is saddle-path stable. Assuming in the following that μ refers to the stable root, i.e.

$$\mu = (1/2)(2 + \alpha/a - \sqrt{(2 + \alpha/a)^2 - 4}),$$

then the stable solution of equation (7) can be written in the form:

$$s_t = \mu s_{t-1} - \mu \sum_{j=0}^{\infty} \mu^j E_t Z_{t+j} - \mu^2/(1-\mu) \sum_{j=0}^{\infty} \mu^j (E_t Z_{t+j} - E_{t-1} Z_{t+j}) \qquad (10)$$

It can be seen that the exchange rate depends on the discounted sum of all future values of Z and on the new information obtained between periods t-1 and t.

After making a simplifying assumption that all changes in exogeneous and predetermined variables are surprises, i.e. $E_t \Delta i_{t+j} = E_t \Delta i^f_{t+j} = E_t \Delta R_{t+j} = 0$ for $j \geq 1$, $E_t s^*_{t+j} = s^*_t$, and that $E_t Z_t = Z_t$, equation (10) reduces to:

$$s_t = \mu\, s_{t-1} + \mu/(1-\mu)(\Delta i^f_t - \Delta i_t + (1/a)\Delta R_t) + (1-\mu)\, s^*_t$$
$$+ \mu(s^*_t - s^*_{t-1}) \qquad (11)$$

It can easily be seen that the steady state form of equation (11) is $s_t = s^*_t$.

Equation (6) implies that $s^*_t = s_t - (1/\alpha)B_t$. After substituting this relation for s^*_t, equation (11) can be solved for the current account B, which can be interpreted as a demand function for net foreign assets in flow form. We obtain

$$B_t = \mu B_{t-1} + a(1-\mu)(\Delta i^f_t - \Delta i_t) + (1-\mu)\Delta_t R \qquad (12)$$

It is worth noting that equation (12) does not include the exchange rate as an explanatory variable. It is the reduced form equation for the adjustment path of the current account in the floating exchange rate regime. As (12) has been derived from the financial side of the model, the adjustment path reacts only to variables affecting the capital account and to the intervention variable R.

Assume next that the supply of money is the target variable of monetary policy. Assume also that the inverted demand for money equation, expressed in difference form, is as follows:

$$\Delta i_t = -\beta_1 \Delta m_t + \beta_2 \Delta y_t \qquad (13)$$

where m and y are the logs of the nominal stock of money and nominal income, respectively. Substitute (13) into (7) and, after assuming that $E_t \Delta m_{t+j} = r_1$ and $E_t \Delta y_{t+j} = r_2$ for $j \geq 1$, proceed in the same way as in the case of the exogenous interest rate. We end up with the following equation for the current account (i.e. demand for net foreign assets):

$$B_t = \mu B_{t-1} + a(1-\mu)(\beta_1 \Delta m_t - \beta_2 \Delta y_t + \Delta i^f_t) + (1-\mu)\Delta R_t \qquad (14)$$

In contrast to equation (12), equation (14) contains the income variable y, which is endogenous in the whole model. However, to agents operating in the foreign exchange market, deviations of y from its expected trend path (including its responses to changes in the exchange rate) are surprises. This is the assumption we made at the beginning of this section. On the other hand, as responses of the current account to changes in the exchange rate in different monetary regimes are known to them, the parameter a and hence the value of μ in equations (12) and (14) are different in the two monetary policy regimes.

Comparing equations (12) and (14) with the corresponding equation with static expectations (3), it is interesting to see that they are, in fact, the partial adjustment versions of the latter. In other words the steady state forms of equations (12) and (14) reduce to (3). Similarly, they can be interpreted as equations defining the demand for net foreign assets in flow form. Together with supply equation (4) they determine the exchange rate.

The partial adjustment property of equations (12) and (14) implies that the impact responses of the exchange rate to the foreign interest rate, the foreign exchange market and money market shocks are much smaller with MS-rational expectations than with static exchange rate expectations. However, if adjustment paths are stable the long-run effects are independent of the expectations formation hypothesis. With an exogenous domestic interest rate, the reactions of the exchange rate to real shocks are, in turn, similar with static and MS-rational expectations both in the short- and the long-run. This is due to the fact that real shocks do not affect the flow demand for net foreign assets in either case and also that the flow supply of net foreign asets is determined in the same way in both cases.

2.3 The short-run comparative statics in the flexible exchange rate regime

Before simulating the BOF4 model in the flexible exchange rate regime, we use a simplified model to show the impact effects of some policy shocks on the total income, on the interest rate and on the exchange rate. We specify the following conventional goods market, money market and foreign exchange market equilibrium conditions:

$$Y = Y(\underset{+}{s}, \underset{+}{G}, \underset{-}{i}) \tag{15}$$

$$i = i(\underset{-}{(D + R)}, \underset{+}{Y}, \underset{+}{s}) \tag{16}$$

$$s = s(\underset{+}{Y}, \underset{-}{i}, \underset{+}{i^f}, \underset{+}{(R - T)}) \tag{17}$$

where Y is aggregate real income, G is real government expenditure D is the stock of domestic credit and T is the central bank's intervention in the forward foreign exchange market. The signs below the arguments of the functions refer to the signs of the partial derivatives. Equation (16) is the inverted demand for money equation with the price level reduced to its argument s. The foreign exchange market equilibrium condition (17) is in accordance with the condition implied by equations (3) and (4) (static expectations) or equations (13) and (4) (MS-rational expectations). We assume that the product of the partial derivatives Y_s and s_Y is less than one.

With the interest rate as a control variable of monetary policy, equations (15) and (17) produce the following impact effects on Y and s:

	exogenous variables					
endogenous varibles	G	i	i^f	R	D	T
Y	+	-	+	+	+	-
s	+	-	+	+	+	-

With the nominal stock of money as a control variable the signs of the effects of the exogenous variables are:

	exogenous variables				
endogenous variables	G	i^f	R	D	T
Y	+	+	+	+	-
i	+	+	?	?	-
s	?	+	+	+	-

We see that the sign of the the effect of increase in government expenditure on the exchange rate is ambiguous. The sign depends on the rate of the substitutability between domestic and foreign bonds. If it is high enough, an increase in government expenditure leads to an appreciation of the currency; otherwise the currency depreciates.

2.4 Endogenizing the exchange rate in the BOF4 model

To endogenizeng the exchange rate in the BOF4 model, estimates for the parameters appearing in equation (3) (static expectations) or in equations (12) and (14) (MS-rational expectations) are needed. As the parameter μ in (12) and (13) is a function of a and α, the estimate of α also has to be known. The parameter a is obtained from the equation estimated for the net import of foreign capital. In the BOF4 model long-term capital imports are treated as an exogenous variable and hence the estimated equation for net capital imports includes only net imports of short-term foreign capital. Moreover, this equation was estimated as a share of nominal GDP (a proxy for domestic nominal wealth). Hence, ΔF, B and ΔR are re-interpreted as short-term capital imports, the current and long-term capital account and the change in official foreign reserves, respectively, all as shares of nominal GDP.

The estimate of the parameter a obtained from the estimated equation for the net import of foreign assets is 0.018. This implies that a one per cent increase in the domestic interest rate or an expected one per cent appreciation of the exchange rate causes a net import of foreign capital equalling nearly two per cent of quarterly nominal GDP.

The parameter α measures the response of the GDP share of the current and long-term capital account to the change in the exchange rate. An estimate for it was obtained by carrying out devaluation simulations with the BOF4 model under the fixed exchange rate regime. In the cases of exogenous and flexible interest rates the estimates for α were 0.044 and 0.078, respectively. Because of the use of annual percentage interest rates in the capital import equation, the annualizing factor 1/400 was needed in calculating the estimate for α/a.

In deriving equation (14), the demand for money equation was assumed static. However, according to the estimated equation in the BOF4 model the demand for money adjusts in nominal terms through a partial adjustment process towards the equilibrium value. This implies that the inverted demand for money equation (13) should also include the percentage change in the stock of money lagged by one period. Moreover, in the estimated equation the demand for money reacts to lagged nominal income rather than to nominal income in the current period. These facts were also taken into account when the parameters of the equation corresponding to equation (14) were calculated. The following equations for the current and long-term capital account were obtained:

The case of static expectations:

$$BPBV/GDPV_{-1} = 0.01798\ (\Delta RFOR - \Delta RS) + (\Delta GFX - \Delta FPBBF)/GDPV_{-1} \qquad (17)$$

The case of MS-rational expectations with a fixed interest rate:

$$BPBV/GDPV = 0.9247\ (BPBV_{-1}/GDPV_{-1}) + 0.001353\ (\Delta RFOR - \Delta RS)$$
$$+ 0.0753\ (\Delta GFX - \Delta FPBBF)/GDPV \qquad (18)$$

The case of MS-rational expectations with an exogenous interest rate:

$$BPBV/GDPV = 0.9010\ (BPBV_{-1}/GDPV-1 + 0.001780\ (\Delta RFOR - \Delta RDT)$$
$$+ 0.1113\ (\Delta KDP + \Delta CUR)/(KDP_{-1} + CUR_{-1})$$
$$- 0.0182\ (\Delta KDP_{-1} + \Delta CUR_{-1})/(KDP_{-2} + CUR_{-2})$$
$$- 0.0869\ \Delta GDPV/GDPV_{-1} - 0.0098\ \Delta GDPV_{-1}/GDPV_{-2}$$
$$+ 0.0990\ (\Delta GFX - \Delta FPBBF)/GDPV \qquad (19)$$

where

BPBV = Current and long-term capital account, FIM million
GDPV = GDP in purchaser's value, FIM million
RFOR = Average 3 month euromarket interest rate for USD, GBP, DEM, CHF, per cent
RDT = Interest rate, time deposits, per cent
KDP = Bank deposits by the public, FIM million
CUR = Currency in circulation, FIM million
GFX = Foreign exchange reserves of the Bank of Finland, FIM million
FPBBF = the Bank of Finland's forward sales of foreign exchange, FIM million

In equation (17) the variable RDT is exogenous and represents the own interest rate of money, which in the inverted demand for money equation (13) was assumed to equal zero.

3 Model simulations

There are four different monetary and foreign exchange policy regimes in which policy simulations can be made with the BOF4 model. Model versions corresponding to each of these policy regimes are shown below:

	Interest rate	
	fixed	flexible
fixed exchange rate	BOF4.AX	BOF4.BX
floating exchange rate	BOF4.AFR BOF4.AFS	BOF4.BFR BOF4.BFS

In the floating exchange rate versions of the model the letters R and S refer to MS-rational and static exchange rate expectations, respectively. These model versions were used to run the following policy simulations:

1. A fiscal shock: a sustained increase in real government consumption outlays of FIM 100 million per quarter

2. A foreign interest rate shock: a sustained 1 percentage point increase in the foreign interest rate

3. A domestic interest rate shock: a sustained 1 percentage point increase in the domestic short-term interest rate

4. Money market intervention: a FIM 1000 million official purchase of FIM-denominated CD's on the interbank market

5. Unsterilized foreign exchange intervention: an official purchase of foreign currency worth of FIM 1000 million

6. Sterilized foreign exchange intervention: a FIM 1000 million forward exchange purchase by the central bank.

Naturally, the domestic interest rate shock simulations were run only with the fixed interest rate versions of the model, the money market intervention shocks only with flexible interest rate versions of the model, and the foreign exchange intervention shocks only with the floating exchange rate versions of the model.

3.1 The results

The effects of the expansive fiscal shock on some selected variables of the model are presented in table 1. We see that in the fixed exchange rate regime (versions AX and BX) the effects on GDP and on the current account balance are rather strong and long-lasting, whereas the price effects are very weak. This is a natural result in a small open economy where in the fixed exchange rate regime domestic prices are very closely linked to foreign prices. When monetary policy is not accommodative (version BX), however, the activity effects start to be crowded out as result of the rising interest rate.

The floating of the exchange rate strengthens the activity effects of expansive fiscal policy. To prevent a widening of the current account deficit the exchange rate has to depreciate following fiscal expansion. Profitabilty increases, especially in the open sectors of the economy, as the depreciaton of the currency is transmitted with a distributed lag to domestic prices and wages. This reinforces the original expansive effects of fiscal policy. This mechanism is particularly strong when monetary policy is accommodative (versions AFR and AFS). With non-accommodative monetary policy (versions BFR and BFS), the rise in the interest rate associated with increased activity lessens the need for depreciation and hence limits the extent

Table 1. The fiscal shock: sustained increase in government real consumption outlays of FIM 100 million per quarter

Multiplier effects on GDP, (FIM/FIM)

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
AX	1.4	1.6	1.7	1.8	1.6	2.0	2.1	1.8
BX	1.4	1.6	1.6	1.7	1.6	1.7	1.4	0.9
AFR	1.7	2.3	3.1	3.8	2.7	5.5	6.5	1.6
AFS	1.7	2.3	3.2	4.1	2.8	6.2	6.2	1.7
BFR	1.6	2.1	2.5	2.7	2.2	2.0	0.2	-0.4
BFS	1.5	1.7	1.9	2.0	1.8	2.1	1.8	1.0

Multiplier effects on the current account balance, (FIM/FIM)

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
AX	-0.4	-0.6	-0.7	-0.6	-0.6	-0.6	-0.6	-0.6
BX	-0.4	-0.6	-0.7	-0.6	-0.6	-0.5	-0.3	-0.2
AFR	-0.0	-0.0	-0.0	-0.1	-0.0	-0.0	-0.1	0.0
AFS	-0.0	0.0	-0.1	-0.1	-0.0	0.1	0.0	0.0
BFR	-0.1	-0.1	-0.4	-0.4	-0.3	-0.3	-0.0	0.0
BFS	-0.2	-0.6	-0.7	-0.5	-0.5	-0.4	-0.2	-0.0

Efects on the exchange rate, %

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
AX	-	-	-	-	-	-	-	-
BX	-	-	-	-	-	-	-	-
AFR	1.2	1.5	3.0	2.6	2.1	4.4	5.6	2.7
AFS	1.1	1.5	3.0	2.8	2.1	4.2	3.5	1.1
BFR	0.8	1.3	1.6	1.1	1.2	0.6	0.1	0.1
BFS	0.6	0.2	0.4	0.4	0.3	0.5	0.6	0.5

Effects on private consumption prices, %

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
AX	0.0	0.1	0.1	0.1	0.0	0.1	0.2	0.2
BX	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3
AFR	0.2	0.3	0.6	0.9	0.5	1.5	2.6	2.7
AFS	0.2	0.3	0.6	0.9	0.5	1.5	2.1	1.8
BFR	0.1	0.3	0.4	0.5	0.3	0.5	0.4	0.5
BFS	0.1	0.1	0.1	0.2	0.1	0.3	0.4	0.5

Effects on the domestic short-term interest rate, percentage points

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
AX	-	-	-	-	-	-	-	-
BX	0.0	0.1	0.1	0.2	0.1	0.3	0.4	0.4
AFR	-	-	-	-	-	-	-	-
AFS	-	-	-	-	-	-	-	-
BFR	0.0	0.2	0.3	0.5	0.3	0.6	0.3	0.2
BFS	0.0	0.1	0.2	0.2	0.1	0.3	0.4	0.5

Table 2. The foreign interest rate shock: sustained 1 percentage point increase in the foreign interest rate

Effects on GDP, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	0.0	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0
BX	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.2
AFR	0.1	0.2	0.3	0.4	0.3	0.5	0.5	-0.5
AFS	1.1	1.7	1.9	1.6	1.6	0.3	-2.1	-4.1
BFR	0.1	0.2	0.2	0.2	0.2	-0.0	-0.4	-0.4
BFS	0.6	0.3	0.3	0.4	0.4	-0.3	-0.5	-0.6

Effects on the current account balance, per cent of nominal GDP

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0
BX	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1
AFR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AFS	1.8	-0.0	-0.2	0.1	0.4	0.0	-0.0	0.0
BFR	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
BFS	0.8	-0.9	0.1	0.7	0.2	0.1	0.3	0.1

Efects on the exchange rate, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	-	-	-	-	-	-	-	-
BX	-	-	-	-	-	-	-	-
AFR	2.2	1.9	2.8	2.4	2.3	3.7	3.6	0.1
AFS	25.7	9.1	-0.8	2.7	10.0	-0.7	-9.9	-15.9
BFR	2.1	2.1	1.8	1.3	1.8	0.4	-0.3	-0.0
BFS	13.3	-4.4	-2.0	6.3	3.6	-1.0	0.7	-0.8

Effects on private consumption prices, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	0.0	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0
BX	0.0	0.0	0.0	-0.0	0.0	-0.0	0.0	-0.0
AFR	0.3	0.5	0.7	0.8	0.6	1.3	1.9	1.5
AFS	3.4	4.0	1.9	2.0	2.8	1.6	-1.6	-5.0
BFR	0.3	0.5	0.5	0.6	0.5	0.5	0.2	0.1
BFS	1.7	0.9	-0.2	1.1	0.9	0.4	0.2	0.1

Effects on the domestic short-term interest rate, percentage points

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	-	-	-	-	-	-	-	-
BX	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.2
AFR	-	-	-	-	-	-	-	-
AFS	-	-	-	-	-	-	-	-
BFR	0.0	0.3	0.5	0.5	0.4	0.5	0.0	-0.2
BFS	0.5	1.0	0.9	0.5	0.7	0.5	-0.0	-0.4

Table 3. The domestic interest rate shock: sustained 1 percentage point increase in the domestic short-term interest rate

Effects on GDP, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	-0.0	-0.1	-0.1	-0.1	-0.1	-0.3	-0.5	-0.6
AFR	-0.1	-0.3	-0.5	-0.6	-0.4	-1.3	-2.2	-0.9
AFS	-2.8	-2.5	-2.9	-2.4	-2.6	-0.2	2.4	3.2

Effects on the current account balance, per cent of nominal GDP

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.2
AFR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AFS	1.8	-0.0	-0.2	0.1	0.4	0.0	-0.0	0.0

Efects on the exchange rate, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	-	-	-	-	-	-	-	-
AFR	-2.3	-2.2	-3.8	-3.6	-3.0	-7.8	-12.2	-7.1
AFS	-42.4	-12.5	3.2	-1.2	-12.1	4.0	12.1	13.3

Effects on private consumption prices, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AX	0.0	-0.0	-0.0	0.0	0.0	0.0	0.1	0.1
AFR	-0.3	-0.5	-0.8	-1.1	-0.7	-2.3	-4.8	-5.5
AFS	-5.1	-6.0	-2.4	-2.4	-3.1	-1.4	2.8	5.2

Table 4. The money market intervention shock: FIM 1000 million official purchase of FIM-demoninated CD's from the interbank market

Effects on GDP, %

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
BX	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2
BFR	0.6	2.2	2.9	3.4	2.3	2.5	-0.3	-1.8
BFS	9.3	-0.4	4.0	3.1	4.0	-2.4	-2.4	-1.4

Effects on the current account balance, percent of nominal GDP

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
BX	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1
BFR	0.9	0.3	-0.0	-0.2	-0.2	-0.3	0.1	0.3
BFS	13.6	-23.7	7.8	5.0	0.7	-1.5	4.7	-2.0

Effects on the exchange rate, %

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
BX	-	-	-	-	-	-	-	-
BFR	11.7	12.8	14.0	12.3	12.7	7.5	1.7	0.1
BFS	200.6	-187.7	29.6	83.0	43.6	-33.7	35.7	-20.4

Effects on private consumption prices, %

Model	Quarters							
version	I	II	III	IV	Years			
BX	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	-0.0	-0.0
BXR	1.5	2.9	3.7	4.5	3.2	4.8	3.5	2.6
BFS	2.7	-0.1	1.8	-0.5	9.0	-0.6	1.3	-1.2

Effects on the domestic short-term interest rate, percentage points

Model	Quarters				Years			
version	I	II	III	IV	1.	2.	3.	4.
BX	-0.9	-0.4	-0.4	-0.4	-0.4	-0.4	-0.2	-0.2
BFR	-15.4	-3.3	-1.4	-0.1	-5.3	1.4	-0.5	-2.4
BFS	-7.6	5.4	8.7	-2.2	-0.9	-1.4	-6.3	-7.2

Table 5. Sterilized and unsterilized FIM 1000 million foreign exchange intervention shock

Effects on GDP, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AFR:								
sterilized	0.1	0.1	0.2	0.3	0.2	0.4	0.3	-0.3
AFS:								
sterilized	0.8	1.1	1.2	1.1	1.1	0.2	-1.6	-2.7
BFR:								
sterilized	0.1	0.1	0.1	0.2	0.1	-0.0	-0.3	-0.2
unsterilized	0.8	2.5	3.2	3.6	2.6	2.6	-0.4	-0.2
BFS:								
sterilized	0.4	0.2	0.2	0.2	0.3	-0.2	-0.4	-0.4
unsterilized	9.6	-0.2	4.2	3.2	4.2	-2.6	-2.7	-1.8

Effects on the current account balance, per cent of nominal GDP

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AFR:								
sterilized	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
AFS:								
sterilized	1.1	-0.0	-0.2	0.1	0.3	0.0	-0.0	0.0
BFR:								
sterilized	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1
unsterilized	1.0	0.3	-0.1	-0.3	0.3	-0.3	0.2	0.2
BFS:								
sterilized	0.5	-0.6	0.1	0.4	0.1	0.0	0.2	0.1
unsterilized	14.2	-24.2	7.8	5.4	0.8	-1.5	4.9	-1.9

Efects on the exchange rate, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AFR:								
sterilized	1.4	1.2	1.8	1.6	1.5	2.4	2.3	-0.0
AFS:								
sterilized	17.5	6.1	-0.7	1.5	6.5	-0.8	-6.8	-10.4
BFR:								
sterilized	1.3	1.3	1.1	0.8	1.1	0.2	-0.2	-0.1
unsterilized	14.2	15.0	15.0	13.2	14.3	8.2	1.5	0.2
BFS:								
sterilized	8.7	-3.0	-1.2	4.0	1.1	0.2	-0.2	-0.1
unsterilized	213.5	-190.2	27.9	86.6	46.0	-34.1	36.4	-20.8

Table 5. Continued

Effects on private consumption prices, %

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AFR:								
sterilized	0.2	0.3	0.4	0.5	0.4	0.8	1.2	0.9
AFS:								
sterilized	2.3	2.7	1.3	1.3	1.9	1.0	-1.2	-3.4
BFR								
sterilized	0.2	0.3	0.3	0.3	0.3	0.3	0.1	0.1
unsterilized	1.8	3.4	4.2	4.9	3.6	5.2	3.7	2.7
BFS								
sterilized	1.1	0.6	-0.1	0.7	0.6	0.3	0.1	0.0
unsterilized	28.0	-0.6	-8.1	18.4	9.5	-0.4	1.5	-1.1

Effects on the domestic short-term interest rate, percentage points

Model version	Quarters I	II	III	IV	Years 1.	2.	3.	4.
AFR:								
sterilized	-	-	-	-	-	-	-	-
AFS:								
sterilized	-	-	-	-	-	-	-	-
BFR:								
sterilized	0.1	0.2	0.3	0.4	0.2	0.3	0.0	-0.1
unsterilized	-16.0	-2.9	-0.4	-0.4	-4.9	1.9	-0.3	-2.7
BFS:								
sterilized	0.4	0.7	0.6	0.4	0.5	0.3	-0.0	-0.4
unsterilized	7.3	6.0	1.2	-1.9	-0.5	-1.1	-6.3	-7.4

of real expansion. As was anticipated in section 2.2 the effects of the expansive fiscal shock are fairly similar both with MS-rational and static exchange rate expectations when monetary policy in accommodative.

In table 2 the simulated results of a foreign interest rate shock are presented: the foreign interest rate is raised permanently by one percentage point. In the fixed exchange rate regime with accommodative monetary policy (version AX) the real economy is insulated from foreign interest rate shocks. All that happens is that the composition of the supply of money changes: as a reaction to the rise in the foreign interest rate there is a loss of foreign reserves, which is neutralized by an expansion in domestic credit.

In the fixed exchange rate regime with non-accommodative monetary policy (version BX) the loss of foreign reserves is fully transmitted to the monetary base, i.e. the supply of money decreases and, hence, the domestic interest rate increases. It can be seen that a one percentage point increase in the foreign interest rate leads to an immediate rises in the short-term domestic interest rate by about 0.6 percentage point. In the longer run, however, this relation is much weaker. This is mainly due to the slow adjustment of the demand for money to changes in the interest rate: in the short-run a greater rise in the interest rate is needed to depress money demand to the level corresponding to the decreased money supply than in the long-run.

The increase in the domestic interest rate depresses domestic demand and improves the current account balance slightly. The effects on domestic prices are negligible. In this respect the simulation results in the floating exchange rate regime are dramatically different. In these simulations the exchange rate and hence the price responses are much stronger. The rise in the foreign interest rate causes a capital outflow, which has to be covered through a strengthening of the current account.

This forces the exchange rate to depreciate. The immediate depreciation is particularly strong in the cases of static exchange rate expectations (versions AFS and BFS). The impact reaction of the exchange rate is clearly much stronger than what is needed in the long run. In response to the lagged effects of the depreciation in the first period the exchange rate has to appreciate in the second period. In general the time pattern of the exchange rate response is strongly zigzagging.

In tables 3-5 we find that similar zigzagging response paths of the exchange rate are also typical in response to other financial market shocks, when exchange rate expectations are static. As this kind of exchange rate behaviour is rather implausible, in the following we concentrate on the results obtained with the MS-rational exchange rate expectations.

In table 2 the rise in the foreign interest rate has a stimulative effect on GDP because of the depreciation of the currency. However, when the monetary policy is non-accommodative, the rise in the domestic interest rate decreases the activity effect somewhat. Moreover the positive activity effect is transitory as in the longer run the depreciation of the exchange rate is gradually transmitted domestic prices. In the case with accommodative monetary policy the GDP effect turns negative after three years (version AFR), and with non-accommodative monetary policy (version BFR) during the second year. In comparing the effects of the rise in the foreign interest rate on the domestic interest rate in the fixed and floating exchange rate regimes we see that in the latter regime the effects are smaller.

Table 3 shows the effects of a sustained one percentage point increase in the domestic interest rate in the fixed the floating exchange rate regimes. GDP decreases in response to the rise in the domestic interest rate GDP decreases and the current account balance improves. The GDP effects are greater in the floating exchange rate regime than in the fixed exchange rate regime. This results from the fact that the rise in the domestic interest rate causes the exchange rate to appreciate. With MS-rational expectations (version AFR) the appreciation of the currency continues for the first three years. The appréciation of the exchange rate takes place in response to a capital inflow caused by the rise in the domestic interest rate.

Price reactions are again quite different in the fixed and floating exchange rate regimes: in the floating exchange rate regime the effects of an increase in the domestic interest rate on domestic prices are rather strong whereas in the fixed exchange rate regime these effects are negligible.

Table 4 shows the effects of a FIM 1000 million increase in the domestic credit component of the monetary base. There is a striking difference in the magnitude of the effects of this policy measure in the fixed and floating exchange rate regimes. These differences in magnitude can be understood, if we first examine how money market intervention is transmitted to the monetary base and further to broad money (i.e. currency plus deposits) in the two exchange rate regimes. The first-quarter effects of a FIM 1000 million official purchase of FIM-denominated CD's in the interbank market on the monetary base and broad money in the BOF4.BX and BOF4.BFR versions of the model are as follows:

Model version	The size of the shock, million FIM	The effect on the monetary base, million FIM	The effect on broad money, million FIM
BX	1000	30	417
BFR	1000	1004	14033

In the fixed exchange rate regime only FIM 30 million of the FIM 1000 million intervention is transmitted to the monetary base. The rest of the shock flows abroad through capital movements. As a result of the money multiplier process, the increase of FIM 30 million in the monetary base causes broad money to increase by FIM 417 million. The change in broad money is, via the demand for money equation, transmitted to the domestic interest rate.

In the floating exchange rate regime the central bank is able to control both the domestic and the foreign component of the monetary base, i.e. intervention in the money market is transmitted in full to the monetary base. The intervention of FIM 1000 million leads, via the money multiplier process, to an increase of FIM 14 033 million in broad money. Hence, there is a huge increase in the effectiveness of monetary policy as the exchange rate regime shifts from the fixed to the floating exchange rate regime.

In the floating exchange regime the domestic interest rate decreases and the exchange rate depreciates in response to expansionary money market intervention. The exchange rate has to depreciate in order for the outflow of capital caused by the decrease in the interest rate to be offset by a corresponding change in the current account balance. During the first two years both the interest rate and exchange rate reactions stimulate real economic activity. However, with MS-rational expectations (version BFR) the adjustment path is cyclical. The effect on GDP turns negative in the third year after intervention in the money market.

The "price-output split" of the effects of expansionary money market intervention in both the fixed and the floating exchange rate regimes is presented in table 6. The figures in the table show how large a share of the increase in nominal GDP takes the form of higher prices. In the fixed exchange rate regime the price effects are very small and, in fact, slightly

Table 6. The price-output split of expansionary money market intervention. The increase in the GDP deflator as a percentage of the increase in nominal GDP.

Years	Fixed exchange rate regime	Floating exchange rate regime
1	-3	53
2	2	67
3	-7	108
4	-8	251

negative as a result of the productivity developments. In the floating exchange rate regime more than half of the effect on nominal GDP is transmitted through prices. Values above 100 in the third and fourth years reveal that the effect on the volume component of GDP has turned negative.

The effects of foreign exchange intervention in different policy regimes are presented in table 5. There were two kinds of intervention: sterilized and unsterilized. In the former case intervention is not allowed to change the money supply. In the latter case intervention is transmitted in full to the monetary base.

In the regime with fixed domestic interes rate the sterilized intervention took the form of a FIM 1000 million official purchase of foreign currency. In the regime with a flexible interest rate, however, this operation is as such unsterilized intervention. In that regime sterilized intervention was implemented as a FIM 1000 million forward purchase by the central bank. The effects of this operation are the same as if the central bank had simultaneously purchased the equivalent of FIM 1000 million in foreign currency and sold FIM 1000 million worth of CD's in the interbank market.

It can be seen that the effects of sterilized foreign exchange intervention are much smaller than those of unsterilized intervention. This results simply from the fact that, in the former case, intervention does not affect the stock of money or its effects on the stock of money are negligible (in the case of a fixed domestic interet rate). The effects of sterilized intervention are quite similar in the two different money market regimes (versions AFR and BFR). It can be seen that in these simulations the price effects are large relative to the GDP effects. This implies that in the floating exchange rate regime sterilized exchange intervention would be an effective tool for controlling domestic prices.

In the floating exchange rate regime with the flexible domestic interest rate (version BFR) the effects of unsterilized intervention are quite similar to those of the money market intervention in table 4. This is due to fact that in both cases the effects of unsterilized exchange intervention on the real economy are chiefly transmitted via changes in the stock of money, which in both cases are quite similar.

4 Discussion and concluding remarks

The purpose of this paper has been to formulate BOF4 model versions corresponding to two monetary policy (pegged vs. flexible interest rate) and two foreign exchange rate (fixed vs. floating exchange rate) regimes, and to examine their response charasteristics under various real and financial shocks. In specifying the floating exchange rate versions of the model two alternative assumptions about the formation of exchange rate expectations were used, i.e. static and MS-rational expectations. In the model versions with MS-rational expectations the information set utilized by investors operating in the foreign exchange market was constrained in a market-specific way: investors know the interest sensitivities of the demand for money and the demand for net foreign assets and the impact effect of the change in the exchange rate on the current account in different monetary policy regimes. It was further assumed that all deviations of the policy variables and the variables exogenous to the financial block of the model from their expected trend paths were surprises.

Qualitatively our simulation results are in accordance with economic theory. This can be seen by comparing the simulation results in tables 1-5 to those obtained in a simple theoretical framework and presented in sectoin 2.3. There are, however, some features in our floating exchange rate simulations worth noting. Firstly, the response reactions of the exchange rate to the simulated policy shocks are rather big in comparison to the results obtained in many other macroeconometric models. This can be seen from tables 7 and 8.

Table 7. The effects of an increase in government expenditure (one per cent of GDP) on the exchange rate in some single country and multicountry models, percentage deviations from the baseline

Single country model	Impact effect	Annual average 1.	2.	3.	5.	7.
Australia	-	1.1	7.5	4.2	-	2.0
France	-	1.4	3.0	3.4	-	4.6
Japan	-	1.3	5.8	7.7	-	5.7
Netherlands	-	0.3	0.6	0.8	-	1.3
BOF4.BFR	4.3	6.6	3.0	0.4	1.6	-
BOF4.BFS	3.2	1.9	2.5	3.3	1.9	-
Multicountry Model, DM/$						
EPA	0.6	1.8	3.9	6.0	8.7	-
LINK	0.3	1.9	2.3	4.0	8.0	-
MCM	0.0	0.4	1.9	3.7	8.0	-
OECD	0.1	0.0	0.4	0.8	1.1	-

Table 8. The effect of a 1 percentage point increase in the home country's interest rate on the exchange rate in some single country and multicountry models, percentage deviations from the baseline

Single country effect model	Impact effect	Annual average 1.	2.	3.	4.	5.
Canada	-	-0.9	-1.7	-2.2	-	-4.3
England	-	-2.1	-2.5	-3.5	-	-2.2
France	-	-0.5	-1.6	-2.2	-	-2.6
Germany	-	-0.6	-1 0	-0.9	-	-0.9
Japan	-	-1.8	-3.6	-4.3	-	-3.5
Netherlands	-	-2.4	-1.8	-2.4	-	-2.9
BOF4.AFR	-2.3	-3.0	-7.8	-12.2	1.7	-
Multicountry Model, DM/$						
EPA	-2.1	-2.2	-2.7	-3.7	-7.4	-
LINK	-1.3	-1.8	-2.4	-2.5	-2.7	-
MCM	-0.8	-0.8	-1.0	-0.5	-1.0	-
OECD	-0.8	-0.8	-0.9	-1.1	-1.2	-

Table 7 lists the response reactions of the exchange rate to a sustained increase in government spending equal to 1 per cent of real GDP in some single country models (Chan-Lee and Kato (1984)) and in four of the major multi-country models (Amano (1986)). We see that the short-run response of the exchange rate to the the fiscal shock is clearly greater than in other models. This is especially so in the model version with MS-rational exchange rate expectations. In the longer-run, however, the effects on the exchange rate in the BOF4-model simulations are smaller than in most other models.

Table 8 presents corresponding reactions of the exchange rate in response to a rise in the domestic interest rate. In this case we see that in the BOF4 model (with MS-rational exchange rate expectations) the impact response of the exchange rate to the interest rate shock is somewhat greater and the second and third year responses are much greater than in the other models in table 8.

Is the magnitude of the exchange rate reactions in the BOF4 model simulations something that we should be worried about? The answer is no, not at least in the light of the following quotation from Pauly and Petersen (1986):

"...With regard to the order of magnitude of exchange rate effects the most striking impression is that they seem to be rather small."

or from Hooper (1986):

"... It appears that the model understates the sensitivity of exchange rates to changes in nominal and real interest rate differentials."

The second prominent feature of the BOF4 model simulations is that with the MS-rational exchange rate expectations the response paths of the exchange rate proved to be strongly cyclical.

As regards static expectations, the response paths of the exchange rate to the financial market shocks were strongly zigzagging and the impact effects were much greater than with MS-rational expectations. The massive and overshooting fluctuations in the exchange rate associated with static expectations do not seem realistic. Hence, our results reinforce the argument for using other expectational formation assumptions in preference to static expectations. Murphy (1986) came to asimilar conclusion with static expectations.

The cyclicality in the response path of the exchange rate associated with MS-rational expectations is something that does not appear with fully rational expectations. With fully rational expectations the impact reaction of the exchange rate is strong and possibly overshooting. Thereafter, however, the exchange rate adjusts smoothly towards the new long-run equilibrium level (see e.g. Minford et al. (1986), Murphy (1986) and Aurikko (1988)).

It is clear that with MS-rational exchange rate expectations cyclicality in the adjustment path of the exchange rate is connected with the informational constraints we imposed. The realism of this kind of adjustment path is by and large an empirical question. The behaviour of the exchange rates between the major currencies after the breakdown of the Bretton Woods is not, at least, in contradiction with this view: when the dollar started to depreciate it did so for years and when it started to appreciate it appreciated for years. Hence, what concerns us in our simulation results is not cyclicality in adjustment paths but the fact that within the time horizon used in our simulation experiments it is unclear. Whether the cyclical response paths are dampening or not. The instability implied by explosively fluctuating adjustment paths would not be a desirable feature of the model. This is an issue which requires further research.

Another topic for further research would be to compare the simulation properties of the model with MS-rational exchange rate expectations with those of fully rational expectations. Because of the rapid progress in the development of solution algorithms required by rational expectations this is no longer impossible, even in the context of realistic large-scale macroeconometric models.

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