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FINANCIAL MARKETS IN THE BOF4 MODEL OF THE FINNISH ECONOMY**

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ABSTRACT

This paper describes the modelling of financial markets and the balance of payments in BOF4, a quarterly macroeconomic model developed by the Bank of Finland.

The short-term interest rate is determined as a result of the interaction of the demand for money and money supply, as in the conventional IS-LM approach. Alternatively, the model may be solved under the assumption that monetary policy is based on pegging interest rates. In that case, the domestic credit of the Central Bank is the equilibrating variable.

The model includes term structure and tax structure equations for determining three market-determined longer-term interest rates: the taxable bond yield, the yield on tax-free bonds and the average bank lending rate. The short-term money market rate is, however, the main underlying determinant for all of these.

Foreign assets are assumed to be less than perfect substitutes for domestic assets. With fixed exchange rates, this is of course a necessary condition for the independent determination of the domestic interest rates. Capital movements are modelled using the Kouri-Porter (1975) approach. This means estimating a form of the portfolio equation for net foreign assets in which the domestic interest rate is reduced to its determinants. The monetary autonomy of the Finnish economy is estimated to be rather limited.

The behaviour of the financial block of equations in the model and the transmission of financial influences to the real side of the model are illustrated by three simulation experiments.

CONTENTS

1 INTRODUCTION

The BOF4 model of the Finnish economy is a quartely econometric model developed at the Bank of Finland for forecasting and policy analysis.[1] The model consists of about 270 equations, 100 of which are estimated behavioural or otherwise approximate relationships. The model may be characterized as an empirical application of the basic "neoclassical synthesis" approach to macroeconomics. Thus, the model can be seen as consisting of aggregate demand (IS), aggregate supply (AS), and monetary (LM) submodels or "blocks".

The present paper describes the modelling of financial behaviour in BOF4, and is part of a series intended to cover all sectors of the model. Reports have previously been published on exports and imports (Tarkka and Willman, 1988), production and employment (Tarkka, Willman and Rasi, 1988), wages and prices (Tarkka, Willman and Rasi, 1989) and on consumption and investment (Tarkka, Willman and Männistö, 1989). Some results on the financial behaviour of the Finnish economy according to the BOF4 model are also presented in Willman (1989).

The basic approaches of financial modelling employed in BOF4 are discussed in chapter 2 below. The demand for and supply of money equations are presented in chapter 3. These equations determine the short-term market rate of interest in the model, when the model is used in the flexible interest rate models. The determination of other interest rates is described in chapter 4, which concentrates on two essential questions, the term structure of interest rates and the influence of capital income taxation on the interest rate mechanism. The modelling of capital flows in the balance of payments is described in chapter 5.

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[1] A preliminary list of the equations of the BOF4 model has been circulated in the Research Paper series of the Bank of Finland Research Department (TU 6/87, 1987). A full documentation of the previous BOF3 version of the model is in Tarkka and Willman (1985).

Chapter 6 presents preliminary results on forward currency markets. The operation of the financial/monetary relationships is illustrated in chapter 7 by means of simulation experiments.

Throughout the paper, reference is made to the list of equations included as appendix 1. Another appendix is devoted to a brief description of how the recent deregulation of the Finnish financial markets and the ensuing structural changes have influenced our modelling effort.

2 THE GENERAL APPROACH

2.1 The Extended Monetary Approach to Financial Modelling

The strategy of modelling the financial markets in BOF4 may be described as the "monetary" or, perhaps more informatively, "residual-asset" approach. This is characterized by the following basic assumptions:

1. All assets which are denominated in domestic currency and are not classified as money are very close substitutes. If there are risk (or term) premia between them, the premia are assumed to remain constant in time.

2. There is a single "leading" market rate of interest, which is sufficient to measure the intertemporal opportunity costs of investment, consumption and holding money. This is a consequence of the first assumption. Long-run interest rates are linked to the "leading" or "benchmark" short-term interest rate by means of relationships like term structure are tax structure equations.

3. Unlike other assets, money is treated like a durable good and stable demand functions exist for the kinds of money included in the model (in BOF4, there are two: currency and broad money).

4. Assets denominated in foreign currency may be treated as imperfect substitutes for domestic assets. If this is not done, a "Mundell-Fleming model" is obtained in which uncovered interest rate parity holds between domestic and foreign financial markets. With imperfect substitutability, as in BOF4, partial independence of the domestic rate of interest is retained.

The term "residual-asset approach" refers to the fact that in this type of model the demand and supply functions for assets bearing the "leading" market rate of interest are not explicitly included. Rather, the demands for and supplies of "bonds" (and other similar instruments) are obtained as residuals for the agents' or sectors' budget constraints and the consistency of the whole model with a market equilibrium in this omitted market is ensured by Walras' law.

The residual asset approach can also be called "monetary". This does not imply any necessary association with the "monetarist" doctrines of economic policy, but is simply due to the fact that in this framework the working of the financial markets can be studied by focusing only on the demand for and supply of money. This is especially obvious in a closed-economy context and is familiar from the common IS-LM framework from which the whole approach originates.

The residual-asset approach has been by far the most common way of modelling financial markets in practical models, because it allows for some degree of flexibility and independence in designing expenditure, money demand and other equations in the model while retaining consistency with budget constraints. The approach should be contrasted with the comprehensive portfolio approach of financial modelling, which aims at treating all assets - even tangibles - in a symmetrical way. This much more demanding strategy was proposed by Brainard and Tobin (1968) and has lately gained increasing popularity in model building (see e.g. Keating (1985)). However, a drawback of this approach is that, besides requiring a major research effort, a lot of subjective judgement concerning parameter restrictions, exogeneity specifications etc. is required to obtain a tractable model. These difficulties would, we think, be especially severe in the context of structural changes such as have occurred in the financial markets in Finland in the 1980s as a result of financial liberalization.

2.2 Overview of the Financial Block

The financial block of BOF4 is built around the balance-of-payments identity and the balance sheets of the central bank and the deposit banks. In this framework, the model includes behavioural equations for external capital movements, demand for currency and the demand for broad money. The concept of broad money includes currency and all bank deposits which do not bear market rates of interest. Thus, the money market liabilities of the banks in the form of CDs etc. are excluded from the concept of money.

The determination of the money supply is governed by the balance sheet identities and a technical equation determining the banks' required reserve deposits at the central bank. These suffice to link the quantity of broad money to the net central bank position of the banks. In the case where the central bank pegs the market rate of interest, the quantity of money is demand-determined and the money supply identities determine the amount of central bank credit; in the case where the central bank fixes its domestic credit the money supply identities determine the quantity of money and the demand for money function in turn determines the rate of interest consistent with it.

BOF4 includes three interest rates which are entirely market-determined. These are the short-term money market rate, the taxable bond (debenture) rate and the yield on tax-free bonds. (At present, the short-term money market rate is measured by the 3-month "HELIBOR" rate, but the data include slightly different definitions for earlier periods.) The banks' average lending rate is partly market-determined and partly exogenously determined; the interest rate on new bank loans is market-determined whereas changes in the interest rates on the outstanding loan stock is closely related to changes in the (exogenous) discount rate. Thus the economics of the average lending rate become rather complicated.

The model also deals with the call money (overnight) rate, but in the normal use of the model this is directly linked to the money market rate. The banks' most common time deposit rate is directly tied to the exogenous discount rate of interest.

The influence of the domestic money supply on the market rate of interest is limited by capital mobility. This is because under the fixed exchange rate regime (assumed in the basic version of the BOF4 model) capital outflows decrease the supply of money and tighten the money market. Capital inflows do, of course, have an effect in the opposite direction. Technically speaking, only short-term foreign capital flows are endogenous in the model, but since the exogenous long-term part has a complete crowding-out effect on the short-term capital account, the model works as if total private capital flows were modelled.

The financial block of the model also contains a few "post-recursive" equations which have no feedback to the rest of the model. On the balance-of-payments side, there are three tentative equations describing the operation of the forward exchange markets and the determination of the forward premium on the markka vis-à-vis the US dollar. On the domestic side, there is the equation for bank loans to the public. In the standard use of the model, autonomous changes in bank loans are completely absorbed by money market deposits at the banks (CDs) and for this reason the bank lending equation is not very important. However, the model may be used to describe the pre-1980's regime, in which the banks did not deal with the public in the short-term money market. In that case, the bank lending equation becomes important from the point of view of the money supply process.

3 THE DEMAND FOR AND SUPPLY OF MONEY

3.1 The Demand for Money: Currency

The demand for currency equation (see equation R.1 in the attached list of equations) is another of the money demand functions of the BOF4 model. It determines the amount of currency in circulation as a function of consumption, consumer prices and the interest rate on bank deposits.

The theoretical idea behind the equation is simply that currency holdings yield liquidity services which are complementary to private consumption - the only category of transactions in which currency is used to a significant degree. The interest rate on bank deposits represents the opportunity cost of holding currency, since bank deposits are obviously the nearest substitute for currency among the different available assets. (Note that in Finland payment services such as small-denomination cheques and a giro system are traditionally provided by banks to holders of interest-bearing time deposits.)

The dynamic form of the equation corresponds to the "nominal adjustment mechanism" of Goldfeld (1976). Accordingly, it takes time to adjust the currency holdings in response to changes in real consumption, the price level and the deposit rate of interest. The functional form is loglinear with the exception of the deposit rate which is included linearly with a lag of one quarter. The dynamic properties of the equation are described in the following table.

Table 1. The Dynamic Elasticities of the Demand for Currency (semi-elasticity in the case of the interest rate)

Variable	Immediate elasticity	One-year elasticity	Long-run elasticity
Consumption	0.13	0.15	0.46
Price level	0.27	0.34	1.00
Deposit rate	0.00	-.47	-1.69

The interest rate elasticity is expressed in the form of a "semi-elasticity", i.e. the percentage effect on the demand for currency of a change of one percentage point in the deposit rate. The proper interest rate elasticities are -0.03 in the first year and -0.11 in the long run (evaluated according to the deposit rate in 1985). It may be noted that the long-run consumption elasticity is not too far from 0.5 implied by the well-known square root rule discovered by Baumol (1952).

3.2 The Demand for Money: Broad Money

As mentioned above, the concept of broad money used in BOF4 includes:

- domestic currency in circulation
- cheque and postal giro deposits of the domestic non-bank public denominated in markkas
- all time deposits of the domestic non-bank public denominated in markkas.

Wholesale deposits bearing the market rate of interest (sometimes called "unregulated deposits", which include large-denomination CDs and similar instruments) are excluded.

The functional form of the demand for broad money equation is the following:

(1) $$M3/Y_{-1} = a_0 - a_1[(1-tm)i - i_D] + a_2\Delta Y/Y_{-1} + a_3 M3_{-1}/Y_{-1}$$

Here M3 is the stock of broad money, Y is nominal GDP, i is the short-term market rate of interest, i_D is the tax-free time deposit rate and tm is the capital market tax rate calculated from the interest rate differential between taxable and tax-free bonds (its determination is presented below in section 5.3).

According to this specification, the inverse of the velocity of circulation of broad money is a linear function of the opportunity cost of holding money, where the opportunity cost is measured by the difference between the after-tax market rate of interest and the own (deposit) rate of money. Dynamically, the equation is in the same nominal-adjustment tradition as the demand for currency equation.

As can be seen from section 6.2 of this paper below, parameters of the demand for money equation (1) (solved for the money market rate of interest) are also contained in the capital flow equation. To capture parameter constraints across these two equations, they were estimated as a system using the nonlinear estimation method MINDIS (minimum distance estimation) (see Berndt, Hall, Hall and Hansman (1975) and Amemiya (1977)). We also studied whether, as a result of structural changes in the Finnish financial markets, the estimates of the parameters of the model changed within the estimation period. We found a break in the data generating process in the second quarter of 1984. At that time, the banks' cartel agreement on rates on money market instruments was broken as a result of action taken by the Bank of Finland. In the estimated equations R.11 and B.7 (see the appendix), the emergence of a competitive money market was taken into account by a dummy variable, which allowed the parameter estimates of the interest sensitivity of the demand for money and the demand for net foreign debt to change in the second quarter of 1984. According to the estimated equation, the interest sensitivities of the demand for money and the demand for net foreign debt increased more than four fold in the quarter.

The elasticities of the demand for broad money equation in the latter part of the estimation period are reported in the following table. Again, the interest rate elasticities are given in the form of semi-elasticities. The elasticities are computed from the 1985 levels of the variables concerned.

Table 2. The Dynamic Elasticities of the Demand for Broad Money (interest rate elasticities are semi-elasticities)

Variable	Immediate elasticity	One-year elasticity	Long-run elasticity
Nominal GDP	0.08	0.69	1.00
Interest rate	-0.31	-0.94	-1.24
Deposit rate	0.40	1.18	1.54

The proper interest rate elasticities may be obtained by multiplying the semi-elasticities by the relevant interest rates in decimal form. For example, the long-run interest rate elasticity of the demand for broad money is -0.12 evaluated at the 1985 level of the interest rates.

3.3 The Supply of Money

The balance sheet framework which determines the supply of money in BOF4 consists of the balance sheets of the central bank and the consolidated deposit bank sector. In addition to these identities, a technical equation determining the banks' required reserves is needed.

Let us adopt the following notation for the purposes of the present exposition:

THE BALANCE SHEETS

The Central Bank:

  foreign reserves, R
+ central bank credit to the government, DG
+ central bank credit to the public, DP
+ central bank credit to the deposit banks, DB
- own capital and other items of the central bank, net OCB
- required reserves of the deposit banks, Q
= currency in circulation, S

Deposit Banks:

+ bank credit to the government, net LG
+ bank loans to the public, LP
+ required reserves of the deposit banks, Q
- own capital and other items of the banks, net OB
- money market deposits at the banks, CD
- central bank credit to the banks, DB
= bank deposits of the public, MD

required reserves:

$$Q = r \cdot MD$$

Broad money, M3, is defined as MD + S.

In the case of pegged interest rates, the demand for bank deposits and the demand for currency are determined from outside the money supply framework. In this case, the money supply framework determines central bank credit to the deposit banks in the following way:

$$DB = S + r \cdot MD - DG - DP - R + OCB$$

Or, expressed with the help of the demand function for broad money,

$$DB = (1-r) \cdot S + r \cdot M3 - DG - DP - R + OCB.$$

On the other hand, if the central bank fixes its domestic credit DB+DG+DP-OCB, it is the supply of money which is determined by the money supply identities:

$$M3 = 1/\left[(r + (1-r) \cdot S/M3)\right] \cdot (DB + DG + DB + R - OCB)$$

It can be seen that the model traces the influences on money supply of all components of domestic central bank credit as well as of the foreign currency reserves. Since BOF4 does not contain a demand for free reserves equation, the reactions of money supply to these monetary policy instruments are quick (immediate, in fact) and very powerful.

The money multiplier $1/(r + (1-r) \cdot S/M3)$ was 8.4 in 1985 and varies as the reserve requirement r and the ratio of the demand for currency to the demand for broad money S/M3 change. Note that the supply of money is sensitive to the market rate of interest since the "cash ratio" S/M depends (positively) on the market rate of interest according to the demand for money functions of BOF4.

There is a practical modelling problem in that the statutory cash reserve base, or the definition of bank liabilities which are subject to the reserve requirement, does not exactly correspond to the bank deposits included in BOF4's definition of money. This has been dealt with by means of rewriting the demand for cash reserve deposits equation in difference form (see equation R.2 in the equation list). This is equivalent to assuming that the share of bank deposits in the cash reserve base remains constant.

3.4 Bank Lending

The role of bank credit in the money supply framework deserves further comment. As can be seen from the above presentation of the money supply framework, required reserves, net central bank debt and deposits of the public are the only items in the banks' balance sheets which have a direct bearing on the money supply process in the model. Changes in bank credit to the public, or to the government, for example, are completely sterilized in this framework by changes in money market deposits with banks (CDs). A necessary condition for this to happen is, however, that the banks participate in the money market.

Things are different, however, if banks do not accept money market deposits (CD = 0 in the notation of this chapter) and if bank lending is rationed. Broadly speaking, these conditions prevailed in Finland in the 1960's and 1970's. In this case the supply of money must be calculated by "credit counterparts":

$$M3 = LP + DP + LG + DG + F - OB - OCB$$

In this money supply regime, the equation determining bank loans to the public LP becomes crucial for the determination of the money stock and the determination of the market rates of interest. This is because it is now the only endogenous domestic component of the money supply and because in the BOF4 model the foreign component does not completely offset the changes in liquidity originating from domestic sources.

The bank lending equation (R.10 in the list) is a supply function designed to be useful in a regime of institutionally controlled lending rates and monetary policy operating through the marginal cost of central bank credit to the banks (for the derivation and estimation of the equation, see Tarkka, 1986). The equation has no particular significance outside the regime of excess demand for credit and non-participation of banks in the market for short-term money market deposits.

The bank loan supply equation determines the flow supply of loans. The explanatory variables in the equation are the difference between the average lending rate and the marginal cost of funds for the banks, and the rate of inflation. According to the equation, an increase in the spread between the lending rate and the marginal cost of funds will eventually accelerate the annual rate of growth of bank loans by 0.9 per cent. An increase in the rate of inflation by one per cent will, *ceteris paribus*, accelerate the rate of growth of bank loans by 0.6 per cent.

The operation of the model in the "repressed markets" regime, i.e. without the money market deposits, is described in Tarkka (1985).

4 THE TERM STRUCTURE OF INTEREST RATES AND THE MILLER EQUILIBRIUM

At any point of time there are many prevailing interest rates, which differ from each other with respect to the maturity, risks and tax treatment associated with them. The central bank cannot control all of them at once. Typically, the operations of the central bank directly affect a short-term interest rate, which is closely related to the equilibrium in the money market. This is also so in Finland. Real economic activity, on the other hand, is more closely linked to the after-tax real returns on claims with longer maturities. Hence, to be able to study the transmission of monetary policy in a macro model, the short-term money market rate must be linked to bond rates and the after-tax returns must be estimated.

In the BOF4 model, the interest rate structure is determined as follows: It is the expectations hypothesis which first, via a simple term structure equation, links the taxable short-term money market interest rate to the market yield on debentures. This yield represents the long-term taxable interest rate in BOF4. Another term-structure relation is estimated for the average interest rate on outstanding bank loans, which in the BOF4 model is important in the housing market and in calculating net interest payments by the household sector.

Further, the taxable long-term interest rate is connected with the long-term tax-free interest rate by the Miller equilibrium relationship, which in an economy with taxes is the counterpart of the well-known Modigliani-Miller equilibrium in a tax-free economy.

4.1 The Term Structure Equation for the Long-Term Interest Rate

Under efficient arbitrage, the market equilibrium implies the following relation between long-term and short-term interest rates:

$$(2) \qquad R(t) = (1/m) \cdot \sum_{i=0}^{m-1} E(t)r(t+i) + k(t)$$

where R denotes the interest rate on loans with a maturity of m periods, r is the one-period rate, k is term premium and E denotes the expectation operator. Equation (2) asserts that, after taking into account transaction costs and risk considerations, the yield on an m period bond has to equal the expected cumulative yield on investment in a series of one-period bonds for m periods.

The equilibrium condition (2) is transformed into the expectations model of the term structure of interest rates, if the term premium k(t) is assumed to be constant. The implication of this assumption is that the yield on long-term bonds can be affected by monetary policy only by influencing the expected path of the yield on short-term assets. If the term premium could vary, then monetary policy could also affect long-term rates through other channels, such as "debt management".

The next step is to specify the formation of interest rate expectations. From many alternative hypotheses we adopted the regressive hypothesis:

(3) $$E_t\, r(t+1) = r(t) + (1-e)(r^* - r(t)) = e \cdot r(t) + g$$

Equation (3) states that, over time, the short-term interest rate is expected to converge to a long-run "normal" level r*. The benefit of the regressive hypothesis, besides being simple, is that it has worked quite well in earlier empirical studies (see Dobson et al. (1976)). This expectations hypothesis is also the rational one if the short-term interest rate follows a linear first order stochastic process such as that formulated by Cox, Ingersoll and Ross (1985).

After subsequent substitution of (3) into (2), we end up with the following term structure equation for the long-term interest rate:

(4) $$R(t) = c + b \cdot r(t),$$

where $c = (1/m) \cdot g \sum_{i=1}^{m-1} \sum_{j=1}^{i} e^{i} + k$ and $b = (1/m) \sum_{i=0}^{m-1} e^{i}$.

In estimating (4), the Cochrane-Orcutt autocorrelation correction was used. Equation R.2 in the list of equations is the resulting empirical term structure model. According to it, changes in the short-term interest rate are transmitted to the long-term taxable interest rate with the weight 0.51. This is the parameter b. From the estimated equation we can calculate the short-term interest rate level, which is forecast to produce a horizontal yield curve (i.e. $R(t) = r(t)$); this interest rate level is 12.1 per cent. (If the term premium were zero, this would also be the estimate of the expected long-term equilibrium level of the short-term interest rate.) If the actual short-term interest rate is below 12.1 per cent, then, according to the estimated equation, the long-term interest rate is above the short-term interest rate. The situation is reversed if the short-term interest rate is above 12.1 per cent.

4.2 The Banks' Average Lending Rate

Until the middle of the 1980's the average bank lending rate was regulated by the Bank of Finland and very closely linked to the base rate (discount rate). Between 1983 - 1986, however, as part of the liberalisation process in the Finnish financial markets, interest rates on new bank loans were gradually deregulated and allowed to be freely determined by market forces.

As the substitutability between bank loans and debt issued by firms must be very close, the bank lending rate on new loans is assumed to be determined by the short-term interest rate via a term structure relation similar to equation (4). However, typically bank loans are not granted as fixed rate loans. Rather, interest rates levied on them are linked to some reference interest rate. As the discount rate is used as the reference interest rate for the major part of bank loans, changes in the discount rate are reflected in the average bank lending rate quite strongly.

The estimated equation for the average rate on outstanding bank loans takes these features into account (equation R.4 in the list of equations). The dynamic properties of the estimated equation are described in the following table.

Table 3. The Dynamic Response Effects on the Average Bank Lending Rate

Variable	Immediate effect	One-year effect	Long-run effect
Discount rate	.98	.82	0
Short-term interest rate	.10	.14	.34

We see that although in the long run the average bank lending rate is independent of the discount rate, short-run variations in the RLB are dominated by changes in the discount rate. Changes in the short-term money market rate, in turn, have quite small immediate effects on the bank lending rate. The steady state form of equation R.4 states, however, that in the long run the bank lending rate is determined solely by the short-term interest rate and the term premia. The yield curve implied by the steady state relation is horizontal if RS is 9.8 per cent; with values of short-term interest rate above (below) 9.8, the bank lending rate is below (above) the short-term interest rate.

4.3 The Determination of the Tax-Free Long-Term Interest Rate: The Miller Equilibrium

In making portfolio choices, rational agents allocate their available resources with reference to the after-tax returns of alternative investments. Therefore in the BOF4 model it is the after-tax long-term interest rate which is used as the argument of private consumption and, via user cost variables, as the argument of private investment. In financial markets, the after-tax short-term interest rate equilibrates the money market and changes in the after-tax short-term interest rate differential between domestic and foreign interest rates determine net capital imports.

Quite often there are difficulties in obtaining data on yields on tax-free assets. In Finland, however, a major part of central government bonds are tax-free and secondary market data on the yields of these bonds are available (see Alhonsuo et al. (1989)). Since domestic assets with the same maturity are assumed to be perfect substitutes in the BOF model, it is legitimate to use the government bond rate as an indicator for all after-tax long-term yields.

The effects of changes in the tax-free long-term interest rate are transmitted to fixed investments through the sectoral user cost variables. User costs are calculated using the standard "Jorgensonian" formula (for a review of the concept and estimation of the user cost of capital, see Koskenkylä (1985)).

(5) $$UC = (RB - inf^{e} + d)\cdot(1 - ts\cdot td/(RB+td))/(1-ts)$$

where inf^{e} is expected inflation, d is the rate of depreciation of capital and s is the statutory corporate tax rate. td is the tax depreciation coefficient, which is infinite in the case of free tax depreciation.

In a more general form the user cost formula also includes the effect of the capital structure. This formula, however, collapses to the one presented above, if the after-tax financing costs from different sources are equal, as is the case in Miller equilibrium.

We now turn to the determination of the tax structure of interest rates. It is clear that, if two assets are similar in all other respects except tax treatment, the interest rate on the taxable asset must be above that on the tax-free asset. Otherwise, no one with a positive income tax rate would be willing to hold the taxable asset.

Assume for simplicity that there are two tax-free assets (government bonds and equities) and one taxable asset (bonds issued by firms). Now the following identity between the expected returns on these assets can be written:

(6) $$RB = RE = (1 - tm)\cdot RT,$$

where RB and RE are the rates of return on tax-free bonds and equities, respectively, RT is the taxable bond rate and tm is the marginal tax rate of the marginal investor. Among investors with different marginal tax rates on interest income, the marginal investor is defined as someone who is indifferent between buying taxable or tax-free claims because he obtains equal after-tax yields on both types of securities. Investors with a lower marginal tax rate than tm demand only taxable claims and investors with a higher marginal tax rates buy only tax-free claims.

The problem is, then, what determines the marginal investor's marginal tax-rate, or who is the marginal (representative) investor. Miller's proposition gives an answer to this question (Miller (1977); see also DeAngelo and Masulis (1980) and Aivazian and Callen (1987)). According to the Miller proposition, the marginal investor's marginal tax rate must in equilibrium (with negligible taxation of equity appreciation) be equal to the effective corporate tax rate. Important implications of this proposition are: (i) capital structure is irrelevant for any single firm; (ii) there is a unique debt-equity ratio for the aggregate corporate sector; (iii) the tax structure of interest rates is determined by the corporate tax parameters.

In a dynamic framework Miller's proposition can be derived as follows. We specify the following demand and supply functions for taxable corporate debt:

(7) $$B^d = A \cdot (RT/RE)^a; \qquad A,\ a > 0 \quad \text{(demand)}$$

(8) $$d\ \log(B^s)/dt = m \cdot \log[RE/(1-tc) \cdot RT]; \qquad m > 0 \quad \text{(supply)}$$

where tc is the effective corporate tax rate. Equation (7) defines aggregate demand for taxable bonds. It can be interpreted as follows: the greater is the interest rate differential between taxable and tax-free securities, the higher is the marginal income tax rate of the marginal investor (see identity (6)). Hence, the widening of the interest rate differential between taxable and tax-free securities increases the demand for taxable bonds, because the number of investors whose marginal income tax rate is below the marginal investor's tax rate becomes greater. As mentioned above, investors in this group hold only taxable bonds. The share of taxable bonds in the portfolios of marginal investors, who under progressive tax scales hold both taxable and tax-free securities, also increases. In this way they maximize their after-tax incomes.

Equation (8), which defines firms' flow supply of taxable bonds, is based on the assumptions that firms maximize their value, debt charges are deductible in calculating the corporate tax bill and that a firm cannot change its capital structure costlessly. Under the first two assumptions the optimal financing solution of a firm would be to issue only bonds, if $RE > (1-tc) \cdot RT$. In the opposite case the optimal solution would be to issue only equity. Only with equality would the capital structure be irrelevant from the point of view of the value of the firm (see DeAngelo and Masulis (1980)). The inclusion of adjustment costs implies that changes in the capital structure of firms do not occur instantaneously but gradually. This is what equation (8) states.

By differentiating the log of equation (7) with respect to time and then equating the result with (8), we obtain the following relation between the tax-free and taxable interest rates:

$$(9) \qquad d\,\log(RE)/dt = d\,\log(RT)/dt + (m/a) \cdot \log[(1-tc)RT/RE]$$

According to equation (9), with the effective corporate tax rate given, all changes in the taxable interest rate are immediately transmitted to the tax-free interest rate. The speed at which the monetary policy is transmitted from short-term interest rates to taxable and tax-free long-term interest rates is the same.

Hence, all changes in the interest rate differential between taxable and tax-free interest rates result from changes in the effective corporate tax rate. According to equation (9), there is a partial adjustment process by which the interest rate differential between taxable and tax-free securities follows the effective corporate tax rate. We see that in the long-run equilibrium $RE = (1-tc)RT$ and, on the basis of identity (6), tm = tc. Hence, it is the effective corporate tax rate which determines the marginal investor's marginal rate. (It is worth noting that equation (9) could be written as a partial adjustment equation for the marginal income tax rate of marginal investors, i.e. $d\log(1-tm)/dt = (m/a)\cdot\log[(1-tm)/(1-tc)]$.)

Before estimating (9) there is still one problem to be solved; corporate income tax rules do not specify the effective tax rate, only the statutory rate, which, owing to various allowances and deductions, can be quite considerably above the effective tax rate. Consequently, we assumed the following relation between the effective and statutory corporate tax rates:

$$(10) \qquad tc = (b_0\cdot ts + b_1\cdot \Delta P/P_{-1})/(1 + RT)^2$$

where ts indicates the statutory corporate tax rate and p the price level. Parameter $b_0 < 1$ and parameter $b_1 \gtrless 0$. This simple relation takes into account the possibility that corporate income taxation is not neutral with respect to the inflation rate. The discount factor $(1+RT)^2$, in turn, takes into account the fact that there is about two years lag from the accrual of tax liabilities to the collection of taxes.

According to Miller's proposition, t_m equals tc in the long-run equilibrium. This allows us to use 1-RB/RT as the dependent variable in estimating parameters b_0 and b_1 using simple regression analysis. For the sample period 1977 - 1988, the estimate for b_0 was .82 and for b_1 11.4. The latter parameter estimate implies that the corporate tax rules are quite unneutral with respect to inflation. The coefficient of the inflation variable may also include some effects of the (relatively light) equity taxation.

Table 4. The Determination of the Implicit Effective Corporate Tax Rate (percentage points)

Variable	Effect
Statutory tax rate	0.67
Inflation rate (per cent)	-0.93

As equation (9) was not estimated for the yield on equities but for the yield on tax-free government bonds, we allowed the short-run dynamics to be determined more freely than implied by equation (9); the short-run effects of changes in the long-run taxable interest rate on the government bond rate were not constrained to equal unity. Hence, the government bond market and the equity market are not assumed to be so closely integrated to each other that at each instant of time RB would equal RE. Rather, we assume it to be the long-run equilibrium relation.

According to the estimated equation for the government bond rate, the speeds at which the effects from the effective corporate tax rate and from the taxable long-term interest rate are transmitted to the government bond rate are equal (see equation R3 in the list of equations).

Table 5. The Dynamic Response Effects on the Tax-Free Bond Rate (percentage points)

Variable	Immediate effect	One-year effect	Long-run effect
Long-term taxable rate	0.19	0.47	0.73
Effective tax rate	0.03	0.06	0.10

5 THE BALANCE OF PAYMENTS

In the above discussion of money supply the determination of the foreign reserves of the central bank was not explained. Actually the foreign reserves are endogenous in the basic version of BOF4. The assumption of a fixed exchange rate implies that the foreign reserves are determined by the current and capital accounts of the balance of payments.

In BOF4, the balance of payments is analyzed within the following framework:

Table 4. The Breakdown of the Balance of Payments in BOF4

        Exports of goods (multilateral)
        Imports of goods (multilateral)
    Surplus on the multilateral trade account

        Exports of goods (bilateral)
        Imports of goods (bilateral)
    Surplus on the bilateral trade account

Trade balance

    Exports of services
    Imports of services

Balance of goods and services

    Investment income from abroad, net
    Transfers from abroad, net

Current account

    Private long-term capital inflow, net
    Government long-term capital inflow, net
    Central bank long-term capital inflow, net

Current and long-term capital account

Short-term capital account

Change in central bank's foreign reserves

5.1 The Current Account

All main components of the current account are endogenous in BOF4. The trade account and the services account are determined from the foreign trade equations by means of the relevant identities. Net investment income from abroad depends on net long-term foreign debt and the average of the ratio of net investment income to foreign debt in the two previous quarters (see equation B.3).

Net foreign transfers are a sum of the government's foreign transfers (mostly development assistance) and private transfers, which are assumed to be proportional to the value of the GDP (see equation B.4).

5.2 Capital Movements

Net long-term borrowing by the government (and the central bank) are exogenous in BOF4. So, too, are, in a technical sense, movements in long-term private capital. However, as foreign long-term and foreign short-term private capital are assumed to be perfect substitutes for each other, the though model operates as if it were the sum of all private capital movements which are explained by the capital movement equation.

The theoretical starting point in the modelling of capital movements is the portfolio approach. According to this theory, private capital movements in the balance of payments reflect portfolio shifts and are caused by changes in relative returns on domestic and foreign assets. In addition, mere accumulation of wealth by investors may also lead to changes in net foreign investment. The portfolio approach to the balance of payments was originally developed by Branson (1968).

The portfolio equations are, however, very difficult to estimate directly. Partly this is is due to simultaneity in the determination of the domestic rate of interest and capital movements. On the other hand, the problems are caused by measurement errors in relative returns, particularly exchange rate expectations. Both of these factors tend to bias the estimates of interest rate sensitivity of capital movements downward. The problems become virtually insurmountable in the limiting case of perfect substitutability of domestic and foreign assets. In that case an attempt to explain capital flows in terms of relative returns would be impossible since arbitrage would by necessity keep the expected returns of domestic and foreign assets equal (allowing for exchange rate expectations). Hence, a zero estimate of interest elasticity would be obtained although the true elasticity would be infinite.

Kouri and Porter (1974) developed a partially reduced form of the capital flow equation which overcomes these problems. The idea, also followed in BOF4, is to substitute the inverted money demand function and the money supply identity for the rate of interest in the capital flow equation. The starting point is the following linearized version of the capital flow equation:

$$(11) \qquad \frac{FP^{uc}}{Y_{-1}} = b\{\Delta[(1-tm)i] - \Delta[(1-tm)i^{f}]\} + v$$

Here the private uncovered capital inflow FP^{uc} is a function of the change in the relative expected yield differential between domestic and foreign assets: $\Delta[(1-tm)i]$ and $\Delta[(1-tm)i^{f}]$ are changes in the domestic and foreign after-tax interest rate, respectively.[1] The interest rate effect is scaled by lagged nominal GDP, Y_{-1}, which serves as a surrogate for wealth. Exchange rate expectations are omitted from the equation although they are certainly important in practice. The obvious reason for neglecting exchange rate expectations in the model is the difficulty of measuring them. However, for most of the data the expected change in the effective exchange rate of the markka is probably small due to the fixed rate regime, which is institutionalized in Finland. The role of

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[1] It is assumed in (11) that capital gains on foreign assets are not taxable. If capital gains were taxable, the government would share the foreign exchange risk with private investors and, hence, instead of being multiplied, the interest rates in (11) should be divided by 1-tm.

the constant term in equation (2) is to take into account the average effect of the growth of wealth (which is an unobservable variable) on net capital flows.

In our formulation of the portfolio equation in a world with taxes, we have implicitly assumed that exchange rate gains and losses are not taxable. This is evident in (2) in that the risk premium is not a function of tax rates.

Note that the uncovered and total private capital flows are different only if the authorities participate in the forward currency market, purchasing a part of the private sector's exchange rate position. In the case where the central bank participates in the forward market, the private sector's uncovered and total capital flows are linked by the following identity:

$$FP^{uc} = FP + FF \text{ (change in the net forward currency position of the central bank)}$$

For the purposes of the Kouri-Porter reduction of the capital flow model, we need the inverted money demand function in its difference form. By solving equation (1) for the after-tax money market interest rate we obtain:

(12) $$\Delta[(1-tm)i] = \Delta i_d - \frac{1}{a_1}\Delta\left(\frac{M3}{Y_{-1}}\right) + \frac{a_2}{a_1}\Delta\left(\frac{\Delta Y}{Y_{-1}}\right) + \frac{a_3}{a_1}\Delta\left(\frac{M3-1}{Y_{-1}}\right)$$

We also need the money supply identity of the model in its difference form:

(13) $$\Delta M3 = FP + FG + CA + \Delta DP + \Delta DG + \Delta LP + \Delta LG - \Delta CD - \Delta OCB - \Delta OB$$

Substituting (4) in (3) and the resulting expression in (11) and solving for FP^{uc} we obtain

$$(14) \quad \frac{FP^{uc}}{Y_{-1}} = k_1 \cdot \{\Delta i_d - \Delta[(1-tm)i^f]\} + k_2 \cdot \Delta(\frac{M3_{-1}}{Y_{-1}})$$

$$+ k_3(\frac{\Delta Y}{Y_{-1}} - \frac{\Delta Y_{-1}}{Y_{-2}})$$

$$- k_4 \cdot \{FG + CA + \Delta DP + \Delta DG + \Delta LP + \Delta LG - \Delta CD$$

$$- \Delta OCB - \Delta OB - FF - M3_{-1} \cdot \frac{\Delta Y_{-1}}{Y_{-2}}\}/Y_{-1}$$

$$+ k_5$$

where $k_1 = \frac{b}{1+b/a_1}$; $k_2 = \frac{a_2 b/a_1}{1+b/a_1}$; $k_3 = \frac{a_3 b/a_1}{1+b/a_1}$; $k_4 = \frac{b/a_1}{1+b/a_1}$; $k_5 = \frac{v}{1+b/a_1}$

This is the Kouri-Porter equation. The coefficients have the following structural interpretation:

- the coefficient k_1 of the foreign interest rate (and the domestic deposit rate) indicates the response of the capital flow to these variables when the domestic component of money supply is held constant. This is not the same concept as the interest sensitivity of the original portfolio equation, which can, however, be recovered from the coefficients of the Kouri-Porter equation, since $b = k_1/(1-k_4)$.

- the parameter k_4 is the famous "offset coefficient" measuring the proportion of changes in domestic credit which is offset by changes in induced private capital flows.

The capital flow equation of BOF4 (see B.7 in the list of equations) corresponds to the basic Kouri-Porter equation (4). The equation has been divided throughout by the lagged broad money stock to eliminate heteroskedasticity. In section 4 it was already mentioned that because of parameter constraints across equations the demand for money equation and the capital flow equation were estimated as a system. In addition a dummy variable was included, allowing the interest sensitivities of the demand for money and the demand for net foreign debt to change in 1984Q2. In that quarter these interest sensitivities became 4.3 times greater compared to the preceding period. It is worth noting that these parameter changes did not affect the estimate of the "offset coefficient" k_4, because relative changes in structural parameters a_1 and b are equal.

According to the estimated capital flow equation, the offset coefficient is 0.86, which means that this proportion of changes in the domestic credit of the banking sector is immediately reflected in capital movements; similarly, current account surpluses and the government's foreign borrowing crowd out private foreign borrowing by 86 per cent. An increase in the foreign rate of interest by one percentage point would lead to a capital outflow of FIM 367 million (computed from the 1985 levels of variables; in 1988 the effect would have been FIM 417 million).

These effects cited above summarize capital mobility if monetary policy operates through fixing domestic credit. If monetary policy pegs the domestic rate of interest, we may calculate from the coefficients of the equation that an increase of one percentage point in the rate of interest would have caused an immediate capital inflow of FIM 2560 million in 1985 (or FIM 3014 million in 1988). This is the common definition of interest sensitivity of demand for foreign capital.

6 FORWARD CURRENCY MARKETS

The BOF4 includes three tentative equations for the forward currency markets. The behaviour of the corporate sector is captured by a supply equation for forward currency. An identity determines the amount of forward cover needed by banks who buy the net forward currency supplied by firms, taking into account the forward currency operations of the central bank. Finally, the behaviour of banks is summarized by the equation determining the forward premium.

The net supply of forward currency by firms (equation B.8) depends on the deviation of the forward premium from covered interest rate parity, as well as on the trade balance and the overall open position of the private sector. The equation is estimated in difference form.

The net forward position of the banks is equal to the net supply of forward currency by firms and the central bank. This is also equal to the amount of spot cover needed by the banks in order to avoid exchange rate risk. The amount of spot cover needed by banks determines how much banks are willing to pay for forward currency (US dollars). If interest arbitrage were perfect, the forward premium would exactly correspond to the interest rate differential between currencies. As it is costly for the banks to obtain spot cover for their forward position, the forward premium is a slightly decreasing function of the banks' net forward position. For example, an increase in the banks' forward position by FIM 10 billion in 1988 would have caused a reduction of 0.23 per cent in the price of USD sold 3 months forward.

7 SIMULATION EXPERIMENTS

To illustrate the interaction of the financial and real sectors of the BOF4 model the following three simulation experiments were run:

1. Central bank credit was increased by FIM 5 billion (about one percent of nominal GDP in 1989) in the flexible interest rate regime.

2. The statutory corporate tax rate was increased by 10 percentage points in the pegged interest rate regime.

3. The statutory corporate tax rate was increased by 10 percentage points in the flexible interest rate regime.

All the simulations were run with exogenous nominal transfers from the central government to the other sectors of the economy. Personal income tax schedules, however, were endogenized to prevent bracket creep despite gradual inflation.

<u>Simulation 1</u>: Central bank credit increased by 1 % of nominal GDP

In this experiment the central bank increases the domestic credit component of the monetary base through an open market operation of FIM 5 billion. The results are summarized in table 6.

Because of the induced capital outflow, the effect on the monetary base is, however, much smaller; only about 1.5 per cent of the increase in central bank credit ultimately shows up in the monetary base, whereas the rest of the shock is offset by a decrease in the foreign currency reserves of the central bank (fig. 1a). On the broad money level, the money multiplier process translates the increase in the monetary base into a FIM 585 million expansion in M3 in the period the money market intervention is implemented.

As a response to the increase in the money supply, the money market interest rate decreases immediately by 1.6 percentage points (fig.

Figure 1. CENTRAL BANK CREDIT INCREASED BY FIM 5 BILLION. DIFFERENCES FROM BASELINE CASE.

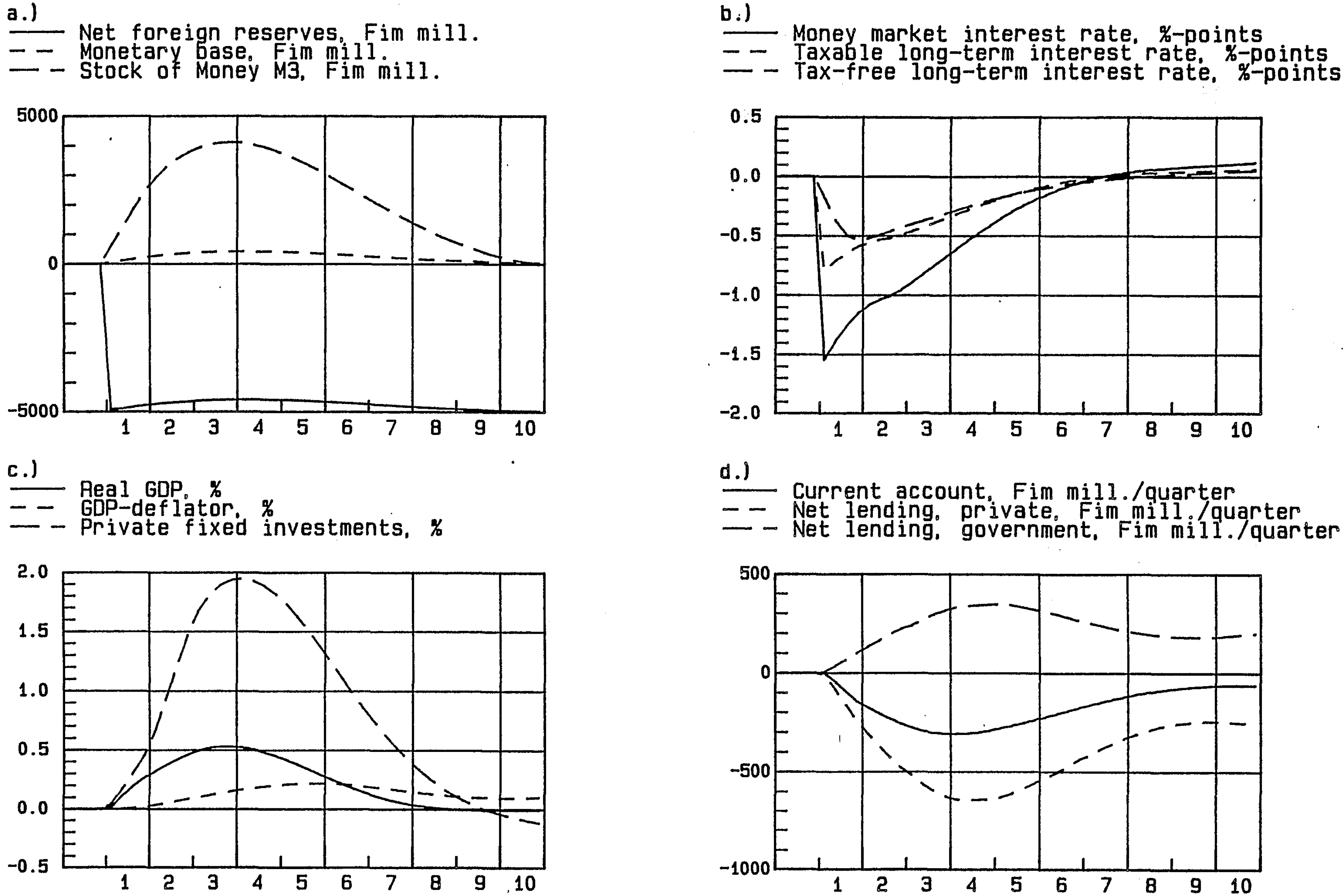


Table 6. Simulation Results

Central bank credit increased by FIM 5 billion (corresponds to one per cent of GDP in year[1])

Difference from baseline case.

years	1	2	3	4	5	6	7
GDP, %	0.1	0.4	0.5	0.5	0.4	0.2	0.1
Imports, total, %	0.2	0.7	0.9	0.8	0.6	0.4	0.2
Exports, total, %	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.2
Private consumption, %	0.2	0.5	0.7	0.7	0.6	0.5	0.3
Private fixed investment, %	0.3	1.1	1.8	1.8	1.5	1.0	0.5
Residential, %	0.6	1.4	1.7	1.7	1.2	0.7	0.4
Non-residential, %	0.2	1.1	1.8	1.9	1.6	1.1	0.6
Domestic demand, %	0.2	0.6	0.8	0.8	0.6	0.4	0.2
GDP deflator, %	0.0	0.1	0.1	0.2	0.2	0.2	0.2
Private consumption deflator, %	0.0	0.1	0.1	0.2	0.2	0.2	0.1
Wage rate, %	0.0	0.1	0.1	0.2	0.3	0.3	0.3
Actual hours worked, %	0.1	0.2	0.4	0.4	0.4	0.2	0.1
Employment, 1000 persons	0.5	3.3	6.5	8.5	8.5	6.8	4.3
Interest rates, percentage points							
Money market rate	-1.3	-1.0	-0.8	-0.5	-0.3	-0.1	0.0
Taxable bond rate	-0.7	-0.5	-0.4	-0.3	-0.1	-0.1	0.0
Tax-free bond rate	-0.4	-0.5	-0.4	-0.2	-0.1	-0.1	0.0
Bank lending rate (av. stock)	-0.2	-0.2	-0.3	-0.2	-0.2	-0.1	-0.1
Balance of payments							
Current account, FIM billion	-0.3	-0.9	-1.2	-1.2	-1.0	-0.8	-0.6
Private capital imports, FIM billion	-4.5	1.0	1.3	1.2	1.0	0.7	0.5
Foreign exhange reserves, FIM billion	-4.8	-4.6	-4.6	-4.6	-4.6	-4.7	-4.8
Central bank domestic credit, FIM billion	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Demand for money							
Monetary base, per cent	0.6	1.0	1.1	1.1	0.9	0.6	0.4
Broad money, per cent	1.0	1.5	1.6	1.4	1.1	0.8	0.5

1b). The effect on the tax-free long-term interest rate, which is the most important interest rate from the point of view of investment behaviour, is about half of this. In the later periods the interest rate effects gradually converge towards zero. During the first few years this is mainly due to increased economic - especially investment - activity, which increases the demand for money (fig. 1c). However, increased activity also results in a deeper current account deficit, which cumulatively decreases the money supply and over time nullifies the original expansive effect (fig. 1d).

All in all, monetary policy is neutral in the long run in the flexible interest rate regime. After about eight years, the GDP effect has vanished. Although prices also react in the medium term, the long-run neutrality of money does not result from price level adjustment, but rather from the leak of money abroad through the current account. This is, of course, a general result implied by the assumption of fixed exchange rates.

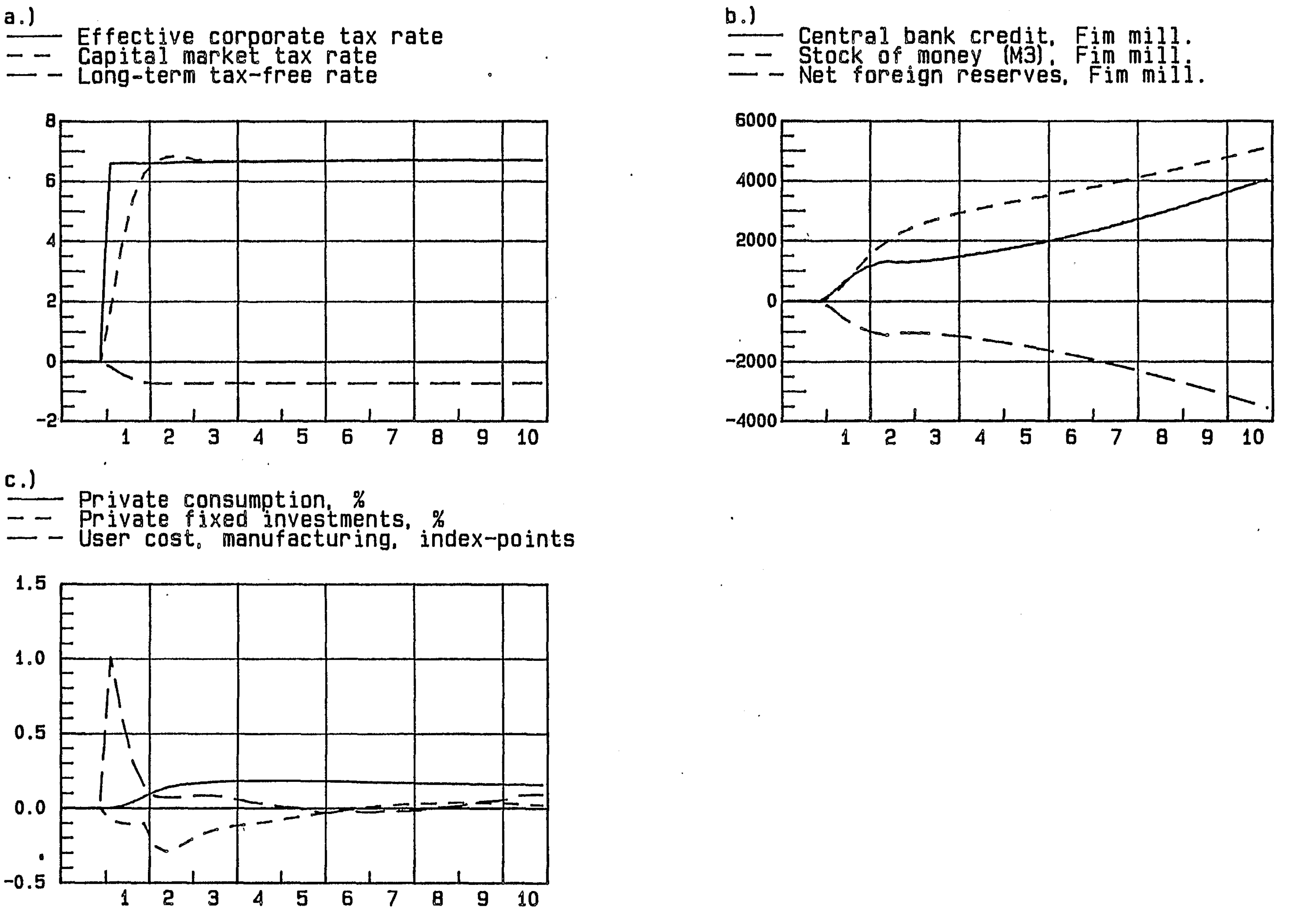
Simulation 2: Corporate tax rate increased by 10 percentage points in the pegged interest rate regime

In this simulation the overall effects on the real economic variables are small. From the point of view of understanding the implications of the Miller equilibrium the results are, however, interesting and illustrative.

The ten percentage point increase in the statutory corporate tax rate increases the effective corporate tax rate by about 7 percentage points (fig. 2a). This increase in the effective tax rate is further gradually transmitted transmitted to the capital market tax rate (the marginal investor's marginal tax rate) through a partial adjustment mechanism. The adjustment process is practically completed within a period of one year.

The spread between the interest rates on taxable and tax-free securities has to widen to preserve the equality of after-tax yields

Figure 2. CORPORATE TAX RATE INCREASED BY 10 PERCENTAGE POINTS, FIXED MONEY MARKET RATE. DIFFERENCES FROM BASELINE CASE.



of the different domestic assets. However, as the money market interest rate is pegged in this experiment, the widening of the interest rate spread is possible only through a decrease in tax-free interest rates. In the present simulation the tax-free long-term interest rate decreases by about 0.7 percentage point.

An interesting result is that the increase in the corporate tax rate causes a capital outflow and a decrease in the stock of foreign reserves (fig. 2b). The reason is that the after-tax interest rate differential between domestic and foreign finance is decreased from the point of view of domestic borrowers. This discourages foreign borrowing and makes domestic finance relatively more competitive. The capital outflow is, however, financed by the central bank in the interest rate pegging regime, and it thus has no further repercussions in the domestic economy.

The real effects of the tax rate increase are modest (fig. 2c). The most important channel through which the effects of a change in the corporate tax rate are transmitted to the real economy is the user cost of fixed capital investments. The increase in the corporate tax rate should, ceteris paribus, raise the user cost and, hence, decrease investment. However, as the tax increase also causes the tax-free long-term interest rate to fall, one cannot, on a priori grounds, even be sure about the direction of the total effect of the increase in the corporate tax rate on the user cost of fixed capital.

In the present simulation user costs, e.g. in the manufacturing and private services sectors, rise by 5.9 and 7.3 per cent, respectively, during the period of implementation of the tax increase. During the following quarters, however, most of the user cost effect vanishes. This kind of time path follows from the slow adjustment of the tax-free long-term interest rate to the change in the corporate rate. Therefore at first the change in the corporate tax rate dominates the interest rate effect in the user cost. Later, the decrease in the tax-free long-term interest rate almost completely neutralizes the original tax effect on the user cost estimates.

As the fixed investments react to the changes in the user cost variables, there is a slight temporary decrease in non-residential fixed investments. There is also a small but permanent positive effect on private consumption. This results from the increased liquidity of households; the fall in the after-tax interest rates increases the demand for money, which the central bank has to finance so as to be able to peg the taxable money market rate.

Simulation 3: Corporate income tax rate increased by 10 percentage points in the flexible interest rate regime

In the flexible interest rate regime, the effects of a change in the corporate tax rate are stronger than in the pegged interest rate regime. This is due to the fact that the widening of the interest rate spread between the taxable and tax-free rates is now transmitted to both rates; the taxable rates increase and the tax-free rates decrease and, consequently, the tax-free bond rate decreases less than in the case of the pegged money market rate (fig. 3b). This weakens the interest rate effect, which in the previous experiment virtually neutralized the direct user cost effect of tighter corporate taxation.

The multiplier-accelerator process, which is set in motion by the increase in the user costs of capital, is strong enough to overcome the increase in the propensity to consume which dominated in the previous simulation and is also visible in the present case (fig. 3c).

In the case of flexible interest rates, the central bank does not accommodate demand for money through its open market operations. Thus, the increased demand for money is financed through an increase in the foreign component of the monetary base i.e. the net foreign reserves of the central bank (fig. 3d). This results from a positive current account effect, which is slightly greater than the capital outflow caused by the increased taxation in the Finnish capital market.

Figure 3. CORPORATE TAX RATE INCREASED BY 10 PERCENTAGE POINTS; FLEXIBLE MONEY MARKET RATE. DIFFERENCE FROM BASELINE CASE.

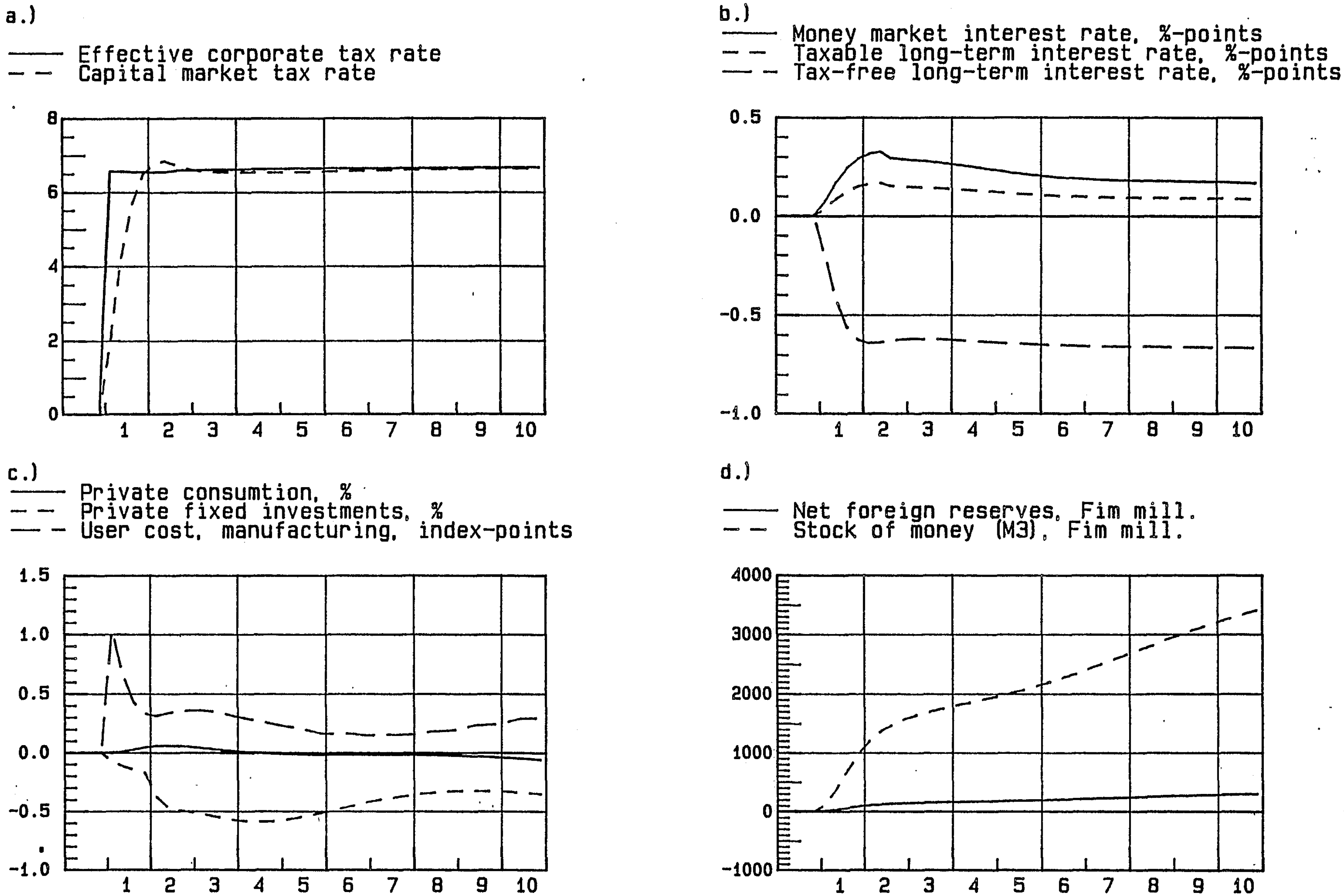


Table 7. Simulation Results

Corporate tax rate increased by 10 percentage points.

Difference from baseline case.

years	1	2	3	4	5	6	7
GDP, %	0.0	-0.2	-0.4	-0.5	-0.5	-0.4	-0.4
Imports, total, %	-0.1	-0.3	-0.6	-0.7	-0.7	-0.6	-0.5
Exports, total, %	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2
Private consumption, %	0.0	0.0	-0.2	-0.3	-0.4	-0.4	-0.3
Private fixed investment, %	-0.2	-1.0	-1.8	-2.4	-2.5	-2.2	-1.8
Residential, %	-0.1	-0.5	-1.0	-1.2	-1.1	-0.8	-0.6
Non-residential, %	-0.3	-1.1	-2.0	-2.7	-3.0	-2.7	-2.2
Domestic demand, %	-0.1	-0.3	-0.5	-0.7	-0.7	-0.6	-0.5
GDP deflator, %	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Private consumption deflator, %	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Wage rate, %	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2
Actual hours worked, %	0.0	-0.1	-0.2	-0.4	-0.4	-0.4	-0.3
Employment, 1000 persons	-0.1	-1.2	-3.5	-6.1	-7.9	-8.4	-7.8
Interest rates, percentage points							
Money market rate	0.5	0.8	0.8	0.7	0.5	0.3	0.1
Taxable bond rate	0.2	0.4	0.4	0.4	0.2	0.1	0.1
Tax-free bond rate	-0.4	-0.6	-0.6	-0.7	-0.8	-0.8	-0.9
Capital market tax rate, percentage points	4.6	6.1	5.8	5.7	5.8	5.9	6.0
Bank lending rate (av. stock)	0.1	0.2	0.2	0.2	0.2	0.2	0.1
Central government borrowing, net, FIM billion	-0.9	-0.8	-0.7	-0.6	-0.6	-0.8	-1.0
Balance of payments							
Current account, FIM billion	0.1	0.4	0.7	0.9	0.9	0.8	0.5
Private capital imports, FIM billion	0.0	-0.3	-0.7	-0.9	-0.9	-0.7	-0.5
Foreign exhange reserves, FIM billion	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Central bank domestic credit, FIM billion	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Demand for money							
Monetary base, per cent	0.2	0.3	0.3	0.3	0.4	0.5	0.7
Broad money, per cent	0.4	0.5	0.5	0.6	0.7	1.0	1.2

APPENDIX 1

INSTITUTIONAL CHANGE AND THE MODELLING OF FINNISH FINANCIAL MARKETS

We believe that BOF4 is the first model of the Finnish economy in which the financial sector is constructed entirely in the mainstream tradition of macroeconomic modelling, assuming that market-clearing interest rates link the financial and real sectors of the economy. The reason for this lies in the institutional development of the Finnish financial markets.

Until recently, Finnish financial markets were dominated by banks and tightly regulated. An organized money market has emerged only in the 1980's, and the long-term capital market was also largely dormant prior to this decade, with the exception of a thin secondary market for tax-exempt government bonds.

As the interest rates applied by banks were traditionally regulated by either the central bank (on the lending side) or by cartel agreements (on the deposit side), data on market-determined interest rates have been virtually nonexistent. Furthermore, since interest rate regulation made credit rationing possible, economists were reluctant to use the controlled interest rates in financial modelling. For example, in BOF3, the predecessor of the present BOF4 model, the regulated bank lending rate was supplemented by a variable measuring excess demand for bank loans in the equations where market rates of interest would have been required. As an alternative to this approach, some researchers have used the Bank of Finland's call money rate as a measure of financial market conditions. However, this method may be criticized on the grounds that only banks had access to the call money market.

In the 1980's, a money market has emerged, at first in the form of special wholesale deposits with banks. Simultaneously, the forward currency market, which has been active since the beginning of 1970's, has grown rapidly and assumed many of the functions which money markets perform in other countries as firms have learned to use covered foreign assets as a subsitute for domestic money market instruments. In the course of 1980's the previously thin market for taxable corporate bonds (debentures) has become much more active.

The short history of organized money markets in Finland means that data on the money market rate of interest is available only for the 1980's. For 1960's and 1970's we have been forced to construct estimates for it. For the period 1972 - 1979, the market rate of interest is operationalized with the covered 3-month eurodollar rate, sometimes called the "euromarkka rate". This is computed on the basis of forward premiums on the US dollar quoted in the Finnish forward market. For the period 1961 - 1971, a proxy for the market rate has been constructed from the regulated bank lending rate and the estimate of excess demand for bank loans provided in Tarkka (1986). The construction of the proxy is based on the following regression for the period 72.1 - 83.4:

$$RS - RLB = \underset{(24.6)}{183.8} * (RHO + RHO_{-1})$$

$$R^2 = 0.269 \qquad SE = 3.91 \qquad DW = 0.711$$

Here RS is the short-term money market rate, RLB is the average bank lending rate (both in per cent) and RHO is the estimate for the relative excess demand for bank loans from Tarkka's study. The regression equation provides a formula for computing RS for the period before the forward premium on USD became available.

APPENDIX 2

LIST OF EQUATIONS

Values of parameter estimates are ordinary least squares estimates.

Standard errors of parameter estimates are in parentheses below the coefficients.

LIST OF EQUATIONS

Weights of Almon lags are denoted by a_i, b_i, etc.

Variables with a subscript are lagged. Subscripts refer to number of lags in quarters.

Δ is the difference operator.

Δ^n denotes difference over n quarters.

log denotes natural logarithms.

Units:

Values are in millions of FIM.

Volumes are in millions of FIM at 1985 prices.

Price indices take the value 100 in 1985.

Interest rates are in per cent.

$\bar{R}^2$ = corrected coefficient of determination

DW = Durbin - Watson statistic

SE = standard error of estimate

rho = coefficient of first-order autocollelation correction

The estimation period is given after the summary statistics

BPCV	Current account, FIM million
BPTSV	Balance of goods and services, FIM million
BPTV	Trade balance, FIM million
GDPV	GDP in purchasers' values, FIM million
KLMN	Long-term foreign debt, net, FIM million
MGV	Imports of goods, total, FIM million
MSV	Imports of services, FIM million
TRCGF	Central government transfers abroad, FIM million
YFIN	Investment income from abroad, net, FIM million
YFTR	Income transfers from abroad, net, FIM million
XGV	Exports of goods, FIM million
XSV	Exports of services, FIM million

B. MAKSUTASE
BALANCE OF PAYMENTS

B.1 Kauppatase
Trade Balance

$$BPTV = XGV - MGV$$

B.2 Tavaroiden ja palvelusten tase
Balance of Goods and Services

$$BPTSV = BPTV + XSV - MSV$$

B.3 Pääomakorvaukset ulkomailta, netto
Investment Income from Abroad, Net

$$YFIN = 0.5 \cdot KLMN_{-1} \cdot (YFIN_{-1}/KLMN_{-2} + YFIN_{-2}/KLMN_{-3})$$

B.4 Tulonsiirrot ulkomailta, netto
Income Transfers from Abroad, Net

$$YFTR - TRCGF = \underset{(0.00006)}{0.00038} \cdot GDPV$$

$\bar{R}^2 = 0.2993$ DW = 1.660 SE = 21.6383 62.1 - 85.4

B.5 Vaihtotase
Current Account

$$BPCV = BPTSV + YFIN + YFTR$$

BPBV	Current and long-term capital account (basic balance), FIM million
BPCV	Current account, FIM million
CUR	Currency in circulation, FIM million
DMM	Dummy for the emergence of the CD market
FLMN	Long-term private capital inflows, net, FIM million
FMCGN	Foreign borrowing by the central government, net, FIM million
FPBBF	Banks' forward purchases of foreign exchange from the Bank of Finland, FIM million
FSMN	Short-term capital account, FIM million
GDPFV	GDP at factor cost, FIM million
GDPV	GDP in purchasers' values, FIM million
KDP	Bank deposits by the public, FIM million
KFBFO	Bank of Finland's other foreign assets, net, FIM million
RDT	Interest rate, time deposits, per cent
RFOR	Weighted average 3-month euromarket interest rate for USD, GBP, DEM and CHF, per cent

B.6 Perustase
Current and Long-Term Capital Account

$$BPBV = BPCV + FLMN + FMCGN + \Delta KFBFO$$

B.7 Lyhytaikaisen pääoman tase
Short-Term Capital Account

$$(FSMN + FLMN - \Delta FPBBF)/(KDP_{-1} + CUR_{-1}) =$$

$$- \underset{(0.04735)}{0.85583} \cdot VVV$$

$$- [\underset{(.00067)}{0.00128} \cdot DMM + \underset{(0.00160)}{0.00551} \cdot (1-DMM)] \cdot$$

$$[\Delta((RB/RDEB)RFOR) - \Delta RDT] \cdot GDPV_{-1}/(KDP_{-1} + CUR_{-1})$$

$$+ \underset{(0.06150)}{0.67186} \cdot \left(\frac{GDPV_{-1}}{KDP_{-1} + CUR_{-1}}\right)\Delta\left(\frac{KDP_{-1} + CUR_{-1}}{GDPV_{-1}}\right)$$

$$+ \underset{(0.05892)}{0.11388} \cdot \left(\frac{GDPV_{-1}}{KDP_{-1} + CUR_{-1}}\right)\left(\frac{\Delta GDPV}{GDPV_{-1}} - \frac{\Delta GDPV_{-1}}{GDPV_{-2}}\right)$$

$$+ \underset{(0.00193)}{0.00251} \cdot GDPV_{-1}/(KDP_{-1} + CUR_{-1})$$

$$- \underset{(0.01017)}{0.01934} \cdot (DMM - DMM_{-1})$$

where $VVV = (\Delta KDP + \Delta CUR - FSMN - FLMN + \Delta FPBBF)/(KDP_{-1} + CUR_{-1}) - \Delta GDPV_{-1}/GDPV_{-1}$

$\bar{R}^2 = 0.859$ SE = 0.0061 72.1 - 86.4

Estimated jointly with equation R.8

BPTV	Trade balance, FIM million
FLMN	Long-term private capital inflows, net, FIM million
FMCGN	Foreign borrowing by the central government, net, FIM million
FPBBF	Banks' forward purchases of foreign exchange from the Bank of Finland, FIM million
FPBP	Banks' forward purchases of foreign exchange from the public, net, FIM million
FPBT	Banks' overall forward position
FSMN	Short-term capital account, FIM million
FXFUS	Three-month forward premium on USD, % pa
FXSD	Exchange rate index for long-term foreign debt, 1960 = 1.00
KFBFO	Bank of Finland's other foreign assets, net, FIM million
KDP	Bank deposits by the public, FIM million
KLMN	Long-term foreign debt, net, FIM million
MIV	Imports of investment goods, FIM million
REUD	Interest rate, 3-month eurodollar deposits, per cent
RS	Money market rate, per cent

B.8 Pankkien ulkomaanvaluutan termiinisaatava yleisöltä
Banks' Forward Purchases of Foreign Exchange from the Public, Net

$$\Delta FPBP = \underset{(0.0601)}{0.5425} \cdot (FSMN + FLMN - FPBBF + FPBBF_{-1}) + \underset{(0.2206)}{0.1314} \cdot \Delta BPTV + \underset{(0.0124)}{0.0205} \cdot KATPAR$$

jossa $KATPAR = ((RS - REUD - FXFUS) - (RS_{-1} - REUD_{-1} - FXFUS_{-1})) \cdot (XV_{-1} + MV_{-1})$

$\bar{R}^2 = 0.758$ DW = 2.330 SE = 1466.17 80.3 - 88.4

B.9 3 kk USD termiinipreemio
Forward Premium on USD

$$FXFUS - RS + REUD = + \underset{(0.14898)}{0.7779} - \underset{(1.3424)}{5.4211} \cdot (FPBT/KDP + FPBT_{-1}/KDP_{-1})$$

$\bar{R}^2 = 0.317$ DW = 1.158 SE = 0.5730 80.3 - 88.4

B.10 Kansantalouden pitkäaikainen ulkomainen nettovelka
Long-Term Foreign Debt, Net

$$KLMN = KLMN_{-1} + FLMN + FMCGN + KFBFO - KFBFO_{-1} + ((FXSD - FXSD_{-1})/FXSD_{-1}) \cdot (KLMN_{-1} + 0.5 \cdot (FLMN + FMCGN + KFBFO - KFBFO_{-1}))$$

BPBV	Current and long-term capital account (basic balance), FIM million
FPBBF	Banks' forward purchases of foreign exchange from the Bank of Finland, FIM million
FPBT	Banks' net forward position in foreign exchange, FIM million
FSMN	Short-term capital account, FIM million
GFXC	Bank of Finland's convertible foreign exchange reserves, FIM million
GFXN	Bank of Finland's foreign claims, net, FIM million
GFXT	Bank of Finland's tied foreign exchange reserves, FIM million
KFBFO	Bank of Finland's other assets, net, FIM million
MGEV	Imports of goods, bilateral, FIM million
XGEV	Exports of goods, bilateral, FIM million

B.11 Suomen Pankin ulkomainen nettosaatava
Bank of Finland's Foreign Claims, Net

$$GFXN = GFXT + KFBFO + GFXC$$

B.12 Pankkien termiinipositio
Banks' Overall Forward Position

$$FPBT = FPBP + FPBBF$$

B.13 Suomen Pankin sidottu valuuttavaranto
Bank of Finland's Tied Foreign Exchange Reserves

$$\Delta GFXT = XGEV - MGEV$$

B.14 Suomen Pankin vaihdettava valuuttavaranto
Bank of Finland's Convertible Foreign Exchange Reserves

$$\Delta GFXC = BPBV + FSMN - \Delta GFXT$$

C	Total private consumption, millions of 1985 FIM
CUR	Currency in circulation, FIM million
PCP	Private consumption prices, 1985 = 100
RDEB	Market yield on debentures, per cent
RDT	Interest rate, time deposits, per cent
RS	Money market rate, per cent

R. RAHOITUSMARKKINAT
FINANCIAL MARKETS

R.1 Setelistö
Currency in Circulation

$$\log(CUR/PCP) = \underset{(0.14518)}{-0.12178} + \underset{(0.02941)}{0.12590} \cdot \log C - \underset{(0.00483)}{0.00523} \cdot RDT_{-1} + \underset{(0.06812)}{0.72629} \cdot \log(CUR_{-1}/PCP)$$

$\bar{R}^2 = 0.913$ DW = 2.457 SE = 0.0321 61.1 - 85.4

R.2 Debentuurikorko
Market Yield on Debentures

$$RDEB = \underset{(0.65617)}{5.88100} + \underset{(0.05061)}{0.51258} \cdot RS$$

$\bar{R}^2 = 0.790$ RHO = 0.23 SE = 0.3265 62.1 - 86.4

CR	Cash reserve deposits by banks, FIM million
CRR	Cash reserve requirement, per cent
KDP	Bank deposits by the public, FIM million
PCP	Private consumption prices, 1985 = 100
RB	Market yield on tax-free bonds, per cent
RCALL	Overnight (Call Money) rate, per cent
RD	Bank of Finland's base rate, per cent
RDEB	Market yield on debentures, per cent
RDT	Interest rate, time deposits, per cent
RLB	Bank lending rate, per cent
RS	Money market rate, per cent
TLGR	Average local government tax rate
TYCR	Corporate tax rate in central government taxation

R.3 Obligaatiokorko
Yield on Tax-Free Bonds

$$\Delta \log RB = \underset{(0.11509)}{0.30993} \cdot \Delta \log RB_{-1}$$

$$+ \underset{(0.08697)}{0.26554} \cdot \Delta \log[(1 - TEFFR)RDEB]$$

$$+ \underset{(0.07438)}{0.30763} \cdot \log[(1 - TEFFR_{-1})RDEB_{-1}/RB_{-1}]$$

where $TEFFR = [0.82266(TYCR + TLGR) - 11.393 \cdot \Delta PCP/PCP_{-1}] / (1 + 0.01RDEB)^2$

$\bar{R}^2 = 0.4027$ DW = 1.8644 SE = 0.035 77.1 - 88.4

R.4 Pankkien keskimääräinen antolainauskorko
Banks' Average Interest Rate on Outstanding Loans

$$\Delta RLB = \underset{(0.02671)}{0.10291} \Delta RS + \underset{(0.05341)}{0.98182} \Delta RD$$

$$+ \underset{(0.01363)}{0.04033} RS_{-1} - \underset{(0.02849)}{0.11846} RLB_{-1}$$

$$+ \underset{(0.23831)}{0.76826}$$

$\bar{R}^2 = 0.965$ RHO = -0.61 SE = 0.099 85.1 - 88.4

R.5 Päiväkorko
Overnight (Call Money) Rate

$$\Delta RCALL = \Delta RS$$

R.6 Aikatalletuskorko
Time Deposit Rate

$$\Delta RDT = \Delta RD$$

R.7 Kassavarantotalletukset
Cash Reserve Deposits by Banks

$$\Delta(CR/KDP) = \underset{(0.00045)}{0.00990} \cdot \Delta CRR$$

$\bar{R}^2 = 0.830$ DW = 1.670 SE = 0.0015 62.1 - 85.4

CR	Cash reserve deposits by banks, FIM million
CUR	Currency in circulation, FIM million
DID	Dummy: credit rationing periods
DMM	Dummy for the emergence of the CD market
GFXN	Bank of Finland's foreign claims, net, FIM million
GDPV	GDP in purchasers' values, FIM million
KDP	Banks' deposits by the public, FIM million
KOBFN	Bank of Finland's capital and other items, FIM million
LBFBN	Banks' net debt to the Bank of Finland, FIM million
LBFBT	Gross central bank debt of the banks, FIM million
LBFCUR	Till money credits to the banks, FIM million
LBFGN	Central government debt to the Bank of Finland, net, FIM million
LBP	Bank loans to the public, FIM million
PGDPF	GDP deflator at factor cost, 1985 = 100
RB	Market yield on tax-free bonds, per cent
RCALL	Overnight (call money) rate, per cent
RDEB	Market yield on debentures, per cent
RDT	Interest rate, time deposits, per cent
RLB	Bank lending rate, per cent
RS	Money market rate, per cent

R.8 Pankkien nettovelka Suomen Pankille
Banks' Net Debt to the Bank of Finland

$$LBFBN = CUR - GFXN - LBFGN - LBFGN + KOBFN$$

R.9 Pankkien keskuspankkirahoitus, brutto
Banks' Gross Debt to the Bank of Finland

$$LBFBT = LBFBN + CR - LBFCUR$$

R.10 Pankkien antolainaus yleisölle
Bank Loans to the Public

$$DID \cdot (LBP - LBP_{-1})/LBP_{-1} = \underset{(0.00210)}{0.03679} \cdot DID$$

$$- \underset{(0.00033)}{0.00229} \cdot DID \cdot \sum_{i=0}^{7} a_i (RCALL - RLB)_{-i}$$

$$+ \underset{(0.01571)}{0.12047} \cdot DID \cdot (PGDPF - PGDPF_{-4})/PGDPF_{-4}$$

viivästymä i	0	1	2	3	4	5	6	7	$\sum$
paino a_i	22	.19	.17	.14	.11	.08	.06	.03	1

$\bar{R}^2 = 0.889$ DW = 1.659 SE = 0.0062 62.1 - 85.4

R.11 Yleisön talletukset pankeissa
Bank Deposits by the Public

$$\Delta\left(\frac{KDP + CUR}{GDPV_{-1}}\right) = \frac{A4 + DMM \cdot (A5 - A4)}{A2} \cdot \left(\Delta RDT - \Delta\left(\frac{RB}{RDEB} \cdot RS\right)\right)$$

$$- \frac{A7}{A2} \cdot \left[\frac{(KDP + CUR)}{GDPV_{-1}} - \frac{(KDP_{-1} + CUR_{-1})}{GDPV_{-1}}\right]$$

$$- \frac{A6}{A2} \cdot \left(\frac{\Delta GDPV}{GDP_{-1}} - \frac{\Delta GDPV_{-1}}{GDPV_{-2}}\right)$$

where $A2 = \underset{(0.04735)}{-.85583}$ $A4 = \underset{(.00160)}{-.00551}$ $A5 = \underset{(.00067)}{-.00128}$

$A6 = \underset{(.05892)}{.11388}$ $A7 = \underset{(.06150)}{.67186}$

$\bar{R}^2 = .748$ SE = .0186 72.1 - 86.4

Estimoitu yhdessä yhtälön B.7 kanssa

FPCGN	Change in holdings of central government bonds by the public, FIM million
GDOP	
KDP	Bank deposits by the public, FIM million
KOBN	Balance sheet of the banks, other items, net, FIM million
LBFBN	Banks' net debt to the Bank of Finland, FIM million
LBP	Bank loans to the public, FIM million
LCGBN	Banks' debt to the central government, net, FIM million
SECPCG	Central government bonds held by the public, FIM million

R.12 Pankkien muut velat
Banks' Other Liabilities

$$KDOB = LBP - KDP - LCGBN - LBFBN - KOBN$$

R.13 Yleisön hallussa olevat valtion obligaatiot
Central Government Bonds Held by the Public

$$SECPCG = FPCGN + SECPCG_{-1}$$

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