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**Book**

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Mikko Spolander

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# Measuring Exchange Market Pressure and Central Bank Intervention

SUOMEN PANKKI  
Bank of Finland



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**Measuring Exchange  
Market Pressure  
and Central Bank  
Intervention**

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Mikko Spolander

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# Abstract

This study contributes to the measurement of exchange market pressure and central bank intervention policy in a system of floating currency and partly sterilized foreign exchange interventions. A model-consistent approach is used. The measures of exchange market pressure and degree of intervention in the foreign exchange market are derived in the context of an empirically oriented small open economy monetary model with rational expectations. Monetary and foreign exchange policies are explicitly defined and foreign exchange interventions are allowed to be partly sterilized. Finally, the model is applied to Finnish data in order to analyse the pressure on the markka, which was floating during the period 1992–1996, and the Bank of Finland's reaction to that pressure. In contrast to most other empirical studies using various proxy variables, actual intervention data is used.

According to the estimation results, the inclusion of the monetary policy reaction function and especially the sterilization of foreign exchange intervention makes the values of the measures of exchange market pressure and intervention policy more realistic and hence easier to interpret. This means that the fact that foreign exchange interventions are at least partly sterilized in the main industrial countries should be taken into account when exchange market pressure and central bank intervention policy are measured. This has not been done in other studies using a model-consistent approach. When the Bank of Finland's reaction to exchange market pressure is analysed, the results seem to suggest that the Bank let the markka float quite freely, reduced its intervention activity gradually as exchange market pressure diminished, and considered markka appreciation more desirable than depreciation during the markka float.

**Key words:** exchange market pressure, foreign exchange intervention, intervention policy, Finland

# Tiivistelmä

Tutkimuksessa rakennetaan mittari mittaamaan valuuttamarkkinoiden painetta ja keskuspankin interventiopolitiikkaa järjestelmässä, jossa valuutta kelluu ja keskuspankki steriloi osan valuuttainterventioistaan. Tutkimuksessa sovelletaan mallikonsistenttia lähestymistapaa. Valuuttamarkkinoiden paineen ja interventiopolitiikan mittarit johdetaan empiirisesti orientoituneesta pienen avotalouden monetaarisesta valuuttakurssimallista, jossa odotusten oletetaan olevan rationaalisia. Mallissa raha- ja valuuttakurssipolitiikat määritellään eksplisiittisesti ja keskuspankin sallitaan steriloida osa valuuttainterventioistaan. Soveltamalla mallia Suomen aineistoon analysoidaan kelluvaan markkaan vuosina 1992–1996 kohdistuneita paineita ja Suomen Pankin reaktioita näihin paineisiin. Useimmissa empiirisissä tutkimuksissa käytetään erilaisia korvikemuuttujia kuvaamaan valuuttainterventioita. Tässä tutkimuksessa käytetään todellisia valuuttainterventioita.

Tulosten mukaan rahapolitiikan reaktiofunktion ja erityisesti valuuttainterventioiden steriloinnin sisällyttäminen malliin tekee valuuttamarkkinoiden paineen ja interventiopolitiikan mittarien arvoista realistisempia ja helpommin tulkittavia. Näin ollen se tosiasia, että valuuttainterventiot teollistuneissa maissa steriloidaan ainakin osittain, pitää ottaa huomioon mitattaessa valuuttamarkkinoiden painetta ja keskuspankin interventiopolitiikkaa. Näin ei aiemmissa mallikonsistenttia lähestymistapaa soveltavissa tutkimuksissa ole tehty. Kun analysoidaan Suomen Pankin reaktioita valuuttamarkkinoiden paineisiin, tulokset viittaavat siihen, että markan kellutuksen aikana Suomen Pankki antoi markan kellua varsin vapaasti, vähensi intervenointiaktiivisuuttaan vähitellen valuuttamarkkinoiden paineen pienentyessä ja piti markan vahvistumista toivottavampana kuin sen heikentymistä.

Asiasanat: valuuttamarkkinoiden paine, valuuttainterventio, interventiopolitiikka, Suomi

# Preface

The roots of this study go back to the last half year of the float of the markka, when I was working in the Monetary Policy Department of the Bank of Finland. At that time, the pros and cons of ERM membership vs continued floating were discussed increasingly. As a part of that discussion, questions were raised as to how much pressure the floating markka had been exposed to and how the Bank of Finland had reacted to that pressure, ie how cleanly the Bank of Finland had allowed the markka to float. This study is an attempt to give some answers to these questions.

Several persons have given me advice and support, without which this study would have been impossible to complete. Pentti Pikkarainen was the one who encouraged me to start with the research project in the first place. Even before I had officially registered as a postgraduate student at the Helsinki School of Economics, Pertti Haaparanta, who was later to become my official supervisor, was always ready to discuss any analytical and practical problems I had with the project, and his support was invaluable in many ways. I also gratefully acknowledge the comments and suggestions of Kari Heimonen and Juuso Vataja my official examiners at the Helsinki School of Economics. Furthermore, I owe a great deal to Lauri Kajanoja with whom I had long and thorough discussions. Lauri helped me to focus the research and to concentrate on the relevant literature and guided me through many difficulties in the analysis. His suggestions were also important in shaping the final text. Special thanks go to Mika Pösö who helped me in checking the data used in the analysis.

The work was done for the most part during a 21-month period that, by the goodwill of my superiors at the Bank of Finland, I was able to spend in postgraduate studies in the Research Department. The department provided a stimulating working environment. Especially, Juha Tarkka and Jouko Vilminen made important comments and suggestions on the various drafts, and Matti Virén gave very useful advice on several, mainly econometric, issues. Päivi Lindqvist took care of the final processing of the text and Heli Tikkinen prepared the graphs. The Bank of Finland library speedily provided me with all the material I could possibly ask for. During the last months of the project Anne Brunila kindly allowed me to use some of my working hours for making late revisions. In the final phase, Glenn Harma was of invaluable help in checking my English and improving it substantially. My sincere thanks are due to all of these people.



Last but not least, I want to thank my wife Kristiina for her enduring patience and support and my children, Elisa and Meri, for bringing sunshine to those rainy days when the faith was about to fade.

Helsinki, December 1999  
Mikko Spolander

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# 1 Introduction

Since the breakdown of the Bretton Woods fixed exchange rate system in the early 1970s, the exchange values of the currencies of the major industrialized countries have been determined by market forces. This means that the exchange rates have been determined by the demands for and supplies of the currencies in the international foreign exchange market, without preannounced fluctuation bands. However, only a few currencies have been left entirely at the mercy of the market. The monetary authorities of many countries have intervened in the foreign exchange markets to influence the paths of exchange rates. At the end of 1997,<sup>1</sup> most of the 184 member nations of the International Monetary Fund managed their exchange rates in one way or another. Of the 184 members, only 46 permitted their currencies to float independently, which means that exchange rates were allowed to fluctuate, but intervention could be used to moderate the fluctuations. The other 138 nations either pegged their currencies or permitted only limited exchange rate flexibility.

Although there have been regional currency groupings, such as the regime of fixed but adjustable peg in the European Monetary System, there has been no successful worldwide restoration of fixed rates.<sup>2</sup> The European development toward a single currency reached its final point at the beginning of 1999 when the exchange rates between the national currencies of 11 European countries were irrevocably fixed. As a result, the number of national currencies decreased and the financial world took a major step toward a tri-polar monetary system, consisting of the euro, US dollar and Japanese yen.

Irrespective of the number of currencies in the world, the question remains, how to react to pressures which tend to arise as a result of the excess demand for or supply of the domestic currency in the international foreign exchange market. The first months of the euro have shown that the free float is not a self-evident answer to the question; the persistent depreciation of the euro has generated a lively debate on the need to engage in implicit or even explicit foreign exchange interventions in order to defend the value of the euro. How to react to the exchange market pressures is also important to those countries that are still outside the euro-zone but are planning to join later; joining the euro-zone requires a

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<sup>1</sup> See International Monetary Fund (1998:992).

<sup>2</sup> See Aldcroft and Oliver (1998:121).

stable exchange rate vs the euro and, therefore, a need to smooth exchange rate fluctuations in one way or another. Finally, there is a large group of transition economies, which are only entering the international financial community and learning the rules of free market forces. Ultimately, they will have to choose between free and various degrees of managed floating.

The need to evaluate the magnitude of exchange market pressure and to explain the development of the exchange rate and the actions of the national monetary authority under various exchange rate regimes remains as long as exchangeable currencies and the international foreign exchange market exist. Therefore, the question here is how to measure the magnitude of exchange market pressure. The aim of this paper is to contribute to this endeavour.

In general, exchange market pressure refers to the magnitude of money market disequilibrium arising from international excess demand or supply of the domestic currency. In this study, exchange market pressure is measured as the exchange rate change which would have been required to remove this excess demand in the absence of foreign exchange market intervention, given that the expectations are generated by the exchange rate policy actually implemented. Furthermore, the degree of such intervention is measured as the proportion of exchange market pressure relieved by the foreign exchange interventions of the central bank.

Defining and measuring pressure on a fixed exchange rate comprise an important part of the vast analytical and empirical literature on currency crises and speculative attacks. The majority of empirical studies, and especially those published in recent years, do not directly apply any economic model.<sup>3</sup> However, there are also a number of studies that do so, starting with the seminal work of Blanco and Garber (1986). To a lesser extent, the concept of an excess demand for a currency has been used in papers measuring exchange market pressure and the degree of central bank intervention under intermediate exchange rate regimes, ie analysing how cleanly the central bank allows the domestic currency to float. Girton and Roper's (1977), Roper and Turnovsky's (1980) and Weymark's (1995, 1997a, 1997b, 1998) measures are the best-known attempts to analytically construct an operational model-dependent summary statistic of exchange market pressure. Eichengreen, Rose and Wyplosz's (1995) simple measure is an example of a recent contribution to model-independent measuring of exchange market pressure.

In all papers mentioned above, the exchange market pressure is measured quantitatively by forming a summary statistic from observed

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<sup>3</sup> See Kaminsky and Lizondo and Reinhart (1998) for an exhaustive bibliography.

changes in exchange rate and foreign exchange reserves of the domestic central bank. Eichengreen, Rose and Wyplosz (1995) also include the short-term interest rate differential in the measure. This means that the central bank is assumed to conduct its exchange rate policy through changes in foreign exchange reserves and, in the case of Eichengreen, Rose and Wyplosz (1995), through changes in interest rates. Because the literature focuses mainly on theoretical aspects of the methodology, the praxis of the central bank's exchange rate management is analysed in a superficial way or even totally neglected. However, the praxis has important effects on the operational measure of exchange market pressure and the degree of intervention.

A major shortcoming of the analytical literature is the operational neglect of the sterilization of the central bank's foreign exchange intervention. Even in the empirical part of Weymark (1995), the sterilization of interventions is not taken into account. In practice, however, central banks in the main industrial countries partly or totally offset the liquidity effect of a foreign exchange intervention with a domestic money market operation.<sup>4</sup> For example, in the United States<sup>5</sup> the Federal Reserve sterilizes the liquidity effect regularly and completely, so that a foreign exchange intervention does not lead to a change in the domestic money market nor hence in the domestic interest rate, compared to that which would have occurred in the absence of foreign exchange intervention. The case is generally the same in Finland.<sup>6</sup> Therefore, it is vitally important for the realistic measurement of exchange market pressure and the degree to which this pressure is removed by the central bank's foreign exchange intervention that sterilization of the intervention be taken into account.

In this paper, the measures of pressure and the degree of intervention are derived in the context of a small open-economy monetary model. Monetary policy is conducted through changes in the monetary base and foreign exchange interventions are allowed to be partially sterilized. The required parameters, including the degree of sterilization, are estimated from the data. In contrast to most other empirical studies using various proxy variables, actual intervention data is used here.

The paper is organized as follows. Chapter 2 summarizes briefly the recent literature on measuring exchange market pressure. A general

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<sup>4</sup> See eg Almekinders (1995:11). The sterilization of foreign exchange interventions is defined and discussed in detail in section 6.3.2 below.

<sup>5</sup> See eg The Federal Reserve System: Purposes and Functions (1994:64).

<sup>6</sup> See eg Aaltonen, Aurikko and Kontulainen (1994:81).

definition of exchange market pressure based on Weymark (1995) is given in chapter 3. In chapter 4, common models of exchange rate determination are summarized in order to review the channels through which the central bank's money and foreign exchange market intervention can affect the exchange rate. In chapter 5, the measures of exchange market pressure and the degree of central bank intervention are derived in the context of a small open-economy monetary model with rational expectations, in which monetary policy is conducted through changes in the monetary base and foreign exchange interventions are partly sterilized. Also explicitly discussed are the assumptions behind the forward-looking reduced-form solution for the change in the exchange rate, which depends on the central bank's exogenous exchange rate policy variable and on exogenous economic fundamentals. The measures of exchange market pressure and the degree of intervention are derived by applying Weymark's (1995) idea of market participants' fixed expectations of the central bank's foreign exchange policy when external imbalance is solved for. In chapter 6, the model is applied to Finnish data. Given the model-consistent measures estimated in chapter 6, chapter 7 discusses the development of exchange market pressure and the degree of intervention during the period when the Finnish markka was floating, September 1992 to October 1996. Chapter 8 concludes the study.

## 2 Recent literature on measuring exchange market pressure

Following Girton and Roper (1977), exchange market pressure can be measured quantitatively by forming a summary statistic from observed changes in the exchange rate and foreign exchange reserves of the domestic central bank. To let the exchange rate change is the passive way of reacting to exchange market pressure. The active way is to purchase or sell foreign bonds, ie to intervene. But why bother?

The major argument for official exchange rate management, especially in a small open economy where the foreign exchange market is thin, is that free floating exchange rates can lead to extreme volatility. This could have an adverse effect on exports and imports, and might increase inflationary pressures, if the effects of a depreciation spill over more readily into the domestic economy than do the effects of an appreciation. In order to reduce the volatility, the official exchange rate management should be effective. The case for effective management in turn relies on the assumption that the authorities have better information than the market about a currency's true or proper long-run equilibrium value and have effective means to push the exchange rate toward this level.

Because an exchange rate is a price relationship between two currencies and hence between two nations, one country's exchange rate policy could have significant spillover effects on other countries. To promote exchange stability, to maintain orderly exchange arrangements and to avoid competitive exchange depreciation, the members of the International Monetary Fund have agreed to comply with certain general obligations regarding exchange arrangements.<sup>7</sup> To this end, each member should seek to promote stability by fostering orderly underlying economic and financial conditions and a monetary system that does not tend to produce erratic disruptions but, at the same time, to avoid manipulating exchange rates or the international monetary system in order to prevent effective balance of payments adjustment or to gain an unfair competitive advantage over other members. Each member should also follow exchange policies compatible with other members' undertakings under these general obligations. This means that foreign exchange intervention is encouraged as long as it helps foster orderly conditions in the foreign exchange market. However, what constitutes orderly market conditions

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<sup>7</sup> See International Monetary Fund (1978:6-7).



depends on the objectives of the exchange rate policy in each individual country.

The literature on measuring exchange market pressure has always recognized the importance of both changes in the exchange rate and foreign exchange interventions in relieving the pressure. The article by Girton and Roper (1977), the best known in the field, uses the asset market approach<sup>8</sup> to measure the excess demand for a currency. It refers to the magnitude of domestic money market disequilibrium which must be removed through changes in foreign exchange reserves or in the exchange rate as 'exchange market pressure'; the domestic central bank is not assumed to change domestic credit to influence the exchange rate. They derive their measure of exchange market pressure in a monetary model with two large interdependent economies and use it to quantify the volume of central bank foreign exchange intervention necessary to achieve any desired exchange rate target. Due to model specification, their measure of exchange market pressure is a simple sum of percentage changes in the exchange rate and in foreign exchange reserves of the domestic central bank. The measure is then used as the dependent variable in estimations investigating the extent to which monetary policy can be formulated independently in open economies.

Girton and Roper's (1977) original exchange market pressure formula has been used extensively as the dependent variable in tests of the monetary approach to external balance, albeit sometimes in an inconsistent way.<sup>9</sup> The small open economy version of the Girton and Roper measure of exchange market pressure is formally derived in Connolly and Da Silveira (1979). The idea of Girton and Roper (1977) has been applied to various empirical studies such as Burdekin and Burkett (1990), Hacche and Townend (1981), Kim (1985), Lee and Wohar (1991), Mah (1991, 1995, 1998), Modeste (1981), Pollard (1999), and Wohar and Lee (1992).

The work of Girton and Roper (1977) was continued by Roper and Turnovsky (1980) who use a stochastic small open economy IS-LM model to quantify the international excess demand for the domestic currency. They assume that excess demand is absorbed through changes in the exchange rate, in foreign exchange reserves or in domestic credit. They also introduce a policy reaction function that describes foreign exchange or money market intervention as a function of the observed deviation of the exchange rate from its long-run equilibrium level. In this framework, they formulate the optimal stabilisation policy in terms of the

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<sup>8</sup> For asset market approach to exchange rate determination see chapter 4 below.

<sup>9</sup> See Weymark (1998:22).

central bank's optimal response to changes in exchange market pressure. In their model, the excess demand for domestic currency is equal to an unequally weighted linear combination of changes in the exchange rate and in the monetary base. Following Girton and Roper (1977), Roper and Turnovsky refer to this excess demand as exchange market pressure.

As Weymark (1998:107) points out, in none of the above-mentioned articles do the authors begin with an independent definition of exchange market pressure for economies with intermediate exchange rate systems and use it to derive an expression for exchange market pressure consistent with the model being employed. The first model-dependent exchange market pressure index based on a general, model-independent definition of the concept of exchange market pressure was constructed by Weymark (1995). Her principal idea is to consider the calculation of exchange market pressure as a measurement experiment at time  $t$  in which the actual magnitude of external imbalance is calculated, given the policy in place during that period. This means that all relevant information about expectations and stochastic disturbances is captured in the changes in the observed variables that relieve this external imbalance. The general applicability of the method is demonstrated in Weymark (1998:116–118), in which the Girton and Roper (1977) and Roper and Turnovsky (1980) formulae for exchange market pressure are derived by applying the general definition and methodology to the structural models that they employ.

It is obvious that Girton and Roper's (1977), Roper and Turnovsky's (1980) and Weymark's (1995, 1997a, 1997b, 1998) indices are model-dependent. Eichengreen and Rose and Wyplosz (1995:278) argue that model-dependence is not a desirable characteristic of an operational index because empirical models linking macroeconomic variables to the exchange rate have little explanatory power at short and intermediate horizons. In contrast, they derive the underlying intuition of their ad hoc approach from Girton and Roper's (1977) original idea of channels through which exchange market pressure can be relieved. As a model-independent measure of speculative pressure, they propose a linear combination of the change in the relevant interest rate differential, the percentage change in the bilateral exchange rate, and the percentage change in foreign reserves of the domestic central bank. The weights assigned to the components of this index are chosen to equalize their conditional volatilities. This is obviously an ad hoc approach.

According to Weymark (1998:118), however, the relative volatilities of observed changes in the exchange rate, in the central bank's foreign reserves, and in the interest rate differential necessarily depend on the structure of the economy as well as on the intervention activities of the

central bank. This means that volatility-smoothing weights cannot be expected to ensure that the components of the index of speculative pressure are commensurate. Consequently, the Eichengreen, Rose and Wyplosz (1995) index cannot be interpreted as a cardinal or even ordinal measure of speculative pressure in the context of any model. Weymark (1998:119) also denies that the poor track record of structural models in forecasting exchange rate changes precludes their use in the construction of operational indices. She argues that a poor understanding of market participants' expectation formation process and an inability to model this process correctly is probably the primary source of these forecasting difficulties. Weymark's approach is to define the calculation of exchange market pressure as a measurement experiment in which expectations are generated by the exchange rate policy actually implemented.<sup>10</sup> Therefore, an explicit formulation of expectation formation process is not needed in the usual sense; all of the relevant information about expectations is already captured in the observed changes in those variables that relieve the external imbalance.

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<sup>10</sup> See Weymark (1998:113–114).

### 3 General definitions of exchange market pressure and the degree of central bank intervention

According to the asset-market approach to exchange rate determination, imbalance between the demand and supply of domestic currency in the international foreign exchange market occurs when the total value of foreign assets and goods demanded by domestic residents is not equal to the total value of domestic assets and goods demanded by foreign residents at the prevailing exchange rate level. To balance the market, the price or quantity of domestic assets in circulation, ie the exchange rate or the money supply, must change. Given the money multiplier, the change in money supply depends on the money and foreign exchange market interventions of the domestic central bank. This offers a natural way of characterizing exchange market conditions: the total international excess demand or supply of the domestic currency can be measured quantitatively by forming a summary statistic from observed changes in exchange rate, domestic credit and foreign exchange reserves of the domestic central bank. This magnitude of money market disequilibrium can also be called exchange market pressure.

The following general model-independent definition of exchange market pressure is given in Weymark (1995:278):

Exchange market pressure measures the total excess demand for a currency in international markets as the exchange rate change which would have been required to remove this excess demand in the absence of money or foreign exchange market intervention, given the expectations are generated by the exchange rate policy actually implemented.

In other words, the amount of exchange market pressure is the size of the exchange rate change that would have occurred if the central bank had unexpectedly refrained from intervening in the money or foreign exchange market. Therefore, because expectations associated with a free float will differ from those held under the policy actually implemented, exchange market pressure is not generally equivalent to the exchange rate change that would have occurred under a free floating exchange rate system. Rather, exchange market pressure is best associated with the magnitude of external imbalance.

According to Weymark (1998:109), the above model-independent definition of exchange market pressure has two important features. First, because it defines exchange market pressure as the excess demand for

domestic currency in international markets, it can be used to obtain model-consistent measures with models that do not emphasize the monetary approach to exchange rate determination,<sup>11</sup> as well as with those that do. The definition is applicable to any model in which the demand for domestic currency responds contemporaneously to exchange rate changes. Second, because it measures the excess demand for domestic currency associated with the expectations held under the exchange rate and monetary policy actually implemented, it measures the actual external imbalance rather than the external imbalance that would have occurred under a pure float.

Weymark argues that, because the definition of exchange market pressure does not allow expectations to change at the time when the size of the external imbalance is calculated from observed changes in the relevant endogenous variables, understanding how expectations are formed is not required in the usual sense; all of the relevant information about expectations is captured in the observed changes in the variables that relieve the international excess demand for currency, given the policy in place during that period. This means that exchange market pressure indices can be calculated without having to obtain closed-form solutions for expectations and without having to specify the nature of stochastic disturbances to the economy.

If the domestic currency were allowed to float freely, exchange market pressure could, of course, be observed directly. If the exchange rate were held fixed, changes in foreign exchange reserves and domestic credit would reflect the size of external imbalance. With intermediate exchange rate systems, the magnitude of exchange market pressure has to be calculated from observed changes in the exchange rate, domestic credit and foreign exchange reserves. However, the monetary units in which changes in reserves and domestic credit are measured are not commensurate with the units in which exchange rate changes are measured. To yield a commensurable composite index of external imbalance, changes in foreign exchange reserves and domestic credit have to be converted into exchange-rate-equivalent units and combined with changes in the exchange rate.

The idea of the methodology is to generate a model-dependent summary statistic based on a model-independent definition of exchange market pressure. An exchange market pressure formula that is consistent with the idea is<sup>12</sup>

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<sup>11</sup> See chapter 4 below for a discussion of the monetary approach to exchange rate determination.

<sup>12</sup> See Weymark (1998:109) and chapter 5 below.

$$EMP_t = \Delta e_t + \eta^d [\Delta d_t^a + (1 - \lambda) \Delta r_t] \quad (3.1)$$

where  $\Delta e_t$  is the change in the exchange rate,<sup>13</sup>  $\Delta d_t^a$  is the autonomous change in domestic credit,  $\Delta r_t$  is the change in foreign exchange reserves,  $\eta^d$  is the negative of the elasticity of the change in the exchange rate with respect to a change in the monetary base, and  $\lambda$  is the proportion of foreign exchange intervention that is sterilized by a change in domestic credit.<sup>14</sup> It is natural to assume that the central bank tries to dampen fluctuations in the exchange rate, ie if purchases foreign bonds when there is excess demand for domestic currency and the exchange market pressure is negative, and sells foreign bonds when there is excess supply of domestic currency and the exchange market pressure is positive. This means that under leaning-against-the-wind policy the conversion coefficient,  $\eta^d$ , should be negative.

The inclusion of  $\Delta d_t^a$  in the exchange market pressure formula (3.1) can be interpreted in the following way. The central bank changes autonomous domestic lending only to affect the exchange rate, ie monetary policy is dependent on conditions in the foreign exchange market as under a fixed exchange rate regime. If  $\Delta d_t^a$  is excluded from formula (3.1), autonomous changes in domestic lending are exogenous to the central bank's foreign exchange policy, ie monetary policy is independent from conditions in the foreign exchange market as under a dirty float exchange rate regime. If the change in domestic credit,  $\Delta d_t$ , and the change in foreign exchange reserves,  $\Delta r_t$ , are of opposite sign, the central bank uses money market intervention to sterilize the effect of a foreign exchange intervention on domestic money supply. If  $\Delta d_t$  and  $\Delta r_t$  are of the same sign, the central bank uses money market intervention to reinforce the effect of a foreign exchange intervention on the exchange rate. In chapter 5 below, it is assumed that a constant part,  $\lambda$ , of the foreign exchange intervention,  $\lambda \Delta r_t$ , is always sterilized with a change in domestic credit  $\Delta d_t^f$  so that the change in the supply of money is determined by  $\Delta m_t^s = \Delta d_t^a + \Delta d_t^f + \Delta r_t$ , in which  $\Delta d_t^f = -\lambda \Delta r_t$ , ie  $\Delta m_t^s = \Delta d_t^a + (1 - \lambda) \Delta r_t$ . The general definitions of unsterilized and sterilized foreign exchange intervention are given in chapter 6 below.

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<sup>13</sup> The exchange rate is expressed as the domestic currency cost of one unit of foreign currency.

<sup>14</sup> The sterilization of foreign exchange interventions is defined and discussed in detail in section 6.3.2 below.

The degree of central bank intervention can be measured as the proportion of exchange market pressure relieved by the central bank.<sup>15</sup> Dividing equation (3.1) by the exchange market pressure gives

$$1 = \frac{\Delta e_t}{\text{EMP}_t} + \frac{\eta^d[\Delta d_t^a + (1 - \lambda)\Delta r_t]}{\text{EMP}_t}, \quad (3.2)$$

in which the second term on the right-hand side measures the proportion of exchange market pressure relieved by the intervention activity of the central bank, ie the degree of intervention and can be expressed as

$$\omega_t = \frac{\eta^d[\Delta d_t^a + (1 - \lambda)\Delta r_t]}{\text{EMP}_t} = \frac{\Delta d_t^a + (1 - \lambda)\Delta r_t}{\Delta d_t^a + (1 - \lambda)\Delta r_t + \frac{1}{\eta^d}\Delta e_t}. \quad (3.3)$$

The degree of intervention in equation (3.3) is related to Frenkel and Aizenman's (1982:235) index of managed float. Frenkel and Aizenman's index is a quantitative measure of the extent to which a currency is allowed to float

$$\omega_t = \frac{\Delta e_t}{\Delta e_t^{\text{float}}}, \quad (3.4)$$

in which  $\Delta e_t$  denotes the observed percentage change in the exchange rate and  $\Delta e_t^{\text{float}}$  denotes the percentage change in the exchange rate which would have occurred if the central bank had allowed the exchange rate to float freely.

Frenkel and Aizenman originally used their index to determine optimal exchange rate management. It has certain desirable properties but also some major operational deficiencies. As discussed by Weymark (1997a:58), it represents various exchange rate regimes as finite numbers, which makes the comparison of relative intensity of intervention activity possible over time, but it is sensitive to the expectations formation process and assumptions about the nature and origin of exogenous disturbances to the economy. The major operational deficiency of the index is that its denominator,  $\Delta e_t^{\text{float}}$ , and hence the value of the whole

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<sup>15</sup> See Weymark (1995:281–282, 1997a:60–61).

index  $\omega_t'$ , cannot generally be observed directly under any exchange rate system other than a pure float.

In addition to having the same desirable properties as the Frenkel and Aizenman (1982) index, the degree of intervention policy in equation (3.3) is highly operational. It is model-dependent because the composition of  $\eta^d$  depends on the specification of a structural model, but it is based on a general model-independent definition of exchange market pressure applicable to any model in which the demand for domestic currency responds contemporaneously to exchange rate changes.

In principle, the intervention index as expressed in equation (3.3) has a range from  $-\infty$  to  $+\infty$ . When the central bank holds the exchange rate fixed,  $\Delta e_t = 0$  and  $\omega_t = 1$ . When the central bank allows the exchange rate to float freely,  $\Delta d_t^d + (1-\lambda)\Delta r_t = 0$  and  $\omega_t = 0$ . Values  $0 < \omega_t < 1$  characterize intermediate intervention policies where the central bank dampens appreciation and depreciation pressures through changes in the monetary base. When  $\omega_t < 0$ , the central bank's operations in the money and foreign exchange markets magnify the exchange rate changes generated by private market forces. At the other extreme, when  $\omega_t > 1$ , the exchange rate is observed to move in the opposite direction to that in the absence of the central bank's intervention.

In what follows, the dirty float exchange rate regime with partly sterilized foreign exchange intervention is considered. It is also assumed that the central bank's domestic monetary policy is completely independent of the demand and supply conditions for the domestic currency in the international foreign exchange market. This means that autonomous money market interventions, ie changes in domestic credit not due to sterilization operations, are not assumed to be an instrument of exchange rate policy. In other words, autonomous money market interventions are executed solely to affect banking sector liquidity, not to affect the exchange rate or remove exchange market pressure. Hence, autonomous changes in domestic credit are exogenous, and the adjusted formula for calculating exchange market pressure is

$$EMP_t = \Delta e_t + \eta(1 - \lambda)\Delta r_t \quad (3.1')$$

and for calculating the degree of intervention policy

$$\omega_t = \frac{\eta(1 - \lambda)\Delta r_t}{EMP_t} = \frac{(1 - \lambda)\Delta r_t}{(1 - \lambda)\Delta r_t + \frac{1}{\eta}\Delta e_t} \quad (3.3')$$



Because the elasticity of the change in the exchange rate with respect to a change in foreign reserves,  $\eta$ , is not directly observable, it must be estimated on the basis of a structural model. Therefore, the summary statistic for international excess demand for the domestic currency is model-specific for any exchange rate policy other than a pure float, where  $\Delta r_t$  equals zero. To continue, a model determining the change in the exchange rate must be specified.

## 4 Models of exchange rate determination

Post war models of exchange rate determination are often interpreted to arise from three basic views of the exchange rate.<sup>16</sup> First, the purchasing power parity theory of exchange rate states that the exchange rate is determined as the relative price of domestic and foreign goods. Second, the monetary theory of exchange rates states that the exchange rate is determined as the relative price of domestic and foreign moneys. Third, the portfolio balance theory of exchange rates states that the exchange rate is determined as the relative price of domestic and foreign bonds. These basic theories and some of their refinements are reviewed below.

### 4.1 Purchasing power parity theory of exchange rates

The purchasing power parity approach to exchange rate determination is one of the oldest and most widely used frameworks for assessing long-term movements of exchange rates. In its simplest form, the PPP theory asserts that in the long run, changes in exchange rates between currencies will tend to reflect changes in relative price levels.<sup>17</sup> The basic building block for any variation of PPP is the so-called 'law of one price', which states that once prices are converted to a common currency, the same good should sell for the same price in different countries, ie

$$P_i = EP_i^* \quad (4.1)$$

where  $P_i$  is the domestic currency price of good  $i$ ,  $P_i^*$  is the foreign currency price, and  $E$  is the exchange rate, defined as the domestic currency cost of one unit of foreign currency. Of course, tariffs, transportation costs, and nontariff barriers drive a wedge between prices in different countries. To provide a broader measure of international price differentials, the absolute version of PPP asserts that the equilibrium

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<sup>16</sup> See Dornbusch (1980: 144–145).

<sup>17</sup> The following is based on Rogoff (1996: 649–651).

exchange rate between two countries' currencies is determined entirely by the ratio of the two countries' national price levels, ie

$$P = EP^* \quad (4.2)$$

where  $P$  and  $P^*$  represent domestic and foreign consumer price indices. The basic idea is that if goods market arbitrage enforces broad parity in prices across a sufficient range of individual goods, then the national aggregate price levels should also be equal, once converted to a common currency. Because price data comes in the form of indices relative to a base year, which means that the magnitude of the absolute PPP deviation for the base year is not known, attention must often be limited to the relative version of PPP, ie

$$\frac{P_t}{P_{t-1}} = \left( \frac{E_t}{E_{t-1}} \right) \frac{P_t^*}{P_{t-1}^*} \quad (4.3)$$

which requires only that the growth rate in the exchange rate offset the differential between growth rates in domestic and foreign price indices.

In practice, because most products are differentiated, consumption baskets (ie national tastes and preferences) are not identical, and transaction costs and impediments to trade can be sizable, the absolute version of PPP surely does not hold exactly. However, the relative version of PPP might still be valid. As long as the factors that lead to deviations from the absolute version of PPP are stable over time, changes in exchange rates may respond to changes in relative prices, when comparisons are made relative to some base period. Results from most studies testing the relative version of PPP<sup>18</sup> suggest that the parity holds in the long run but not in the short run.

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<sup>18</sup> See Froot and Rogoff (1995) and Rogoff (1996).

## 4.2 Balance of payments theory of exchange rates<sup>19</sup>

In its basic formulation, the balance of payments (BOP) model posits that the equilibrium exchange rate is determined when the net inflow (outflow) of foreign exchange arising from current account transactions just matches the net outflow (inflow) of foreign exchange arising from capital account transactions. In other words, changes in the exchange rates are explained by underlying changes in balance of payments flows. Integrating the commercial demand for foreign exchange arising from normal trade flows with the supply of foreign exchange arising from direct or portfolio investments is essential since, in practice, capital account transactions dominate the impact of trade flows on exchange rates in the short and medium run.

In the BOP flow model, the exchange rate change necessary to correct a balance of payment imbalance will depend on the exchange rate elasticities of the supply of and demand for imports and exports. As discussed by eg Gomes (1990: 184–188, 201) and Obstfeld and Rogoff (1996: 53–54), this theorem on the critical value of the sum of demand elasticities in international trade, commonly known as the Marshall-Lerner condition, states that net exports will rise in the short run in response to a depreciation of the domestic currency if the sum of the price elasticities of domestic and foreign import demand exceeds unity.

Different versions of the BOP flow model were widely used in the analysis of devaluation or revaluation in the Bretton Woods fixed exchange rate regime in the 1950s and 1960s. The model by Robert Mundell and Marcus Fleming in particular was widely used in theoretical and empirical studies. The Mundell-Fleming model extends the standard closed-economy Keynesian IS-LM model to incorporate the role of the balance of payments in an open economy. In the model, changes in monetary and fiscal policy promote changes in the exchange rate because policy-induced changes in domestic interest rates and output lead to temporary balance of payments surpluses or deficits, which lead to changes in the exchange rate, which in turn work to restore the balance of payments equilibrium.

As discussed by Rosenberg (1996: 88–89), the BOP flow model of exchange rate determination came under heavy and fundamental criticism in the early 1970s with the rise of the monetary and portfolio balance approaches to exchange rate determination. Advocates of the new

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<sup>19</sup> This chapter owes much to Rosenberg (1996: 68–92).

approaches argued that the equilibrium exchange rate balances the demand and supply of the outstanding stock of financial assets denominated in foreign currencies and not the flows of foreign exchange passing through the exchange market. It was argued that the flow supply and demand are only relevant for determining the equilibrium market price for non-durable goods, while the equilibrium market price for durable goods, such as financial assets, is determined by the stock supply and demand. Hence, the actual volume of domestic and foreign currencies that changes hands in foreign exchange transactions is not relevant for the determination of the equilibrium exchange rate. What is relevant is that, once the exchange rate has changed, the outstanding stock of domestic and foreign currencies is willingly held by the market participants at the new market price.

### 4.3 Monetary theory of exchange rates

Since the monetarist and rational expectations revolution in macroeconomics in the early 1970s, the exchange rate has been more and more viewed as an asset price which depends on the current and expected future values of relative supply of domestic and foreign financial assets, ie monies and bonds, and the relative domestic and foreign income. Monetary models<sup>20</sup> seek to explain how changes in the domestic and foreign supply and demand for money, both directly and indirectly, influence the exchange rate. In contrast to the Keynesian Mundell-Fleming model in which prices are assumed to be fixed in the short run, the monetary model of exchange rate determination is more classical in spirit, in that prices are assumed to be flexible also in the short run.<sup>21</sup>

The essential elements of the monetary theory of exchange rates are best illustrated with a variant of the log-linear Cagan-type flexible price two-country model.<sup>22</sup> The domestic money supply,  $m_t^s$  is assumed to be exogenous and completely controlled by the central bank. The demand for money,  $m_t^d$ , is assumed to depend on price level,  $p_t$ , real income,  $y_t$ , and the level of nominal interest rate,  $i_t$ . The real demand for money

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<sup>20</sup> The principal papers of the original version of the monetary approach are to be found in Frenkel and Johnson (eds.) (1976).

<sup>21</sup> See Rosenberg (1996: 138–140).

<sup>22</sup> See Cagan (1956). The approach below is pioneered by Frenkel (1976) and Bilson (1978) and described concisely in Almekinders (1995: 25–28), on which the model presented below is based. The discussion owes also much to Taylor (1995: 21–22).

varies positively with the level of income and negatively with the level of interest rate. Both the income elasticity,  $\beta_1$ , and interest rate semi-elasticity,  $\beta_2$ , of the demand for money are assumed to be the same in both the domestic and foreign countries. The foreign country is assumed to be identical to the domestic country. With foreign variables denoted by an asterisk and all variables except interest rates expressed in logarithms, monetary equilibria equating supply and demand for money in the domestic and foreign country respectively are given by

$$m_t^s = m_t^d = p_t + \beta_1 y_t - \beta_2 i_t \quad (4.4)$$

$$m_t^{s*} = m_t^{d*} = p_t^* + \beta_1 y_t^* - \beta_2 i_t^* \quad (4.5)$$

It is further assumed that the purchasing power parity

$$e_t = p_t - p_t^* \quad (4.6)$$

and the uncovered interest-rate parity

$$i_t = i_t^* + E_t(e_{t+1}) - e_t \quad (4.7)$$

hold continuously. The notation  $E_t(e_{t+1})$  represents the value that the rational market participants expect the domestic currency to take in period  $t+1$ , conditional on the information available in period  $t$ .

Uncovered interest-rate parity in equation (4.7) means that if the foreign exchange market is efficient and the market participants risk-neutral – and if eg domestic currency is expected to appreciate – the expected foreign exchange gain from holding domestic rather than foreign currency must be exactly offset by the opportunity cost of holding funds in domestic rather than foreign currency. This is to say that, in the flexible-price monetary model, domestic and foreign assets are freely-traded perfect substitutes. Thus, the domestic and foreign bond markets are regarded as a single market, which implies that foreign exchange policy conducted through unsterilized foreign exchange interventions, and monetary policy conducted through money market interventions, cannot be separated. Therefore, if the central bank wants to satisfy some exchange rate objective, eg to keep the exchange rate fixed, domestic monetary policy must be altered consistently with the exchange rate

objective. In this case monetary policy independence is completely lost, resulting in Mundell's (1963) famous 'Holy Trinity' argument: the incompatibility of fixed exchange rate, freedom of capital movement and monetary policy independence.

As noted eg by Taylor (1995: 22), the flexible-price monetary model can be seen as a market-clearing general equilibrium model. An open economy consists of six aggregate markets: goods, labour, domestic money, foreign currency, domestic bonds and foreign bonds. By assuming perfect substitutability of domestic and foreign assets, the domestic and foreign bond markets become a single market so that only five markets remain. By assuming that the perfectly flexible exchange rate clears the foreign currency market, perfectly flexible prices the goods market and perfectly flexible wages the labour market, equilibrium obtains in three of the five markets. Hence, by Walras' law,<sup>23</sup> equilibrium of the full system is determined by equilibrium conditions for the domestic money market, and the bond market need not be modelled separately.

Combining equations (4.4), (4.5), (4.6) and (4.7) results in a stochastic first-order linear difference equation<sup>24</sup>

$$E_t(e_{t+1}) - \left( \frac{1 + \beta_2}{\beta_2} \right) e_t = \left( \frac{-1}{\beta_2} \right) [(m_t^s - m_t^{s*}) - \beta_1(y_t - y_t^*)]. \quad (4.8)$$

Because the system is unstable, it is solved forward. The convergent rational expectations solution for equation (4.8) is

$$e_t = \left( \frac{1}{1 + \beta_2} \right) \sum_{i=0}^{\infty} \left( \frac{\beta_2}{1 + \beta_2} \right)^i E_t[(m_{t+i}^s - m_{t+i}^{s*}) - \beta_1(y_{t+i} - y_{t+i}^*)]. \quad (4.9)$$

Equation (4.9) states that the nominal exchange rate depends on a weighted average of current and expected future values of the relative supply of domestic and foreign monies and the relative domestic and foreign income, with weights that decline geometrically as the future unfolds. According to equation (4.4), an increase in the domestic money

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<sup>23</sup> Equilibrium in  $n-1$  markets of an  $n$ -market system implies equilibrium in the  $n$ -th market.

<sup>24</sup> For solving deterministic and stochastic systems of linear difference equations, see Obstfeld and Rogoff (1996: 726–741).

stock relative to the foreign money stock leads to an instantaneous rise in the domestic price level and, according to the purchasing power parity equation (4.6), to a rise in  $e_t$ , ie to a depreciation of the domestic currency in terms of the foreign currency. An increase in domestic real income relative to foreign real income creates an excess demand for the domestic money stock. To restore equilibrium, the domestic price level, and hence the exchange rate, must change.

The implications of the model can be further characterized as follows. Current and expected domestic and foreign money supplies determine current and expected domestic and foreign price levels and changes in current and expected relative price levels determine changes in the current exchange rate, which implies that current and expected domestic and foreign money supplies determine current changes in the exchange rate. The real variables influence the exchange rate only indirectly through changes in the demand for domestic money. Interest rate differentials between domestic and foreign bonds only reflect expected changes in the future exchange rate and hence in future domestic and foreign money supplies.

Empirical evidence against continuous purchasing power parity led to the development of versions of sticky-price monetary models.<sup>25</sup> Dornbusch (1976) used the Keynesian framework developed by Mundell and Fleming to introduce stickiness of goods prices into a standard flexible-price monetary model. In the Dornbusch's model, goods prices are assumed to adjust in proportion to goods market excess demand until long-run purchasing power parity is restored. Stickiness in goods prices is compensated for by continuously adjusting exchange and interest rates. This means that the exchange rate reacts to an unanticipated monetary shock by overshooting its long-run equilibrium level in the short run.

In the flexible-price monetary model, an increase in the domestic money supply affects the exchange rate directly since purchasing power parity holds at all times. Because domestic prices rise immediately, a nominal increase in the domestic money supply does not translate into a real increase and hence a liquidity-induced decline in domestic interest rate does not take place. As a result, the exchange rate depreciates pro rata to the increase in the domestic money supply. In the sticky-price model a nominal increase in domestic money supply translates into a real increase and a liquidity effect obtains, which leads to temporary overshooting. This reflects the fundamental difference between flexible and sticky-price monetary models. In the flexible-price model, a relative rise in the domestic interest rate is assumed to reflect a rise in the

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<sup>25</sup> The following discussion is based on Rosenberg (1996: 148–151).



domestic price level and, as a result, to lead to a depreciation of the domestic currency, whereas in the sticky-price monetary model, a relative rise in the domestic interest rate is assumed to reflect relative tightening of domestic liquidity, which results in an inflow of capital and an appreciation of the domestic currency.

The most fundamental methodological drawback of the Dornbusch model is its lack of microfoundations, which deprives it of any welfare content by which to evaluate alternative macroeconomic policies.<sup>26</sup> Stockman (1980) and Lucas (1982) were the first to introduce choice-theoretic foundations into the standard flexible-price monetary model in order to be able to analyse the effects of shifts in preferences on the exchange rate.<sup>27</sup> In this equilibrium exchange rate model, relative domestic monetary expansion leads to a depreciation of the domestic currency as in the flexible- and sticky-price monetary models above. The main message of the equilibrium model is that, in addition to the relative money supply, the exchange rate is determined by economic fundamentals, production technology and market participants' preferences.

## 4.4 Portfolio balance theory of exchange rates

At the same time that the monetary theory of exchange rate determination was being developed, an alternative model based on financial portfolio-balance analysis was being developed.<sup>28</sup> McKinnon and Oates (1966) extended the Mundell-Fleming model by replacing the formulation in which capital flows were determined by the flows of foreign exchange passing through the foreign exchange market, by a new, more realistic specification where capital flows are a consequence of adaptations to stocks of financial assets. This means that the necessary condition for equilibrium is that outstanding stocks of national monies and other financial assets is willingly held by the market participants at the equilibrium market price. Furthermore, the central role of wealth variables was recognized; individuals allocate their wealth among domestic and foreign monies and bonds, and money demand depends not

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<sup>26</sup> See Obstfeld and Rogoff (1996: 605).

<sup>27</sup> A concise review of equilibrium exchange rate models can be found in Taylor (1995: 24–26).

<sup>28</sup> The discussion below is based on Gomes (1990: 198–199) and Rosenberg (1996: 186–207).

only on income, but also on wealth and interest rates. Shifts in the international distribution of wealth induced eg by current account imbalances create shifts in relative asset demands. The asset markets are rebalanced with a change in the exchange rate. Therefore, the current account plays a prominent role in exchange rate determination. On the other hand, exchange rate changes affect the trade balance and current account and hence net foreign assets. Thus the portfolio-balance model describes a dynamic feedback mechanism between foreign asset accumulation and exchange rates. The feedback mechanism continues to operate until the current account is in balance and the change in net foreign assets is zero.

In monetary models of exchange rate determination, domestic and foreign bonds are viewed as perfect substitutes, which means that asset holders will be indifferent as to the currency composition of their international bond portfolios. Under such conditions, domestic and foreign currency bonds may be aggregated into a single asset, no shifts in relative bond supplies or shifts in asset preferences among global investors can take place, and the bond market will not have any role in determination of the exchange rate. Empirical literature, however, has generated increasingly strong evidence against the perfect substitutability of domestic and foreign currency bonds.<sup>29</sup> In portfolio-balance models domestic and foreign currency bonds are viewed as imperfect substitutes having different risks and returns. This means that there is a risk premium separating expected depreciation and the domestic-foreign interest rate differential, ie uncovered interest rate parity as in equation (4.7) above does not hold

$$(\text{risk premium})_t = i_t - i_t^* - E_t(e_{t+1} - e_t). \quad (4.10)$$

Being risk averse, global investors will wish to hold a diversified portfolio of domestic and foreign currency bonds and allocate investments according to the expected return and relative riskiness of each asset. Such portfolio balancing can result in significant changes in the exchange rate.

As an illustrative example, a simple model is considered in which the net financial wealth of the private sector,  $W_t$ , is divided into money,  $M_t$ , domestic bonds,  $B_t$ , and foreign bonds denominated in foreign currency

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<sup>29</sup> For a survey of the empirical literature see Frankel (1988), Taylor (1995: 14–21), Lewis (1995).

and held by domestic residents,  $B_t^*$ .<sup>30</sup> Asset demands in equations (4.12)–(4.14) are defined as functions of the excess return offered by bonds and of wealth, which is also the scale variable. Because, under a free float, a current account surplus on the balance of payments is exactly matched by a capital account deficit, the current account gives the rate of accumulation of foreign currency bonds held by domestic residents. The current account in equation (4.15) equals the sum of the trade balance,  $T_t$ , and net debt service receipts,  $i_t^*B_t^*$ .

$$W_t = M_t + B_t + e_t B_t^* \quad (4.11)$$

$$M_t = m[i_t - i_t^* - E_t(e_{t+1}) + e_t]W_t, \quad m_i < 0, \quad m_{i^*} < 0 \quad (4.12)$$

$$B_t = b[i_t - i_t^* - E_t(e_{t+1}) + e_t]W_t, \quad b_i > 0, \quad b_{i^*} < 0 \quad (4.13)$$

$$e_t B_t^* = b^*[i_t - i_t^* - E_t(e_{t+1}) + e_t]W_t, \quad b_i^* < 0, \quad b_{i^*}^* > 0 \quad (4.14)$$

$$B_t^* - B_{t-1}^* = T_t + i_t^* B_t^* \quad (4.15)$$

$$T_t = t \begin{bmatrix} e_t \\ p_t \end{bmatrix}, \quad t_{\frac{e}{p}} > 0, \quad (4.16)$$

Next, an increase in the money supply is considered that is conducted through an open market purchase of domestic currency bonds and paid for by printing money. In order to induce agents to hold more money and fewer bonds, the domestic interest rate falls and, as market participants attempt to compensate for the reduction in their portfolios of domestic interest-bearing assets by buying foreign currency bonds, the exchange rate depreciates, driving up the domestic currency value of foreign bonds. Assuming that the economy was initially in equilibrium with zero trade balance and zero current account and, according to equation (4.16), that

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<sup>30</sup> A comprehensive treatment of the portfolio-balance model is given in Branson and Henderson (1985). This example is described in greater detail in Taylor (1995: 27–28).

the Marshall-Lerner condition holds,<sup>31</sup> an improvement in competitiveness improves the trade balance. This means that the current account goes into surplus and domestic residents begin to acquire net foreign assets.

To rebalance their portfolios, domestic residents attempt to sell some of their foreign assets. As a result, the exchange rate begins to appreciate and, due to the erosion of competitiveness, the trade balance begins to deteriorate. Meanwhile, the increase in the supply of money has begun to raise prices, adding to the deterioration of competitiveness and the trade balance. At some point, the trade balance must be back at zero. Because domestic residents have acquired a positive level of net foreign assets and are receiving a stream of interest income from abroad, the zero trade balance is no longer enough to restore long-run equilibrium in the exchange rate. In order for the current account balance to be zero, the trade balance must actually go into deficit. This requires a further appreciation of the exchange rate. The exchange rate will reach its long-run equilibrium level when the current account is just balanced so that there is no further net accumulation of foreign assets. The overall effect on the exchange rate of the increase in money supply with an open market purchase of domestic currency bonds is a long-run depreciation of the domestic currency, with an initial overshoot.

In contrast to monetary models of exchange rate determination, where the exchange rate is a purely monetary phenomenon, non-monetary assets and the goods market play significant roles in determining the equilibrium exchange rate in portfolio-balance models. Current account balances, ie the net rate of foreign asset accumulation, and the exchange rate are intertemporally related because of the two-way interaction between goods and asset markets. Thus a current account surplus (deficits) is associated with a domestic currency appreciation (depreciation), which tends to eliminate the surplus (deficit). This means that in the long-run exchange rate determination is a macroeconomic problem involving the interaction of goods and asset markets.

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<sup>31</sup> For the Marshall-Lerner condition, see the discussion under the balance of payments theory of exchange rates above.

## 4.5 Some recent developments

The bulk of empirical evidence starting with Meese and Rogoff (1983) shows that none of the theories identified above can satisfactorily explain observed exchange rate developments, including large short-run volatility, persistent departures from the purchasing power parity, large and persistent real exchange rate misalignments, speculative bubbles and immediate over-reactions to exogenous and policy induced news. However, this does not imply that none of these can be relevant for the understanding of particular phases of reality. In the 1980s, matters of considerable policy interest, such as the effects of uncoordinated national monetary and fiscal policies on national output, the real exchange rate and the current account in open economies, led to renewed interest in the extended Mundell-Fleming model as a general framework for modelling the exchange rates.

In the 1990s, the contradiction between the traditional macroeconomic approach to exchange rate determination and reality led to a growing interest in the market microstructure. According to the micro-foundations approach to exchange rate determination, a more realistic description of the foreign exchange market microstructure, obtained eg by relaxing the assumption on identical agents, perfect information or costless trading, and identifying the economic effects of the organization of foreign exchange market, might help sort out some of the empirical problems of the standard macroeconomic exchange rate models. According to Frankel and Rose (1995), however, the research on foreign exchange market microstructure is newborn and it will take a while before it can claim to produce a model of exchange rate determination.<sup>32</sup>

In his near-rationality model, De Grauwe (1989) suggests that, in a highly uncertain economic environment, it is not necessarily profitable for market participants to use all available information on economic fundamentals and take positions accordingly. In other words, as noted by Almekinders (1995: 56), when the future path of the exchange rate is highly uncertain, market participants who normally implement fundamental analysis can at times rely on technical analysis. The way in which markets participants form their expectations of the future path of the exchange rate is of fundamental importance since it affects significantly the way in which the exchange rate is actually determined in the market.

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<sup>32</sup> For a selected introduction to the field of microstructural research, see Frankel and Rose (1995) and Frankel, Galli and Giovannini (1996).

## 4.6 The role of foreign exchange intervention in exchange rate models

Whether unsterilized or sterilized foreign exchange intervention of the central bank plays any role in exchange rate determination is an important question when the effects and effectiveness of foreign exchange policy are studied in the context of structural exchange rate models. From the above discussion it is clear that unsterilized foreign exchange intervention should lead to an instantaneous change in the exchange rate, both in flexible- and sticky-price monetary models and in portfolio balance models. It is also clear that a sterilized foreign exchange intervention which leaves the domestic money supply unchanged should have no direct effect on the exchange rate in flexible- or sticky-price monetary models. In portfolio balance models, however, even sterilized foreign exchange intervention can be effective.

In portfolio balance models of exchange rate determination, a sterilized purchase of foreign currency bonds by the domestic central bank creates an excess demand for foreign currency bonds and an excess supply of domestic currency bonds. To encourage market participants to hold the increased supply of domestic currency bonds, they must be compensated by a higher expected return. To increase the demand for domestic currency bonds, their price must decline in relation to the price of foreign currency bonds, i.e. the domestic interest rate must rise, domestic currency must depreciate or the foreign interest rate must fall, given that exchange rate expectations are fixed in the short run. Since sterilized intervention leaves the money supply and thus the domestic and foreign interest rate unchanged, the current exchange rate must change; a sterilized purchase of foreign currency bonds by the domestic central bank should lead to an immediate depreciation of the domestic currency.

Furthermore, sterilized and unsterilized foreign exchange interventions and even statements given by central bank officials could have an effect on market participants' exchange rate expectations. If market participants believe that a central bank uses foreign exchange interventions or official statements to signal the future course of monetary policy, a foreign exchange intervention or official statement can alter market participants' expectations of the future domestic money supply, the  $m_{t+i}$ 's with  $i \geq 1$ , and the future exchange rate and, according to equation (4.9), the current exchange rate. For example, a sterilized purchase of foreign bonds from the domestic private sector may be interpreted as signalling an expansionary future monetary policy, which,

according to equation (4.9), will make the domestic currency depreciate immediately. Thus, the signal magnifies the direct effect on the exchange rate, even though the money market effect of the initial intervention is neutralized in the short run.

This signalling hypothesis was first proposed by Mussa (1981). If it works, the central bank can affect exchange rates by providing the market with relevant information that was not previously known or incorporated in current exchange rates – given, of course, that the central bank has superior information compared to other market participants and that it is willing to reveal this information through an official statement or a foreign exchange intervention. According to Obstfeld (1996: 770), it should be emphasized that an official statement or a sterilized foreign exchange intervention is not a macroeconomic policy instrument in the same sense as monetary and fiscal policies if it affects exchange rates only through the signal it sends. It derives its power entirely from its ability to influence market perceptions or expectations about other economic factors in a time-consistent way. If a central bank does not have a good idea of its own policy intentions, or fails to make possibly uncomfortable policy adjustment signalled earlier by foreign exchange interventions, the expectations of market participants will not be fulfilled and the signalling channel will become ineffective.

As argued by Hung (1991a, 1991b), the presence of non-fundamentalist noise traders whose trading behaviour is more or less predictable, ie who do not use any structural model based on economic fundamentals as a yardstick when they make forecasts and take positions, can constitute a channel through which foreign exchange policies can be transmitted effectively even when sterilized foreign exchange intervention is used. Noise traders may be chartist-oriented investors who rely on analyses of past price patterns to predict the future direction of exchange rate movements or speculators who take positions on the basis of news and rumours. The idea is to exploit the trend-following behaviour of noise traders by intervening unexpectedly on technically overbought or oversold markets on which short-run noise traders have already begun to question whether they have taken exchange rates too far from their long-run equilibrium levels. By giving the noise traders a sign or an excuse to reverse their position at a time when they are looking for such, the central bank may be able to reverse the present trend of the exchange rate.

According to Rosenberg (1996: 313), the noise trading approach to exchange rate determination differs from the signaling approach described above in that the central bank does not use foreign exchange intervention as a signal of its policy intentions. Instead, the central bank attempts to force investors to cover their existing positions and to take

new positions, betting on a trend reversal. In practice, in order to be able to use noise traders in the transmission of foreign exchange policy, the central bank needs to be able to beat noise traders at their own game in interpreting market sentiment.

In the next chapter, in which model-consistent measures of exchange market pressure and the degree of central bank's intervention policy are derived, an empirically oriented version of a monetary model is used and an empirically reasonable assumption of incomplete sterilization of foreign exchange interventions is adopted. This means that in the analysis below foreign exchange interventions have an important role in exchange rate determination and hence the empirical measure of exchange market pressure can be formed by using data on exchange rates and foreign exchange interventions.

## 4.7 Empirical evidence on the models of exchange rate determination and on the effectiveness of central bank intervention

There is a large number of studies that have sought to test the relevance of monetary, portfolio-balance, signaling and noise trading models of exchange rate determination. In this context, numerous investigations have been conducted to assess whether central bank foreign exchange interventions have statistically significant and quantitatively important impacts on the exchange rate. In what follows, results from this literature are briefly summarized. For the most part, the presentation is based on the surveys of Edison (1993: 14–36), Almekinders (1995: 61–93), Taylor (1995: 28–37), and Rosenberg (1996: 276–323), to which an interested reader can turn for a comprehensive summary of individual studies.

Some of the early studies<sup>33</sup> broadly support the flexible-price monetary model. Since the late 1970s, however, the flexible- as well as sticky-price monetary models have ceased to explain variations in exchange rate data, although MacDonald and Taylor (1993) find some evidence to support the monetary model as a long-run equilibrium toward which the exchange rate converges.

Because of a set of necessary simplifying assumptions, such as uniform preferences or a specific utility function which no one would expect to hold exactly in the real world, equilibrium and liquidity models are not amenable to direct econometric testing. Although the empirical

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<sup>33</sup> Bilson (1978), Dornbusch (1979).



evidence rejects the simplest equilibrium models, Taylor (1995: 32) states that the empirical (in)validity of the whole class of equilibrium or liquidity models cannot be firmly verified.

Results from most studies that directly test the structural asset-demand equations of a portfolio-balance model have also been poor. Many of the coefficients have either wrong signs or are statistically insignificant. Another way to test the portfolio-balance model is to invert the asset-demand functions and test the existence of a risk premium. A nonzero risk premium that responds systematically to changes in relative domestic and foreign bond supplies would imply that domestic and foreign bonds are imperfect substitutes. The problems are the data limitations and the fact that only the joint hypothesis on perfectly substitutable assets and rational expectations can be tested. This means that, if expectations are not rational, the portfolio-balance model will be accepted even if domestic and foreign bonds are perfect substitutes. Also results from these studies are poor: in most studies risk premiums either do not differ statistically from zero or are short-lived and small in absolute magnitude.

This suggests that sterilized intervention does not have any long-run effect on the exchange rate and hence does not constitute an independent tool of monetary policy. The most obvious reason for this result is that the volume of foreign exchange intervention is generally too small relative to the total outstanding stock of domestic and foreign bonds to exert a marked influence on relative bond supply. Furthermore, even if a change in relative bond supply could be verified to affect a risk premium, it is not clear that a change in a risk premium would result in a one-for-one change in current exchange rate. A change in a risk premium could as well result in a change in the domestic or foreign interest rate or in the expected exchange rate.

Although no common model exists among studies examining the signalling channel, two general approaches seem to appear in the literature: to examine the signalling effect on exchange rate expectations in the context of a portfolio-balance model, or to examine whether foreign exchange intervention actually signals a change in monetary policy and hence in the expected exchange rate. Most of the empirical evidence suggests that foreign exchange intervention can temporarily affect the exchange rate through the signalling channel. It is not clear, however, whether the statistically significant effect reflects the impact of foreign exchange intervention on expectations as to monetary policy or as to other policy decisions.

The extra-effectiveness of coordinated foreign exchange intervention is also investigated in the signalling channel context. It would seem

reasonable to expect that coordinated foreign exchange intervention by a number of central banks could be more effective than unilateral intervention by a single central bank. As Rosenberg (1996: 287) points out, a joint intervention effort will enhance the credibility of signals by demonstrating to the market that there is a unanimous view on the equilibrium level of an exchange rate as well as a common policy resolve to deal with an undesirable change in the exchange rate. According to Edison (1995: 35–36), however, the results are rather mixed. This indicates that whether or not market participants pay attention to the interventions may also depend on the availability of other news. Furthermore, statements of politicians and monetary authorities which accompany the unilateral or coordinated intervention can lead to or detract from its effectiveness. A related issue is to test the relevance of economic fundamentals for exchange rate determination by examining how news about fundamentals is related to unexpected exchange rate movements. Tests seem to support the news effect, indicating the importance of fundamentals in explaining exchange rate movements.<sup>34</sup>

Evidence for the existence of a quantifiably important noise trading channel is presented by Hung (1991a, 1991b). Her findings suggest that effectiveness of sterilized foreign exchange intervention depends critically on market conditions and intervention strategy. She argues that highly visible interventions conducted via the interbank market could give the clearest and most effective signal to market participants.

In sum, finding statistical support for empirical exchange rate models which would link macroeconomic variables to the exchange rate is difficult. As far as the instruments of foreign exchange policy are concerned, unsterilized foreign exchange intervention – as monetary policy in general – is generally assumed to have significant effects on the exchange rate but the evidence on the effectiveness of sterilized foreign exchange intervention is unclear. Although some studies find a significant signalling channel and episodes of successful intervention can be found, other studies suggest that there is no systematic and quantifiably important relationship between sterilized foreign exchange intervention and the exchange rate. The subject is still under dispute.

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<sup>34</sup> See Frankel and Rose (1995) for a recent survey of work on news and foreign exchange markets.

## 5 Model-consistent measures of exchange market pressure and the degree of central bank intervention

In this chapter, the model-consistent measures of exchange market pressure and the degree of central bank intervention are derived. The general idea in deriving model-consistent indices was discussed in chapter 3 above. In principle the general definition of exchange market pressure is applicable to any model in which foreign exchange market intervention has a direct and contemporaneous effect on at least one domestic market through its effect on the exchange rate. Therefore, depending on the assumptions made, various monetary, equilibrium, liquidity, portfolio-balance, signalling or noise-trading models could be used. Here the measures are derived by using an empirically implemented version of a standard small open-economy monetary model with rational expectations, in which monetary policy is conducted through changes in monetary base and foreign exchange interventions are partly sterilized. The simple model was chosen in order to highlight the essential aspects of the methodology.

The model is summarized in equations (5.1)–(5.7). Foreign variables are denoted by asterisks and all variables except interest rates are expressed in logarithms.  $\Delta$  is the difference operator.

$$\Delta m_t^d = \beta_0 + \Delta p_t + \beta_1 \Delta c_t - \beta_2 \Delta i_t \quad (5.1)$$

$$\Delta p_t = \alpha_0 + \alpha_1 \Delta p_t^* + \alpha_2 \Delta e_t \quad (5.2)$$

$$\Delta i_t = \Delta i_t^* + E_t(\Delta e_{t+1}) - \Delta e_t \quad (5.3)$$

$$\Delta m_t^s = \Delta d_t^a + (1-\lambda)\Delta r_t \quad (5.4)$$

$$\Delta r_t = -\rho_t \Delta e_t \quad (5.5)$$

$$\Delta d_t^a = \gamma_0 + \Delta y_t^{\text{trend}} + (1 - \gamma_1) \Delta p_t - \gamma_2 y_t^{\text{gap}} \quad (5.6)$$

$$\Delta m_t^d = \Delta m_t^s \quad (5.7)$$

The variables and parameters are defined as follows

$$y_t^{\text{gap}} = y_t - y_t^{\text{trend}}, \quad (5.8)$$

$$\Delta m_t^s \approx \frac{\kappa(D_t + R_t) - \kappa(D_{t-1} + R_{t-1})}{\kappa(D_{t-1} + R_{t-1})},$$

$$\Delta D_t = \Delta D_t^a + \Delta D_t^f, \quad (5.9)$$

$$\Delta D_t^f = -\lambda \Delta R_t,$$

$$B_t = D_t + R_t,$$

that is

$$\begin{aligned} \Delta m_t^s &= \frac{\Delta B_t}{B_{t-1}} \approx \frac{\Delta D_t^a - \lambda \Delta R_t + \Delta R_t}{B_{t-1}} \\ &= \frac{\Delta D_t^a}{B_{t-1}} + (1 - \lambda) \frac{\Delta R_t}{B_{t-1}} \\ &= \Delta d_t^a + (1 - \lambda) \Delta r_t, \end{aligned} \quad (5.10)$$

$m_t$  = money stock, with s and d denoting supply and demand

$p_t$  = domestic price level

$c_t$  = real domestic income<sup>35</sup>

$y_t$  = real domestic output<sup>36</sup>

$y_t^{\text{trend}}$  = long-term trend component of real domestic output

$i_t$  = domestic short-term interest rate level

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<sup>35</sup> For the definition of  $c_t$ , see appendix.

<sup>36</sup> For the definition of  $y_t$ , see appendix.

$e_t$  = exchange rate expressed as domestic currency per unit of foreign currency

$D_t$  = stock of domestic credit

$\Delta D_t^a$  = autonomous change in domestic credit

$\Delta D_t^f$  = sterilizing change in domestic credit

$R_t$  = stock of foreign exchange reserves

$B_t$  = monetary base

$M_t = \kappa B_t$  = money stock

$\kappa$  = constant money multiplier

$\lambda$  = central bank's sterilization coefficient

$\rho_t$  = central bank's time-variant exchange rate policy response coefficient

$\alpha_1$  = foreign price elasticity of domestic price level

$\alpha_2$  = exchange rate elasticity of domestic price level

$\beta_1$  = income elasticity of the demand for money

$\beta_2$  = interest rate semi-elasticity of the demand for money

$\gamma_1$  = central bank's monetary policy response coefficient for inflation

$\gamma_2$  = central bank's monetary policy response coefficient for output gap

The model is a variant of the log-linear Cagan model. Market participants are assumed to form expectations rationally. The contemporaneous changes in the exchange rate, the values of all past endogenous and exogenous variables, and the structure of the model are assumed to be common knowledge to all market participants. The central bank conducts its foreign exchange and monetary policies through interventions in the foreign exchange and domestic money markets respectively.

According to equation (5.1), the change in real domestic demand for money is assumed to vary positively with the change in domestic income and negatively with the change in the domestic interest rate. Changes in domestic output and foreign prices are taken as exogenous. Domestic inflation in equation (5.2) is assumed to be influenced by foreign inflation and changes in the exchange rate. Relative purchasing power parity holds if  $\alpha_0$  is restricted to equal zero and  $\alpha_1$  and  $\alpha_2$  to equal unity.

Uncovered interest rate parity in equation (5.3) is assumed to hold, ie financial markets are assumed to be well-developed and efficient, market participants risk-neutral, and domestic and foreign bonds perfect substitutes. The notation  $E_t(\Delta e_{t+1})$  represents the expected value of the change in the exchange rate in period  $t+1$ , conditional on the information available in period  $t$ . To avoid currency substitution, domestic residents are assumed to hold domestic currency for transaction purposes and domestic and foreign bonds for speculation.

According to equation (5.9), the money supply is a multiple of the monetary base, which is assumed to be completely controlled by the

central bank. Monetary base is composed of domestic credit and foreign exchange reserves, which are held in foreign bonds. To prevent any change in the money multiplier from strengthening or dampening the effect of money market and foreign exchange intervention on money market liquidity or the exchange rate and hence on the measure of exchange market pressure, the money multiplier is assumed to be constant. In the extreme case, the change in money multiplier could change the sign of the measure of exchange market pressure. If the money multiplier were to increase sufficiently, money market liquidity would increase and strengthen the depreciation pressure on the domestic currency even if the central bank has been selling foreign bonds in order to reduce money market liquidity and dampen the depreciation pressure.

In this model, the central bank uses changes in the banks' liquidity position, ie their net debt to the central bank,  $\Delta D_t$ , to conduct monetary policy and sterilize foreign exchange interventions. Foreign exchange policy is conducted through foreign exchange interventions, ie changes in foreign reserves,  $\Delta R_t$ . This means that changes in the monetary base and, as money multiplier is assumed to be constant, in the money supply are determined by autonomous changes in domestic credit,  $\Delta D_t^a$ , and the unsterilized part of foreign exchange intervention,  $(1-\lambda)\Delta R_t$ , as stated in equations (5.4) and (5.10). The idea behind this distinction is to separate the conduct of monetary policy from foreign exchange policy. In other words, it is assumed that the exchange rate could be included in the set of immediate or intermediate targets of monetary policy but that decisions to either tighten or loosen the stance of monetary policy are separate from decisions to intervene in the foreign exchange markets and then partially sterilize the intervention. This means that the central bank is assumed to use autonomous changes in domestic credit to affect overall economic developments and the unsterilized part of foreign exchange intervention only to dampen major fluctuations in the exchange rate.<sup>37</sup> Overall, this assumption follows Mundell's (1963) famous 'Holy Trinity' argument, which states that the floating exchange rate is the precondition of independent monetary policy when international capital movements are free.

According to Taylor (1998: 2), a monetary policy rule of the central bank can be defined as a description of how the instruments of policy, such as the monetary base or short-term interest rate, change in response to economic variables. A policy rule can be normative or descriptive and

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<sup>37</sup> According to Aaltonen, Aurikko and Kontulainen (1994: 54), although no target had been set (by definition) for the value of the markka in the context of the floating exchange rate system, the Bank of Finland sought to influence exchange rates through foreign exchange intervention, aiming to dampen major fluctuations in exchange rates.

an outcome of many different institutional arrangements for monetary policy. The rule employed in this model is determined by equation (5.6). The reasoning behind it can be easily seen from the following non-reduced form:

$$\Delta d_t^a = \Delta p_t + \Delta y_t^{\text{trend}} - \gamma_1(\Delta p_t - \Delta p^{\text{target}}) - \gamma_2(y_t - y_t^{\text{trend}}). \quad (5.6')$$

The central bank is assumed to increase bank liquidity as the domestic economy grows and prices rise. This positive relationship derives from the equation of exchange:

$$\kappa B_t v = P_t Y_t. \quad (5.11)$$

According to the equation of exchange, the growth of nominal output determines the growth of base money, as long as the money multiplier,  $\kappa$ , and the velocity of money,  $v$ , are constants. The anchor for a monetary policy could be formulated according to the equation of exchange alone if monetary and credit aggregates were used as intermediate targets of monetary policy. In that case, assuming again that the money multiplier and the velocity of money are constants, the growth rate of base money or the central bank's domestic lending,  $\Delta d_t^a$ , would be the sum of the inflation target,  $\Delta p_t^{\text{target}}$ , and the trend growth rate of real output,  $\Delta y_t^{\text{trend}}$ . According to Aaltonen, Aurikko and Kontulainen (1994: 55–56), however, monetary policy based solely on control of the monetary base, the central bank's domestic lending or some measure of bank reserves is problematic. They also list various reasons for which the Bank of Finland has had no publicly set growth targets for the supply of money or credit. Even in countries where monetary aggregates are official intermediate objectives, central banks do not calibrate monetary policy on the basis of the money supply itself. Therefore, in the model employed here, the equation of exchange part of the monetary policy rule in equation (5.6') represents only the banking system's and the public's demand for money, which the central bank must simply accommodate by providing sufficient liquidity.

In addition to simply accommodating the demand for money, the central bank is assumed to try to directly influence economic activity and the demand for money by setting targets for inflation and real growth and reacting to deviations from those targets. If actual inflation is higher than the target or the actual level of real output above its long-term non-

inflationary trend, bank liquidity is squeezed. Response coefficients  $\gamma_1$  and  $\gamma_2$  determine how strongly the central bank reacts to these deviations.

This active part of the monetary policy is similar to the following interest rate rule introduced by Taylor (1993),<sup>38</sup>

$$i_t - \Delta p_t = 1 + 0.5\Delta p_t + 0.5y_t^{\text{gap}} \quad (5.12)$$

in which the monetary policy instrument is the short-term money market interest rate most closely related to the interest rate that the central bank either targets, such as the federal funds rate in the United States, or adjusts in response to the state of the economy and uses in providing the banking sector with liquidity, such as tender rate in Finland. In contrast to equation (5.6'), the Taylor rule determines the stance of monetary policy through the short-term interest rate and not through changes in monetary base or the central bank's domestic lending. However, substituting changes in the monetary base for the short-term interest rate in the Taylor rule simply means that the signs and magnitudes of the response coefficients are changed; the central bank reacts to an increase in inflation and output gap by higher interest rates or lower money supply.

The rule or autonomous change in domestic credit presented in equation (5.6') also resembles the rule introduced by McCallum (1984):

$$\Delta b_t = \gamma_0 - \gamma_1 (p_{t-1} - p_{t-1}^{\text{target}} + y_{t-1} - y_{t-1}^{\text{target}}) \quad (5.13)$$

where  $\gamma_0$  on the right hand side is the prespecified growth rate of nominal output, which is equal to the economy's prevailing long-term average growth rate of real output. This means that keeping the growth of nominal output at the prespecified value should yield approximately zero inflation over any extended period. The block in parentheses is the deviation of the level of nominal output from its target path. The basic rule has been slightly revised in McCallum (1987) but the basic idea still is<sup>39</sup> that, since economists do not understand how changes in nominal demand are divided between inflation and growth of real output, the most useful thing that monetary policy can accomplish is to keep nominal demand growing smoothly at a noninflationary rate.

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<sup>38</sup> For a broader discussion of monetary policy rules, see eg McCallum (1997) or Taylor (1998).

<sup>39</sup> McCallum (1987: 17).



As can be seen from equation (5.6), the operating instrument of monetary policy is the change in the central bank's autonomous domestic lending,  $\Delta d_t^a$ . However, as mentioned before, almost all central banks in fact try to influence economic activity and the demand for money by using a short-term interest rate as an operational instrument. According to McCallum (1997: 33), this is due to the observation that targeting monetary base and using it as an operational instrument tends to entail more variability in short-term interest rates, which is considered harmful. Another weakness is introduced by the long-term trend component of real domestic output,  $y_t^{\text{trend}}$ . McCallum (1997: 24) argues that since there is no widely accepted and conceptually sound measure for the long-term trend component, output gap and hence the response coefficient  $\gamma_2$ , the change in domestic income, and the whole rule are rather sensitive to the particular measure adopted. In spite of this criticism, using the central bank's autonomous domestic lending as an operational instrument and a hybrid variable that sums inflation and the real output gap as a target is a standard procedure in the academic literature.<sup>40</sup> The central bank's domestic lending policy reaction functions including both autonomous lending,  $\Delta d_t^a$ , and the part of foreign exchange intervention which is left unsterilized,  $(1-\lambda)\Delta r_t$ , have also been successfully estimated in several studies.<sup>41</sup>

To have an alternative monetary policy rule for testing the robustness of the parameter estimates, the following more simple rule is used:

$$\Delta d_t^a = -\gamma_1 (\Delta p_t - \Delta p^{\text{target}}) \quad (5.6'')$$

in which the central bank is assumed to try to influence economic activity and the demand for money by only setting a target for inflation and reacting to deviations from that target. There are at least three reasons for leaving out the equation of exchange and the target for real growth. First, it is not obvious that the central bank has an explicit real growth target. For example, in February 1993, in order to formulate an anchor for the monetary policy, the Bank of Finland publicly announced an inflation target the aim of which was to permanently stabilize the inflation rate, as measured by the indicator of underlying inflation, at the two per cent level by 1995. However, it has not set any explicit real growth target. Instead, the Bank of Finland has emphasized that the best way of securing stable growth for the Finnish economy is to keep actual and

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<sup>40</sup> See McCallum (1997: 14).

<sup>41</sup> See Kajanoja (1998b). For a short review of other studies, see Edison (1993: 40–41).

expected inflation at the targeted two per cent level. Therefore, it can be assumed that real growth plays no explicit role in the Bank of Finland's monetary policy reaction function.

Second, there is also a more operational reason for leaving out the real growth variable: credible data on current output growth are available only after a considerable lag, which means that any view of the current output growth must be based on a combination of various early indicators. Hence, even if the central bank had some kind of real growth target, it is hard to find any one variable which would sum up the available information on the output growth and which could be included in the central bank's reaction function.

Third, the equation of exchange (5.11) is a long run relationship whereas this study focuses on short run reactions of the central bank to current money market disequilibrium. However, the practical problem is that the frequency of the data used here (monthly) is probably too low to catch the true short-run effects of the current money market disequilibrium. Keeping the above reasoning in mind, both the restricted equation (5.6'') and the unrestricted equation (5.6') are included as alternatives in the model when the measures of exchange market pressure and degree of central bank foreign exchange intervention are solved analytically and the model is estimated in later chapters.

The central bank is assumed to react to a change in the exchange rate with a partly sterilized purchase or sale of foreign exchange reserves.<sup>42</sup> The introduction of sterilization into the model is reasonable because in practice central banks generally offset the liquidity effect of a foreign exchange intervention with a domestic money market operation.<sup>43</sup> In United States<sup>44</sup> the Federal Reserve sterilizes liquidity effects regularly and completely so that foreign exchange interventions do not lead to changes in the domestic money market and hence in domestic interest rates that differ from those that would have occur absent foreign exchange intervention. This is generally the case in Finland also,<sup>45</sup> which suggests that the sterilization coefficient,  $\lambda$ , should equal one and, according to equations (5.4) and (5.10), that foreign exchange intervention has absolutely no role in the model or in the measure of

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<sup>42</sup> When  $\Delta e_t$  is positive (negative) domestic currency depreciates (appreciates) and when  $\Delta r_t$  is negative (positive) the central bank sells (purchases) foreign bonds.

<sup>43</sup> The sterilization of foreign exchange interventions is defined and discussed in detail in section 6.3.2 below.

<sup>44</sup> See eg The Federal Reserve System: Purposes and Functions (1994: 64).

<sup>45</sup> See eg Aaltonen, Aurikko and Kontulainen (1994: 81).

exchange market pressure. However, because in practice central banks do intervene in the foreign exchange market, it is natural to assume that even sterilized foreign exchange intervention has at least a short-lived effect on the exchange rate, eg through the portfolio or signalling channel. In our model this means that the sterilization coefficient should be less than unity and that foreign exchange intervention plays an important role in the measure of exchange market pressure.

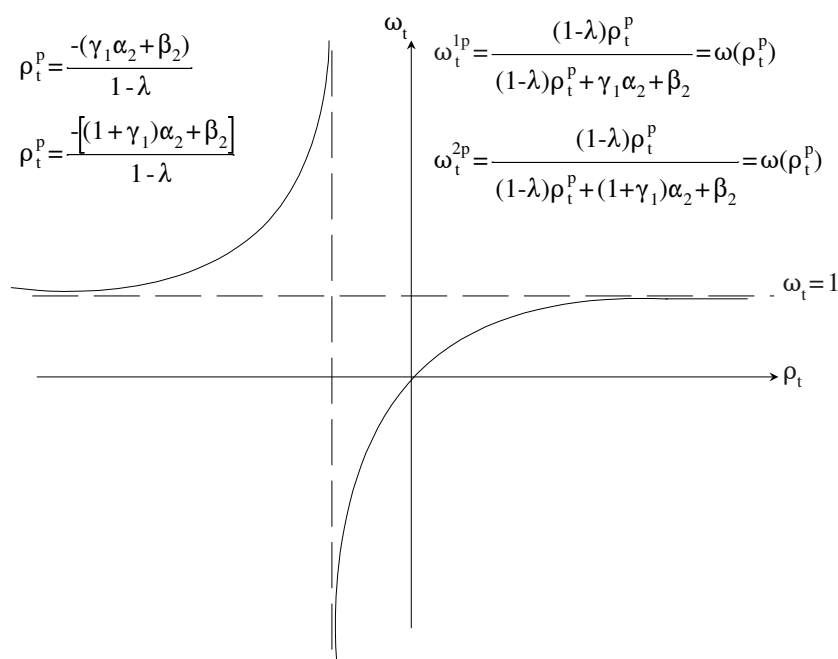
According to equation (5.5), foreign exchange reserves change as a result of the central bank's response to an observed contemporaneous change in the exchange rate. A time-varying response coefficient,  $\rho_t$ , characterizes exchange rate policy in each period. The central bank is assumed to react to the appreciation of domestic currency (negative  $\Delta e_t$ ) by purchasing foreign bonds (positive  $\Delta r_t$ ) and to the depreciation of domestic currency (positive  $\Delta e_t$ ) by selling foreign bonds (negative  $\Delta r_t$ ), so that the response coefficient,  $\rho_t$ , should be zero or positive in equation (5.5). Actually, one reason for having a time-varying response coefficient is that in practice the central bank sometimes reacts to a change in the exchange rate and sometimes does not, ie it does not intervene even though the exchange rate changes. Moreover, in actual intervention data, the response coefficient is sometimes observed to have a 'wrong' sign. This would suggest that the central bank had leaned with the wind in the foreign exchange market by selling foreign bonds (negative  $\Delta r_t$ ) when the domestic currency was already appreciating (negative  $\Delta e_t$ ) or by purchasing foreign bonds (positive  $\Delta r_t$ ) when the domestic currency was already depreciating (positive  $\Delta e_t$ ). Interventions in the 'wrong' direction can be observed in aggregated data when the central bank reacts more strongly to pressure in the one direction than to pressure in the other during the aggregation period. Each individual operation could still be in the 'right' direction, ie dampening fluctuations in the exchange rate. In this case, however, the central bank has clearly set at least a trend target for the exchange rate and the exchange rate regime can indeed be considered a dirty one. Of course, another possibility is that the central bank does not always observe the direction of exchange market pressure and makes a mistake.

The relationship  $\omega_t = \omega(\rho_t)$  between the intervention index  $\omega_t$  and the response coefficient  $\rho_t$  from equation (5.27) below is illustrated in figure 1. When  $\rho_t = \infty$ , the central bank uses foreign exchange intervention to hold the exchange rate fixed, ie  $\omega_t = 1$ . When  $\rho_t = 0$ , the central bank allows the exchange rate to float freely, so that  $\omega_t = 0$ ; there are no foreign exchange interventions and hence no changes in the domestic money supply due to foreign exchange interventions. In this case, any existing excess demand for domestic currency must be eliminated by private

market forces. Values  $0 < \rho_t < \infty$  characterize intermediate intervention policies where the central bank dampens appreciation and depreciation pressure by purchasing or selling foreign bonds, implying  $0 < \omega_t < 1$ . When  $-(\gamma_1\alpha_2 + \beta_2)(1 - \lambda)^{-1} < \rho_t < 0$ , the central bank's actions magnify changes in the exchange rate implying,  $\omega_t < 0$ ; it actively depreciates (appreciates) the domestic currency vs its free float value when there is an excess supply of (demand for) domestic currency and the exchange rate is already depreciating (appreciating). When  $\rho_t < -(\gamma_1\alpha_2 + \beta_2)(1-\lambda)^{-1}$ , the central bank aggressively reverses the exchange rate movement, implying  $\omega_t > 1$ ; the exchange rate is observed to move in the direction opposite to what would have occurred in the absence of central bank intervention. This means that the central bank has at least a trend target for the exchange rate or it simply overreacts.

Figure 1.

**Degree of intervention,  $\omega_t$ , as a function of the central bank's exchange rate policy response coefficient,  $\rho_t$**



- When  $\omega_t = 1$ , the exchange rate is fixed.
- When  $\omega_t = 0$ , the exchange rate floats freely.
- When  $0 < \omega_t < 1$ , the central bank's actions dampen exchange market pressure.
- When  $\omega_t < 0$ , the central bank's actions magnify exchange market pressure.
- When  $\omega_t > 1$ , the central bank's actions more than offset exchange market pressure.

The central bank chooses  $\rho_t$  in each period. Below, the model presented in equations (5.1) through (5.7) is solved for exchange market pressure. In the solution, the market participants' perception of future  $\rho_t$  is assumed to be such that  $\rho_t$  follows some process. The process can be left unspecified except that anything that happens in period  $t$  is assumed not to affect the expectations concerning  $\rho_{t+k}$  for any  $k \geq 1$ . Note that the (non)specification of the  $\rho_t$  process leaves open the possibility that market participants expect  $\rho_t$  to follow a nonconstant path in the future. For example, they can expect an exchange rate regime shift to affect future values of  $\rho_t$ .

Now, let us solve the model for the exchange rate change. Equations (5.1) through (5.7) can be written as (temporarily dropping the expectation operator)

$$A(L)Z_t = X_t \quad (5.14)$$

where  $Z_t$  is the vector of endogenous variables defined as

$$Z_t = [\Delta p_t \quad \Delta i_t \quad \Delta e_t \quad \Delta d_t^a \quad \Delta r_t]', \quad (5.15)$$

$X_t$  is the vector of exogenous variables defined as

$$X_t^1 = \begin{bmatrix} x_{1,t} \\ x_{2,t} \\ x_{3,t} \\ x_{4,t} \\ x_{5,t} \end{bmatrix} = \begin{bmatrix} -\beta_0 - \beta_1 \Delta c_t \\ \alpha_0 + \alpha_1 \Delta p_t^* \\ \Delta i_t^* \\ \gamma_0 + \Delta y_t^{\text{trend}} - \gamma_2 y_t^{\text{gap}} \\ 0 \end{bmatrix}, \quad (5.16)$$

when the unrestricted form of the monetary policy reaction function in equation (5.6') is used and

$$X_t^2 = \begin{bmatrix} x_{1,t} \\ x_{2,t} \\ x_{3,t} \\ x_{4,t} \\ x_{5,t} \end{bmatrix} = \begin{bmatrix} -\beta_0 - \beta_1 \Delta c_t \\ \alpha_0 + \alpha_1 \Delta p_t^* \\ \Delta i_t^* \\ \gamma_0 \\ 0 \end{bmatrix}, \quad (5.16')$$

when the restricted form of the monetary policy reaction function in equation (5.6'') is used.

The respective coefficient matrices  $A^1(L)$  and  $A^2(L)$  are defined as

$$A^1(L) = \begin{bmatrix} 1 & -\beta_2 & 0 & -1 & -(1-\lambda) \\ 1 & 0 & -\alpha_2 & 0 & 0 \\ 0 & 1 & (1-L^{-1}) & 0 & 0 \\ -(1-\gamma_1) & 0 & 0 & 1 & 0 \\ 0 & 0 & \rho_t & 0 & 1 \end{bmatrix} \quad (5.17)$$

and

$$A^2(L) = \begin{bmatrix} 1 & -\beta_2 & 0 & -1 & -(1-\lambda) \\ 1 & 0 & -\alpha_2 & 0 & 0 \\ 0 & 1 & (1-L^{-1}) & 0 & 0 \\ \gamma_1 & 0 & 0 & 1 & 0 \\ 0 & 0 & \rho_t & 0 & 1 \end{bmatrix} \quad (5.17')$$

where  $L$  denotes the lag-operator.

Each endogenous variable in the linear-equation system above can be solved using Cramer's rule. Here, only the solution value of the change in the exchange rate,  $\Delta e_t$ , is needed. The determinants of coefficient matrices  $A^1(L)$  and  $A^2(L)$  are given by

$$|A^1(L)| = \gamma_1 \alpha_2 + \beta_2 + (1-\lambda) \rho_t - L^{-1} \beta_2 \quad (5.18)$$

and

$$|A^2(L)| = (1 + \gamma_1) \alpha_2 + \beta_2 + (1-\lambda) \rho_t - L^{-1} \beta_2 \quad (5.18')$$

Let us now focus on the exchange rate change,  $\Delta e_t$ , which is the third element in the vector of endogenous variables defined in equation (5.15). The determinants of the matrices  $A^1(L)$  and  $A^2(L)$ , with the third column

replaced by the vector of exogenous variables ( $X_t^1$  and  $X_t^2$  respectively) are given by

$$\begin{aligned}
|A_3^1(L)| &= x_{1,t} - \gamma_1 x_{2,t} + \beta_2 x_{3,t} + x_{4,t} \\
&= -\beta_0 + \gamma_0 - \gamma_1 \alpha_0 - \beta_1 \Delta c_t + \Delta y_t^{\text{trend}} - \gamma_1 \alpha_1 \Delta p_t^* + \beta_2 \Delta i_t^* - \gamma_2 y_t^{\text{gap}} \quad (5.19) \\
&\equiv -\text{EDC}_t^1
\end{aligned}$$

and

$$\begin{aligned}
|A_3^2(L)| &= x_{1,t} - (1 + \gamma_1) x_{2,t} + \beta_2 x_{3,t} + x_{4,t} \\
&= -\beta_0 + \gamma_0 - (1 + \gamma_1) \alpha_0 - \beta_1 \Delta c_t - (1 + \gamma_1) \alpha_1 \Delta p_t^* + \beta_2 \Delta i_t^* \quad (5.19') \\
&\equiv -\text{EDC}_t^2.
\end{aligned}$$

Equations (5.19) and (5.19') define the excess demand for domestic currency ( $\text{EDC}_t^1$  or  $\text{EDC}_t^2$ ) that is generated by exogenous variables in period  $t$ . According to equations (5.19) and (5.19') the excess demands for domestic currency are measured in exchange rate changes. The negative signs are needed since excess demand causes the domestic currency to appreciate and appreciation is defined as a negative change in the exchange rate.<sup>46</sup>

Next, the model including the unrestricted-form monetary policy reaction function from equation (5.6') is solved. Substituting the restricted-form monetary policy reaction function from equation (5.6'') for the unrestricted one simply means replacing  $\gamma_1$  with  $(1 + \gamma_1)$  and  $-\text{EDC}_t^1$  with  $-\text{EDC}_t^2$  in all the equations below.

Solving the model for the change in the exchange rate yields

$$\Delta e_t = \frac{-\text{EDC}_t^1}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_t - L^{-1} \beta_2}. \quad (5.20)$$

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<sup>46</sup> The exchange rate is expressed as domestic currency per unit of foreign currency.

Multiplying both sides of equation (5.20) by  $|A^1(L)|$  and taking expectations conditional on the information available in the current period yields a stochastic first-order linear difference equation:

$$-\beta_2 E_t(\Delta e_{t+1}) + (\gamma_1 \alpha_2 + \beta_2) \Delta e_t + (1 - \lambda) \rho_t \Delta e_t = -EDC_t^1, \quad (5.21)$$

Solving for  $\Delta e_t$  gives

$$\Delta e_t = \frac{1}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_t} \left[ -EDC_t^1 + \beta_2 E_t(\Delta e_{t+1}) \right]. \quad (5.22)$$

Iterating equation (5.22) forward gives

$$\begin{aligned} \Delta e_t &= \frac{-1}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_t} \left\{ EDC_t^1 \right. \\ &\quad + E_t \left[ \left( \frac{\beta_2}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_{t+1}} \right) EDC_{t+1}^1 \right] \\ &\quad + E_t \left[ \left( \frac{\beta_2}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_{t+1}} \right) \cdot \right. \\ &\quad \left. \left( \frac{\beta_2}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_{t+2}} \right) EDC_{t+2}^1 \right] + \dots \left. \right\} \\ &= \frac{-1}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_t} \sum_{i=0}^{\infty} E_t(\delta_i EDC_{t+i}^1) \end{aligned} \quad (5.23)$$

in which

$$\begin{aligned} \delta_0 &= 1 \\ \delta_i &= \prod_{k=1}^i \frac{\beta_2}{\gamma_1 \alpha_2 + \beta_2 + (1 - \lambda) \rho_{t+k}}, \text{ when } i \geq 1. \end{aligned} \quad (5.24)$$

Equations (5.23) and (5.24) show that the current exchange rate change depends on current interventions through  $\rho_t$  and on expectations



concerning future values of exogenous fundamentals, including the response coefficient,  $\rho_t$ .

According to the definition presented by Weymark (1995: 278), exchange market pressure measures the excess demand for a currency as the exchange rate change which would have been required to remove the excess demand in the absence of money or foreign exchange market intervention, given that expectations are generated by the exchange rate policy actually implemented. In the model employed here, exchange rate policy is completely defined by the response coefficient. As discussed above, the expected future exchange rate policy is fixed when the size of the external imbalance is imputed from observed changes in the exchange rate. This means that whether or not the central bank actually intervenes in the foreign exchange market at time  $t$  does not affect market participants' expectations on the value of the response coefficient. The expected future exchange rate policies are included in the time-varying discount factor,  $\delta_t$ , and hence affect  $-\sum E_t(\delta_t EDC_{t+i}^1)$ , which creates the total international excess demand for the domestic currency at time  $t$ . The total excess demand is by definition equal to the weighted sum of observed  $\Delta e_t$  and  $\Delta r_t$  that relieve the excess demand at time  $t$ . This means that the conditions for a proper measurement of exchange market pressure are fulfilled and hence that the general model-independent methodology of deriving the measure for exchange market pressure introduced by Weymark (1995) is valid. Note that the assumption of  $\rho_t$  not affecting  $\rho_{t+k}$  for  $k \geq 1$  implies that interventions are assumed not to convey any information about future monetary policy. Therefore, the signalling effects of intervention are ruled out here. Taking into account the signalling channel would strengthen the effects of interventions on the exchange rate.

The model-consistent measure of exchange market pressure is formed by rearranging equation (5.23) so that the left-hand side is similar to equation (3.1') above, in which the model-independent exchange market pressure is defined as the sum of the actual change in the exchange rate and the unsterilized part of foreign exchange intervention, converted into exchange-rate-equivalent units. Model-consistency comes from the explicit conversion factor,  $\eta$ , obtained as a result of the rearrangement.

Using equations (5.23) and (5.5), the exogenous total excess demand for domestic currency in international foreign exchange markets on date  $t$ , given the expectations generated by the exchange rate policy actually implemented, can be rewritten as

$$(\gamma_1\alpha_2 + \beta_2)\Delta e_t - (1-\lambda)\Delta r_t = -\sum_{i=0}^{\infty} E_t(\delta_i EDC_{t+i}^1). \quad (5.25)$$

Equation (5.25) gives the magnitude of the exogenous total excess demand which must be removed by some combination of changes in exchange rate and foreign exchange reserves. Whether the central bank removes some or none of it by intervening in the foreign exchange market on date  $t$ , does not change the underlying excess demand for domestic currency, as long as market participants' expectations concerning the future response coefficient, and hence the exchange rate policy, are exogenous on date  $t$ .

The right-hand side of the equation (5.25) is itself a measure of exchange market pressure. To express it in terms of exchange rate change, both sides of the equation (5.25) are divided by  $(\gamma_1\alpha_2 + \beta_2)$ . The resulting right-hand side of the equation (5.25) is now called the exchange market pressure,  $EMP_t^1$ , and can thus be written as

$$EMP_t^1 = \Delta e_t - \frac{1-\lambda}{\gamma_1\alpha_2 + \beta_2} \Delta r_t. \quad (5.26)$$

Equation (5.26) can be used to determine the degree of central bank intervention according to equation (3.3') as

$$\begin{aligned} \omega_t^1 &= \frac{-(1-\lambda)\Delta r_t}{(\gamma_1\alpha_2 + \beta_2)EMP_t^1} = \frac{(1-\lambda)\Delta r_t}{(1-\lambda)\Delta r_t - (\gamma_1\alpha_2 + \beta_2)\Delta e_t} \\ &= \frac{(1-\lambda)\rho_t}{(1-\lambda)\rho_t + \gamma_1\alpha_2 + \beta_2}. \end{aligned} \quad (5.27)$$

The formulae for exchange market pressure and the degree of central bank intervention when the central bank is assumed to follow the restricted form of the monetary policy rule in equation (5.6'') are given by

$$EMP_t^2 = \Delta e_t - \frac{1-\lambda}{(1+\gamma_1)\alpha_2 + \beta_2} \Delta r_t \quad (5.26')$$

and

$$\omega_t^2 = \frac{(1-\lambda)\Delta r_t}{(1-\lambda)\Delta r_t - [(1+\gamma_1)\alpha_2 + \beta_2]\Delta e_t} = \frac{(1-\lambda)\rho_t}{(1-\lambda)\rho_t + (1+\gamma_1)\alpha_2 + \beta_2}. \quad (5.27')$$

Equations (5.26) and (5.26') give the model-consistent measure of exchange market pressure and equations (5.27) and (5.27') the model-consistent intervention index. The conversion factor,  $\eta$ , in the general formulae for exchange market pressure and intervention index in equations (3.1') and (3.3') is now  $-(\gamma_1\alpha_2 + \beta_2)^{-1}$  or  $-[(1+\gamma_1)\alpha_2 + \beta_2]^{-1}$ , ie the negative of the inverse of the sum of the monetary policy response to the inflation gap (plus one, in the latter case) times the exchange rate elasticity of the domestic price level and the interest rate elasticity of the demand for money. To calculate the actual values of exchange market pressure and the intervention index in this simple small open economy rational expectations monetary model context, the structural parameters  $\lambda$ ,  $\gamma_1$ ,  $\alpha_2$  and  $\beta_2$  must be obtained by estimating the change in domestic demand for money (equation 5.1), the domestic inflation (equation 5.2) and the central bank's domestic lending policy reaction function, which is a combination of equations (5.4) and (5.6).

Of course, the components of the conversion factor,  $\eta$ , change when the underlying model specification is altered, and the difficulties associated with such estimation can be expected to vary widely among different classes of models. But, as suggested by Weymark (1998: 115–116), because exchange market pressure simply measures the actual international excess demand for the domestic currency at time  $t$ , given the foreign exchange policy that was in place at time  $t$ , all of the relevant information on expectations about the future and on the nature of stochastic disturbances to the economy is included in changes in the observed variables that relieve this international excess demand. This means that one need not obtain explicit solutions for expectations concerning exogenous variables nor specify the nature of stochastic disturbances. This simplifying property is the core of this methodology and is of great operational importance.

## 6 Estimating the conversion factor

This chapter presents the estimation of parameters in the money demand, domestic price level and money supply equations. The estimation is required to yield estimates of the sterilization coefficient,  $\lambda$ , the elasticity of the monetary base with respect to the domestic price level,  $\gamma_1$ , the elasticity of the domestic price level with respect to the exchange rate,  $\alpha_2$ , and the elasticity of the money demand with respect to the domestic interest rate,  $\beta_2$ . These estimates are needed to calculate the actual conversion factor,  $\eta$ , in the measure of exchange market pressure in equations (5.26) and (5.26') and in the measure of the degree of central bank intervention in equations (5.27) and (5.27') during the months when the Finnish markka was floating.

The model summarized in equations (5.1)–(5.7) above consists of six endogenous and six exogenous variables.<sup>47</sup> The endogenous variables are change in money demand,  $\Delta m_t^d$ , change in domestic price level,  $\Delta p_t$ , change in the exchange rate,  $\Delta e_t$ , change in domestic short-term interest rate level,  $\Delta i_t$ , the central bank's foreign exchange interventions,  $\Delta r_t$ , and change in money supply,  $\Delta m_t^s$ . The exogenous variables are change in real domestic income,  $\Delta c_t$ , change in foreign price level,  $\Delta p_t^*$ , change in foreign short-term interest rate level,  $\Delta i_t^*$ , expected change in the exchange rate,  $E_t(\Delta e_{t+1})$ , change in the long-term trend component of real domestic output,  $\Delta y_t^{\text{trend}}$ , and the gap between real domestic output and its long-term trend component,  $y_t^{\text{gap}}$ . Even though the change in the exchange rate does not show on the left-hand side of any of the equations, it is the exchange rate which is determined by this model. It is also assumed that causality runs in both directions between the change in the exchange rate and the central bank's foreign exchange intervention; the central bank is assumed to react to changes in the exchange rate, and the central bank's foreign exchange interventions are assumed to be effective.

### 6.1 Estimation method

As can be seen, there are not only exogenous but also endogenous variables on the right-hand side of each of the equations. This means that in each equation some of the regressors, ie the endogenous variables on the right-hand side, are expected to correlate with the disturbance term

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<sup>47</sup> The operational counterparts of the theoretical variables are listed in appendix.

and hence the ordinary least square estimates would be biased. To overcome the simultaneity problem, two-stage least square estimates are used. Here, limited information two-stage least squares was chosen rather than full information three-stage least squares because of the relatively small number of observations and the greater robustness of limited information methods in the presence of misspecification. Two-stage least squares tends to limit the damage done by misspecification to the equation in which misspecification occurs, whereas three-stage least squares spreads the damage through all the equations in the system.

In the first stage, two-stage least squares takes variables that are uncorrelated with the disturbance term (instruments) and uses them to find the component of an endogenous variable that is attributable to these instruments, ie the fitted value of the endogenous variable. This is done for each endogenous variable on the right-hand sides of the equations. In the second stage, the original equations are estimated with the first-stage fitted values replacing the endogenous variables on the right-hand sides of the equations.

Finding good instruments can be difficult. Here, the contemporaneous and one-month lagged values of all exogenous and one-month lagged values of all endogenous variables of the model are considered as possible instruments. The actual instruments are selected by running the first stage regressions on endogenous variables having all possible instruments as regressors and selecting regressors which prove to be statistically fairly significant as actual instruments. This is done separately for the narrow,  $\Delta r_t^{\text{narrow}}$ , and broad,  $\Delta r_t^{\text{broad}}$ , measures of foreign exchange intervention.<sup>48</sup> In order to emphasize that the estimated equations are a part of a larger system, the same list of instruments is used in every single equation estimation.

The list of actual instruments and the  $R^2$  measures for the first stage regressions using the actual instruments are presented in table 1. The validity of the instruments, ie the assumption that all instruments are uncorrelated with the error term, is tested using the test by Sargan (1958). It is based on a comparison of the unrestricted and restricted reduced form of the structural model, and its asymptotic distribution is derived under the assumption of no error-term autocorrelation. The null hypothesis is that the instruments are valid. The Sargan test statistic is presented in tables 5 and 6 in section 6.5 below.

The possible inconsistency due to the simultaneity of the model, ie the need to use two-stage least squares instead of ordinary least squares, could be tested using the specification test by Hausman (1978) where it is

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<sup>48</sup> For the definitions of  $\Delta r_t^{\text{narrow}}$  and  $\Delta r_t^{\text{broad}}$ , see section 6.3.3 below.

considered whether ordinary least squares and two-stage least squares vector estimates differ from each other significantly. This need not be done here since the simultaneity derives from the structure of the system by definition.

Table 1. **The R<sup>2</sup> measures for the first stage regressions of change in real money demand, domestic price level and domestic component of monetary base.**

	Narrow interventions	Broad interventions
Dependent variable	instr.: $\Delta p_t^*, \Delta i_t^*, \Delta i_{t-1}^*, \Delta i_{t-1}$ , $\Delta r_{t-1}^{\text{narrow}}$	instr.: $\Delta p_t^*, \Delta p_{t-1}^*, \Delta i_t^*, \Delta i_{t-1}^*$ , $\Delta i_{t-1}, \Delta r_{t-1}^{\text{broad}}$
$\Delta m_t^d - \Delta p_t$	0.6136	0.6026
$\Delta i_t$	0.7459	0.7417
$\Delta p_t$	0.6768	0.7105
$\Delta e_t$	0.3019	0.2993
$\Delta B_t/B_{t-1} - \Delta r_t - \Delta y_t^{\text{trend}} - \Delta p_t$	0.3065	0.2685
$\Delta r_t^{\text{narrow}}$	0.3929	
$\Delta r_t^{\text{broad}}$		0.3051
$\Delta p_t$	0.3509	0.3507
$\Delta B_t/B_{t-1} - \Delta r_t$	0.2693	0.2586
$\Delta r_t^{\text{narrow}}$	0.3318	
$\Delta r_t^{\text{broad}}$		0.2791
$\Delta p_t$	0.3504	0.3481

The actual instruments are listed at the top of the respective columns. The dependent variables in the original (and second stage) regression are printed in boldface. The operational counterparts of the theoretical variables are listed in appendix.

## 6.2 Stationarity of the variables and a note on cointegration analysis

The stationarity of regressors is assumed in the derivation of standard inference procedures for regression models. If regressors are nonstationary, many standard results are invalidated and special treatment is required.

A Phillips-Perron test for a unit root is used to examine the stationarity of the time series used. This is a test of the hypothesis  $\rho=1$  in the equation

$$\Delta y_t = \mu + \rho y_{t-1} + \delta t + \varepsilon_t. \quad (6.1)$$

The equation is estimated by ordinary least squares, and the t-statistic of the  $\rho$  coefficient is corrected for heteroscedasticity and serial correlation in  $\varepsilon_t$  by the Newey-West procedure for adjusting the standard errors. Following the suggestion of Newey and West (1987) the truncation lag,  $q$ , used to approximate the dynamics of  $\varepsilon_t$  is set as

$$q = \left( \frac{T}{100} \right)^{\frac{2}{9}} \approx 3, \quad (6.2)$$

where  $T=48$  is the number of observations. The MacKinnon critical values for rejection of the null hypothesis of a unit root, ie non-stationarity of a series, are presented in table 3.

Table 3. **MacKinnon critical values for rejection of the null hypothesis of a unit root**

	incl. intercept and trend	incl. intercept
1% critical value	-4.1584	-3.5713
5% critical value	-3.5045	-2.9228
10% critical value	-3.1816	-2.5990

Since the levels data for Finnish consumer prices,  $p_t$ , foreign consumer prices,  $p_t^*$ , Finnish M1 money,  $m_t$ , three-month HELIBOR,  $i_t$ , and three month foreign interest rate,  $i_t^*$ , show clearly trending behaviour, an intercept and a linear trend term are included in the test equations for the levels data of these variables to allow for trend stationarity under the alternative hypothesis. Since the first differencing seems to remove trends from the data, only intercepts are included in the test equations for the first differenced data. The test results are shown in table 4.

Table 4.

**Phillips-Perron unit root tests for variables used**

Variable	Level	1st difference
$p_t$	-2.657099	-6.476505**
$p_t^*$	-2.128694	-4.823895**
$e_t$	-0.860705	-6.470778**
$c_t$	-2.131242	-8.445824**
$y_t^{\text{trend}}$		-8.286413**
$y_t^{\text{gap}}$	-5.482082**	
$i_t$	-6.488918**	-6.451125**
$i_t^*$	-5.019951**	-9.674134**
$m_t$	-2.825732	-7.151980**
$\Delta B_t/B_{t-1}$	-13.07860**	
$\Delta \Gamma_t^{\text{narrow}}$	-6.233269**	
$\Delta \Gamma_t^{\text{broad}}$	-6.839204**	

The test results suggest that first differences of regressors should be used in the money demand and domestic price level equations, although three-month Finnish and foreign interest rate levels seem to be (trend) stationary. In the money supply equation, foreign exchange interventions and the percentage change in monetary base are flow variables by nature and hence are already differenced and stationary.

Normally, the next step would be to carry out cointegration analysis for the money demand and the domestic price level equations and estimate the equations in the form of a vector error correction model in order to catch the short-term interactions and the long-term equilibrium relations of the variables. However, to get the parameter values for the model-consistent conversion factor presented in this paper, it is not proper to estimate the equations in error correction form. Model-consistency requires that the equations be estimated exactly in the form presented in the theoretical model from which the conversion factor is analytically derived. Estimating the equations in the error correction form would change the theoretical model and, in order to acquire the new conversion factor consistent with that new model, the model would need to be solved again. Including more dynamics in the model would undoubtedly improve it but, at the same time, further complicate it. This rigidity of model construction is clearly a weakness of the model-consistent method. It should be taken into account when applying the method and finding the parameter estimates needed in the conversion factor.



## 6.3 Some definitions

According to Adams and Henderson (1983: 2), a foreign exchange intervention occurs when the central bank's net foreign assets change. Foreign exchange interventions include unsterilized and sterilized interventions. Unsterilized intervention changes the monetary liabilities of the central bank while sterilized intervention leaves the monetary liabilities unchanged. In the following section, the effects of unsterilized and sterilized foreign exchange intervention on a stylized balance sheet of the central bank are analyzed.

A stylized balance sheet of the central bank is displayed in table 2 below. The net assets of the central bank are divided into net foreign assets (NFA) and net domestic assets (NDA). Net foreign assets include gold, foreign currency reserves and the forward position of the central bank. Net domestic assets include the central bank's claims on financial institutions, eg liquidity credits and securities with repurchase commitments. The liabilities of the central bank are divided into monetary liabilities (ML) and net worth (NW). Monetary liabilities include domestic currency in circulation, ie notes and coins held by financial institutions and the public, certificates of deposit issued by the central bank and liabilities to financial institutions, ie excess reserve and required reserve deposits. Monetary liabilities are often referred as the monetary base. The net worth is affected by eg current operating returns, receipt of net interest payments and capital gains on the central bank's holdings of net domestic and foreign assets.

Table 2. **A stylized balance sheet of the central bank**

ASSETS	LIABILITIES
Net foreign assets	Monetary liabilities
Net domestic assets	Net worth

### 6.3.1 An unsterilized foreign exchange intervention

When the central bank sells (spot) foreign currency to the banks for domestic currency, the banks' liquidity position at the central bank is immediately squeezed, ie  $\Delta NFA = \Delta ML < 0$ . This decreases, ceteris paribus, the supply of domestic currency, which, according to models of

exchange rate determination reviewed in the chapter 4, results in an appreciation of the domestic currency. Similarly, when the central bank purchases (spot) foreign currency from the banks against domestic currency, the banks' liquidity position at the central bank is immediately eased, ie  $\Delta NFA = \Delta ML > 0$ . This increases, ceteris paribus, the supply of domestic currency, which results in a depreciation of the domestic currency.

### 6.3.2 A sterilized foreign exchange intervention

A sterilized foreign exchange intervention involves offsetting changes in net foreign and net domestic assets, ie  $\Delta NFA = -\Delta NDA$ , and no immediate change in either monetary liabilities or net worth, ie  $\Delta ML = \Delta NW = 0$ .

Sterilized interventions can take different forms. When the central bank sells foreign currency to the banks against domestic currency, the banks' liquidity position is squeezed. The central bank can sterilize the effect of the outright sale on the banks' liquidity position, ie temporarily increase liquidity, either through a security deal under repurchase agreement or through the combination of a spot purchase and a forward sale of foreign currency, ie a foreign exchange swap.

If the decrease in foreign exchange reserves is exactly matched by the increase in securities with repurchase commitments, the banks' current liquidity position remains unchanged but the share of foreign currency bonds is immediately decreased and domestic currency bonds increased in the central bank's balance sheet. In the banks' investment portfolio the share of foreign currency bonds is immediately increased and domestic currency bonds decreased. The sterilization effect, however, is only temporary since the banks' liquidity position is eventually squeezed at the day of maturity when the banks' repurchase their securities from the central bank.

If the decrease in foreign exchange reserves is exactly matched by a swap operation, both the banks' liquidity position and the central bank's spot foreign exchange reserves remain unchanged but the central bank's forward position decreases immediately. This means that the central bank's holdings of foreign currency bonds, ie claims on future delivery of foreign currency, decreases and its holdings of domestic currency bonds increases. In the banks' investment portfolio the holdings of foreign currency bonds increases and domestic currency bonds decreases. Again, the sterilization effect is only temporary since the banks' liquidity position and the central bank's foreign exchange reserves are eventually

squeezed at the maturity date when the central bank delivers foreign currency per the forward agreement. As a matter of fact, since the spot transactions cancel each other out, an outright forward agreement in which the central bank simply sells foreign currency to be delivered at a certain date in the future would have exactly the same immediate and eventual effects on the banks' liquidity position and on the central bank's foreign exchange reserves and forward position.

In contrast to the sale of foreign currency, when the central bank purchases foreign currency from the banks against domestic currency, the banks' liquidity position is eased. Again, the central bank can sterilize the effect of the outright purchase on the banks' liquidity position, ie temporarily reduce liquidity, either through a sale of its own certificates of deposit or through the combination of a spot sale and a forward purchase of foreign currency. Everything happens as described above, except that the signs of the transactions are reversed.

In models of exchange rate determination, whether the increase in the share of foreign currency bonds and decrease in the share of domestic currency bonds in the banks' investment portfolio affects the exchange rate depends on the substitutability of foreign and domestic bonds. If foreign and domestic bonds are perfect substitutes, ie there is no risk premium in the interest rate parity condition, a sterilized sale of foreign currency has no effect on the exchange rate. In contrast, if foreign and domestic bonds are imperfect substitutes, ie a risk premium exists, a sterilized sale of foreign currency reduces the risk premium on the domestic currency, which results in a change in one or in all of the components of the interest rate parity condition. This means that when foreign and domestic bonds are imperfect substitutes, a sterilized sale of foreign currency can result in appreciation of the domestic currency.

### 6.3.3 Narrow and broad measures of foreign exchange intervention

In their paper, Adams and Henderson (1983: 3–4) also discuss the role of customer transactions in defining and measuring foreign exchange intervention. Customer transactions comprise those central bank foreign exchange transactions carried out directly with other entities that otherwise would have transacted with market agents. Customers can include a wide array of entities, but the most important customer of the central bank is probably the central government, due to its foreign currency-denominated receipts or obligations. The central government, after having raised a loan denominated in foreign currency, may change

the proceeds into domestic currency through the central bank, which later supplies the foreign currency needed to make interest payments and finally to repay the loan.

In Finland the central government's capital imports and exports go through the Bank of Finland balance sheet because the State Treasury does not have foreign exchange deposits.<sup>49</sup> According to Adams and Henderson (1983: 3), these transactions should be included in the comprehensive foreign exchange intervention measure. On the other hand, they discuss the voluntariness of certain customer transactions, and say that only voluntary transactions should be counted as foreign exchange interventions because they manifest the central bank's choice to alter its net foreign assets.<sup>50</sup> Whether customer transactions with the central government and especially their timing are voluntary or not is an open question. If the central bank has absolutely no choice in the matter, customer transactions with the central government are involuntary and should not be included in the intervention measure. If the central bank can decide eg on which day of a week or a month the transaction is executed, customer transactions with the central government are voluntary to certain extent and should be included in the intervention measure.

In this paper, two measures of the central bank's foreign exchange intervention are used when the money demand, price level and money supply equations are estimated. The narrow measure,  $\Delta R_t^{\text{narrow}}$ , comprises ordinary spot transactions, changes in forward position, including both outright forwards and forwards in swap contracts, and spot transactions connected with swap contracts. The broad measure,  $\Delta R_t^{\text{broad}}$ , includes also the central government's foreign exchange transactions with the Bank of Finland. The foreign exchange interventions scaled by the one-month lagged monetary base using the two definitions,  $\Delta r_t^{\text{narrow}}$  and  $\Delta r_t^{\text{broad}}$ , are shown in figure 2, where a positive value indicates that the Bank of Finland has purchased and a negative value that it has sold foreign currency bonds. As can be seen,  $\Delta r_t^{\text{broad}}$  is more often positive than is  $\Delta r_t^{\text{narrow}}$ , which means that the Bank of Finland purchased more foreign currency from the central government than it sold to the central government. This is due to the fact that the large fiscal deficits were to a large extent financed through foreign currency loans via the international financial market during the markka's float. Toward the end of the floating period, foreign borrowing decreased and repayment increased. This reversed the capital flow ensuing from the foreign debt management

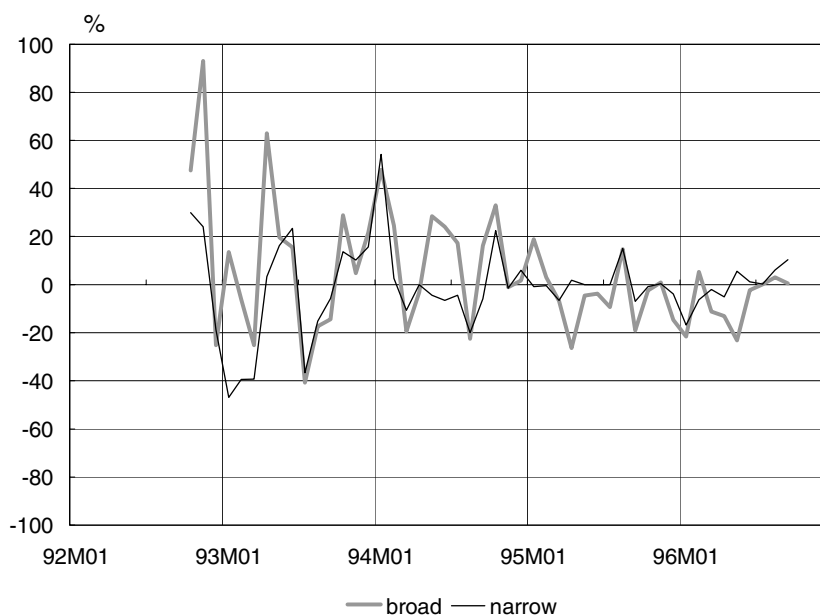
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<sup>49</sup> See Aaltonen, Aurikko and Kontulainen (1994: 83).

<sup>50</sup> See Adams and Henderson (1983: 4).

from inflow to outflow, and in 1995 and 1996  $\Delta r_t^{\text{broad}}$  is clearly more often negative than is  $\Delta r_t^{\text{narrow}}$ .

Figure 2. **Broad and narrow measures of foreign exchange intervention, scaled by one-month lagged monetary base**



### 6.3.4 Monetary base

The central bank's foreign exchange interventions are scaled by the lagged monetary base,  $B_{t-1}$ , in order to form a relative measure of foreign exchange intervention comparable to relative changes of other variables of the model. The monetary base is defined as notes and coin in circulation plus banks' free reserves at the Bank of Finland plus banks' required reserves at the Bank of Finland. This follows the standard definition of monetary base. However, it is not obvious that banks' required reserves should be included in the measure of monetary base. This is because banks' required reserves at the Bank of Finland do not, as such, affect their liquidity and are not counted as readily available liquidity;<sup>51</sup> changes in reserve requirements do not affect the amount of high powered money that banks can use to create money. To prevent changes in reserve requirements from affecting the level of monetary base, the data is adjusted for a constant reserve ratio.

<sup>51</sup> See Aaltonen, Aurikko and Kontulainen (1994: 17).

Sometimes, also borrowed reserves or call money credits are considered as a negative part of free reserves and monetary base. Here, following the suggestion by eg Kajanoja (1998b: 5), they are not included in the measure of monetary base, since only the amount of high powered money in circulation is of interest. For example, it is irrelevant whether money supply changes through borrowing from the discount window or through an open market operation and, under definitions used here, both show up as changes in banks' free reserves. Finally, as the money multiplier is assumed to be constant, the change in money supply,  $\Delta m_t^s$ , equals the change in monetary base,  $\Delta B_t/B_{t-1}$ .

## 6.4 Equations

The following equations are estimated using monthly data from October 1992 to September 1996.

$$\begin{aligned} \Delta m_t - \Delta p_t = & \beta_0 + \beta_1 \Delta c_t + \beta_2 \Delta i_t + \beta_3 \text{DUMDEC}_t + \beta_4 \text{DUM9302}_t \\ & + \beta_5 \text{DUM9409}_t + \varepsilon_{m,t}, \end{aligned} \quad (\text{MD})$$

where, according to equation (5.1) above,  $\beta_1$  should be positive and  $\beta_2$  negative,

$$\Delta p_t = \alpha_0 + \alpha_1 \Delta p_t^* + \alpha_2 \Delta e_t + \alpha_3 \Delta \text{DUM9301}_t + \alpha_4 \Delta \text{DUM9406}_t + \varepsilon_{p,t}, \quad (\text{P})$$

where, according to equation (5.2) above,  $\alpha_1$  and  $\alpha_2$  should be positive and

$$\frac{\Delta B_t}{B_{t-1}} - \Delta r_t - \Delta y_t^{\text{trend}} - \Delta p_t = \gamma_{10} + \lambda_1 \Delta r_t + \gamma_{11} \Delta p_t + \gamma_{12} y_t^{\text{gap}} + \varepsilon_{1r,t}, \quad (\text{MS1})$$

$$\frac{\Delta B_t}{B_{t-1}} - \Delta r_t = \gamma_{20} + \lambda_2 \Delta r_t + \gamma_{21} \Delta p_t + \varepsilon_{2r,t} \quad (\text{MS2})$$

where, according to the equations (5.4) and (5.6) above,  $\lambda_1$ ,  $\lambda_2$ ,  $\gamma_{11}$ ,  $\gamma_{21}$  and  $\gamma_{12}$  should be negative and the absolute value of  $\lambda_1$  and  $\lambda_2$  less than

unity. The operational counterparts of the theoretical variables are listed in appendix.

## 6.5 Estimation results

The two-stage least squares estimation results are presented in tables 5 and 6 for foreign exchange interventions defined respectively broadly,  $\Delta r_t^{\text{broad}}$ , and narrowly,  $\Delta r_t^{\text{narrow}}$ . The estimates of sterilization coefficient,  $\lambda_{,i}$ , elasticity of the monetary base with respect to the domestic price level,  $\gamma_{i1}$ , elasticity of domestic price level with respect to the exchange rate,  $\alpha_2$ , and the semi-elasticity of the money demand with respect to the domestic interest rate,  $\beta_2$ , are needed to calculate the actual conversion factor,  $\eta$ , in the measure of exchange market pressure in equations (5.26) and (5.26') and in the measure of the degree of central bank intervention in equations (5.27) and (5.27') during the months when the Finnish markka was floating. The sub-index,  $i=1,2$ , indicates the two variants of money supply equations (MS1) and (MS2). When  $i=1$  the equation of exchange and the central bank's real growth target are included and when  $i=2$  they are excluded from the money supply equation.

As can be seen in tables 5 and 6, the signs of the parameter estimates are consistent with the theoretical model and almost all of them are significantly different from zero. Especially the results from the money demand and domestic inflation equations are satisfactory. The elasticity of money demand with respect to the domestic interest rate,  $\beta_2$ , and with respect to consumption,  $\beta_1$ , are somewhat smaller than but still in line with those found in earlier studies of the demand for M1 in Finland.<sup>52</sup> Also the elasticity of domestic inflation with respect to the exchange rate,  $\alpha_2$ , and with respect to the foreign inflation,  $\alpha_1$ , is smaller but in line with those found in similar studies of the determinants of domestic inflation in Finland.<sup>53</sup> The fact that the equations are in difference form is one reason for the small parameter estimates. Here, the emphasis is on the short-run relationship between dependant and explanatory variables. In this study, however, this is not a serious drawback, since in analysing the central bank's reactions to exchange market pressures emerging day by day even a period of one month can be too long a run.

In the case of domestic inflation equation, the White test indicates potential heteroscedasticity in error terms, but this does no harm since the

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<sup>52</sup> See Kajanoja (1998a) and Ripatti (1994, 1998).

<sup>53</sup> See Kajanoja (1998a).

standard errors of parameter estimates are corrected for heteroscedasticity and serial correlation in the error term by the Newey-West procedure. Otherwise the error terms in money demand and domestic inflation equations seem to pass the standard test diagnostics: error terms seem to be normally distributed and there seems to be no serial autocorrelation, autoregressive conditional heteroscedasticity or heteroscedasticity (in the case of the money demand equation), and the chosen instruments seem to be valid.

The results from the money supply equations are somewhat poorer. The signs are correct but only the parameter estimates of sterilization coefficient,  $\lambda_i$ , are significantly different from zero. This means that the Bank of Finland has not allowed its foreign exchange interventions fully to affect the monetary base. In fact, the parameter estimates of the sterilization coefficient do not differ significantly from minus unity, which implies full sterilization. This result is expected since according to Aaltonen, Aurikko and Kontulainen (1994: 81), the Bank of Finland generally sterilizes the liquidity effects of its foreign exchange interventions. However, since the Bank of Finland has not announced publicly that it always, ie with no exception, sterilizes all foreign exchange interventions, the actual sterilization coefficient should be derived from its actual behaviour, ie from the monetary base and foreign exchange intervention data. Therefore it is assumed that the parameter estimates of the sterilization coefficient,  $\lambda_i$ , imply less than full sterilization, although they are not significantly different from minus unity.

The result is well in line with earlier studies of the central bank's sterilization activity. Kajanoja (1998b) finds that the Bank of Finland sterilized 93% of its foreign exchange interventions on average when the markka floated but that the sterilization coefficient does not differ significantly from unity, ie from the full sterilization value. Other empirical estimates of sterilization coefficients for modern industrialized countries typically indicate that central banks have sterilized their foreign exchange interventions at least to some extent. In many cases, parameter estimates correspond to only partial sterilization but, as in the Finnish case, do not differ significantly from full sterilization values.<sup>54</sup> The recent empirical literature on the degree of sterilization has been briefly surveyed by Edison (1993: 40–41).

The parameter estimates of elasticities of the monetary base with respect to the domestic price level,  $\gamma_{11}$ , are not quite significantly different from zero when the broad measure of foreign exchange intervention is

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<sup>54</sup> See Kajanoja (1998b: 3).



used and are even more insignificant when the narrow measure is used. The performance of the elasticities of the monetary base with respect to the domestic output gap,  $\gamma_{12}$ , are not significant. The problem stems from deficient specification of the equation and, unfortunately, it is a common drawback in many studies of monetary policy rules and reaction functions. According to McCallum (1997: 8), although there has been much debate on the subject of monetary policy rules, professional agreement concerning the appropriate specification of a model suitable for the analysis of monetary policy rules does not exist.

One reason to include possible monetary policy target variables in the monetary policy reaction function is to try to avoid possible omitted variables bias. Omitted variables bias arises when a variable contributing to the explanation of the dependent variable is missing from the right hand side of the equation if that variable is correlated with a variable that is included in the right hand side. Hence, if the central bank has set targets for inflation and real growth and is assumed to react to deviations from those targets, domestic inflation,  $\Delta p_t$ , and output gap,  $y_t^{\text{gap}}$ , should appear in the right-hand side of the equation.

The White test indicates potential heteroscedasticity and the Ljung-Box potential serial correlation in error terms, but this does no harm since the standard errors of parameter estimates are corrected for heteroscedasticity and serial correlation in the error term by the Newey-West procedure. Otherwise the error terms in money supply equations seem to pass the standard test diagnostics: error terms seem to be normally distributed and there seems to be no autoregressive conditional heteroscedasticity. The chosen instruments seem to be valid although the Sargan test statistic is almost significant when the broad measure of foreign exchange interventions is used.

Table 5.

## Estimation results when foreign exchange interventions include central government's net foreign exchange transactions with the Bank of Finland

Estimation of equations (MD), (P), (MS1) and (MS2) with two-stage least squares.

Estimation period: October 1992 – September 1996

Instrument list:  $\Delta p_t^*$ ,  $\Delta p_{t-1}^*$ ,  $\Delta i_t^*$ ,  $\Delta i_{t-1}^*$ ,  $\Delta i_{t-1}^*$ ,  $\Delta r_{t-1}^{\text{traded}}$

Money demand (MD)				Domestic inflation (P)				Unrestricted money supply (MS1)				Restricted money supply (MS2)			
Parameter	Estimate	Standard error	Prob.	Parameter	Estimate	Standard error	Prob.	Parameter	Estimate	Standard error	Prob.	Parameter	Estimate	Standard error	Prob.
$\beta_0$	0.0054	0.0019	0.0056	$\alpha_0$	0.0000	0.0005	0.8938	$\gamma_{10}$	0.0067	0.0080	0.4075	$\gamma_{20}$	0.0094	0.0076	0.2218
$\beta_1$	0.2075	0.0512	0.0002	$\alpha_1$	0.4416	0.2133	0.0445	$\gamma_{11}$	-6.8422	4.7827	0.1596	$\gamma_{21}$	-5.2776	4.7393	0.2714
$\beta_2$	-0.7298	0.3093	0.0230	$\alpha_2$	0.1028	0.0422	0.0192	$\gamma_{12}$	0.0829	0.1498	0.5530	$\lambda_2$	-0.9767	0.0641	0.0000
								$\lambda_1$	-0.9497	0.0682	0.0000				
R <sup>2</sup> = 0.6009, SEE = 0.0105, DW = 1.9407				R <sup>2</sup> = 0.4067, SEE = 0.0022, DW = 1.6146				R <sup>2</sup> = 0.9317, SEE = 0.0718, DW = 2.3703				R <sup>2</sup> = 0.9346, SEE = 0.0695, DW = 2.3628			
Test statistic	Value	Distr.	Prob.	Test statistic	Value	Distr.	Prob.	Test statistic	Value	Distr.	Prob.	Test statistic	Value	Distr.	Prob.
J-B	0.0817	$\chi^2(2)$	0.9600	J-B	1.3133	$\chi^2(2)$	0.5186	J-B	0.4337	$\chi^2(2)$	0.8051	J-B	0.2858	$\chi^2(2)$	0.8668
Q <sub>LB</sub> (6)	4.8695	$\chi^2(6)$	0.561	Q <sub>LB</sub> (6)	9.0847	$\chi^2(6)$	0.169	Q <sub>LB</sub> (6)	10.384	$\chi^2(6)$	0.109	Q <sub>LB</sub> (6)	10.898	$\chi^2(6)$	0.092
LM(6)	6.3512	$\chi^2(6)$	0.3850	LM(6)	10.341	$\chi^2(6)$	0.1110	LM(6)	10.749	$\chi^2(6)$	0.0965	LM(6)	13.071	$\chi^2(6)$	0.0419
ARCH(6)	2.0395	$\chi^2(6)$	0.9160	ARCH(6)	3.3366	$\chi^2(6)$	0.7656	ARCH(6)	5.1194	$\chi^2(6)$	0.5286	ARCH(6)	5.3010	$\chi^2(6)$	0.5058
WHITE	4.8307	$\chi^2(10)$	0.9022	WHITE	28.921	$\chi^2(7)$	0.0002	WHITE	16.482	$\chi^2(9)$	0.0575	WHITE	8.3816	$\chi^2(5)$	0.1364
RESET	0.8239	F <sub>3,39</sub>	0.4460	RESET	0.6043	F <sub>3,40</sub>	0.5513	RESET	0.8347	F <sub>3,41</sub>	0.4411	RESET	1.1413	F <sub>3,42</sub>	0.3289
SARGAN	4.7691	$\chi^2(5)$	0.4447	SARGAN	2.8994	$\chi^2(4)$	0.5748	SARGAN	8.6968	$\chi^2(4)$	0.0691	SARGAN	7.8850	$\chi^2(4)$	0.0959

Notes.

- The standard errors of parameter estimates are corrected for heteroscedasticity and serial correlation in the error term by the Newey-West procedure. Following the suggestion of Newey and West (1987), the truncation lag,  $q$ , used to approximate the dynamics of the error term is set as  $q = 4(T/100)^{2/9} \approx 3$ , where  $T=48$  is the number of observations. For a more detailed description of Newey-West method, see eg EViews User Guide (1995: 197).
- Parameter estimates of dummy variables in equations (MD) and (P) are not presented in the table. The estimates differ significantly from zero.
- Tests: **J-B**: The Jarque-Bera test for normality of the error term. **Q<sub>LB</sub>(6)**: The Ljung-Box test for serial correlation of the error term, up to 6 lags. **LM(6)**: The Breusch-Godfrey Lagrange multiplier test for serial correlation of the error term, up to 6 lags. **ARCH(6)**: Lagrange multiplier test for autoregressive conditional heteroscedasticity of the error term, up to 6 lags. **WHITE**: The White test for heteroscedasticity of the error term using squares and cross-products of the regressors, **RESET**: The Ramsey regression specification test for functional form mis-specification, adding powers 2 and 3 of the fitted values to the original regression. **SARGAN**: The Sargan test for the validity of instruments.

Table 6. **Estimation results when foreign exchange interventions do not include central government's net foreign exchange transactions with the Bank of Finland**

Estimation of equations (MD), (P), (MS1) and (MS2) with two-stage least squares.

Estimation period: October 1992 – September 1996

Instrument list:  $\Delta p_t^*$ ,  $\Delta i_t^*$ ,  $\Delta i_{t-1}^*$ ,  $\Delta i_{t-1}$ ,  $\Delta r_{t-1}^{\text{arrows}}$

Money demand (MD)				Domestic inflation (P)				Unrestricted money supply (MS1)				Restricted money supply (MS2)			
Parameter	Estimate	Standard error	Prob.	Parameter	Estimate	Standard error	Prob.	Parameter	Estimate	Standard error	Prob.	Parameter	Estimate	Standard error	Prob.
$\beta_0$	0.0053	0.0019	0.0078	$\alpha_0$	-0.0003	0.0005	0.6131	$\gamma_{10}$	0.0058	0.0078	0.4568	$\gamma_{20}$	0.0085	0.0076	0.2684
$\beta_1$	0.2078	0.0509	0.0002	$\alpha_1$	0.5100	0.1883	0.0097	$\gamma_{11}$	-3.1300	6.4000	0.6272	$\gamma_{21}$	-2.9194	6.4168	0.6513
$\beta_2$	-0.7597	0.2869	0.0114	$\alpha_2$	0.0771	0.0453	0.0960	$\gamma_{12}$	0.0963	0.1464	0.5142	$\lambda_2$	-0.9806	0.1278	0.0000
								$\lambda_1$	-0.9742	0.1270	0.0000				
R <sup>2</sup> = 0.6016, SEE = 0.0105, DW = 1.9420				R <sup>2</sup> = 0.5179, SEE = 0.0020, DW = 1.6830				R <sup>2</sup> = 0.8815, SEE = 0.0687, DW = 2.3404				R <sup>2</sup> = 0.8815, SEE = 0.0682, DW = 2.3408			
Test statistic	Value	Distr.	Prob.	Test statistic	Value	Distr.	Prob.	Test statistic	Value	Distr.	Prob.	Test statistic	Value	Distr.	Prob.
J-B	0.0737	$\chi^2(2)$	0.9638	J-B	1.8546	$\chi^2(2)$	0.3956	J-B	0.4443	$\chi^2(2)$	0.8008	J-B	0.3137	$\chi^2(2)$	0.8548
Q <sub>LB</sub> (6)	4.7995	$\chi^2(6)$	0.570	Q <sub>LB</sub> (6)	9.3618	$\chi^2(6)$	0.154	Q <sub>LB</sub> (6)	11.603	$\chi^2(6)$	0.071	Q <sub>LB</sub> (6)	11.617	$\chi^2(6)$	0.071
LM(6)	6.2679	$\chi^2(6)$	0.3939	LM(6)	16.397	$\chi^2(6)$	0.0118	LM(6)	15.4135	$\chi^2(6)$	0.0173	LM(6)	16.333	$\chi^2(6)$	0.0121
ARCH(6)	2.0413	$\chi^2(6)$	0.9159	ARCH(6)	3.5396	$\chi^2(6)$	0.7387	ARCH(6)	7.1933	$\chi^2(6)$	0.3033	ARCH(6)	5.8862	$\chi^2(6)$	0.4361
WHITE	4.6335	$\chi^2(10)$	0.9143	WHITE	23.381	$\chi^2(7)$	0.0015	WHITE	23.391	$\chi^2(9)$	0.0054	WHITE	20.708	$\chi^2(5)$	0.0009
RESET	0.1614	F <sub>3,39</sub>	0.8515	RESET	0.2873	F <sub>3,40</sub>	0.7518	RESET	0.3800	F <sub>3,41</sub>	0.6862	RESET	0.3413	F <sub>3,42</sub>	0.7128
SARGAN	5.5828	$\chi^2(5)$	0.2325	SARGAN	2.4438	$\chi^2(4)$	0.4855	SARGAN	4.3301	$\chi^2(4)$	0.2280	SARGAN	4.1253	$\chi^2(4)$	0.2482

- Notes.
- The standard errors of parameter estimates are corrected for heteroscedasticity and serial correlation in the error term by the Newey-West procedure. Following the suggestion of Newey and West (1987), the truncation lag, q, used to approximate the dynamics of the error term is set as  $q = 4(T/100)^{2/9} \approx 3$ , where T=48 is the number of observations. For a more detailed description of Newey-West method, see eg Eviews User Guide (1995: 197).
  - Parameter estimates of dummy variables in equations (MD) and (P) are not presented in the table. The estimates differ significantly from zero.
  - Tests: **J-B**: The Jarque-Bera test for normality of the error term. **Q<sub>LB</sub>(6)**: The Ljung-Box test for serial correlation of the error term, up to 6 lags. **LM(6)**: The Breusch-Godfrey Lagrange multiplier test for serial correlation of the error term, up to 6 lags. **ARCH(6)**: Lagrange multiplier test for autoregressive conditional heteroscedasticity of the error term, up to 6 lags. **WHITE**: The White test for heteroscedasticity of the error term using squares and cross-products of the regressors, **RESET**: The Ramsey regression specification test for functional form mis-specification, adding powers 2 and 3 of the fitted values to the original regression. **SARGAN**: The Sargan test for the validity of instruments.

## 6.6 Alternative measurements of exchange market pressure and degree of intervention

Table 7 shows the different model-consistent estimates of the conversion factor  $\eta^{kp}$ , where the superscript k equals 1 for the unrestricted and 2 for the restricted form of the monetary policy reaction function, and the superscript p equals b for the broad and n for the narrow measure of central bank foreign exchange intervention. Two reference factors are also presented. First, the conversion factor denoted by the superscripts wp ( $\eta^{wp}$ ) is calculated by ignoring the monetary policy reaction functions (5.6') and (5.6'') and assuming that the central bank always leaves its foreign exchange interventions completely unsterilized, ie  $\lambda=0$ . Such a model was used by Weymark (1995) when she estimated exchange market pressure and the degree of exchange market intervention for Canada. Second, the model-independent conversion factor suggested by Eichengreen and Rose and Wyplosz (1995) and denoted by the superscripts erwp ( $\eta^{erwp}$ ) is calculated by equalizing the conditional volatilities of the change in the exchange rate,  $\Delta e_t$ , and the unsterilized foreign exchange interventions,  $\Delta r_t^{\text{broad}}$  and  $\Delta r_t^{\text{narrow}}$ .

Table 7. **Estimates of the conversion factors**

$\Delta r_t^{\text{broad}}$	$\Delta r_t^{\text{narrow}}$
$\eta^{1b} = -0.0351$	$\eta^{1n} = -0.0258$
$\eta^{2b} = -0.0169$	$\eta^{2n} = -0.0183$
$\eta^{wb} = -1.2010$	$\eta^{wn} = -1.1950$
$\eta^{\text{erwb}} = -0.0645$	$\eta^{\text{erwn}} = -0.0906$

$\eta^{kp}$  where k equals 1 for the model including unrestricted money supply equation, 2 for the model including restricted money supply equation, w for the model excluding the money supply equation, and erw for the model-independent conversion factor.

The formula for the model-consistent conversion factor is

$$\eta^{1p} = \frac{-1}{\gamma_{11}\alpha_2 + \beta_2} \quad (6.3)$$

for the unrestricted form of money supply equation and

$$\eta^{2p} = \frac{-1}{(1 + \gamma_{21})\alpha_2 + \beta_2} \quad (6.4)$$

for the restricted form of the money supply equation.

The alternative formulae for calculating exchange market pressure and degree of central bank intervention are as follows. First, when the central bank is assumed to sterilize part of its foreign exchange interventions, the formulae for exchange market pressure and degree of central bank intervention are

$$EMP_t^{kp} = \Delta e_t + \eta^{kp}(1 - \lambda^{kp})\Delta r_t^p \quad (6.5)$$

and

$$\omega_t^{kp} = \frac{\eta^{kp}(1 - \lambda^{kp})\Delta r_t^p}{EMP_t^{kp}}. \quad (6.6)$$

Second, when the money supply equations (5.6') and (5.6'') are ignored and the central bank is assumed to leave its foreign exchange interventions completely unsterilized, the formulae for exchange market pressure and degree of intervention are

$$EMP_t^{wp} = \Delta e_t + \eta^{wp}\Delta r_t^p \quad (6.7)$$

and

$$\omega_t^{wp} = \frac{\eta^{wp}\Delta r_t^p}{EMP_t^{wp}}, \quad (6.8)$$

where the formula for the conversion factor is as suggested by Weymark (1995):

$$\eta^{wp} = \frac{-1}{\alpha_2 + \beta_2}. \quad (6.9)$$

Deriving the conversion factor  $\eta^{wp}$  is straightforward and hence is not presented here. One can do it by introducing the change in domestic credit,  $\Delta d_t$ , as an exogenous variable in the vector of exogenous variables  $X_t$  presented in equation (5.16), eliminating the the fourth row from the vector  $X_t$  and the fourth row and column from the coefficient matrix  $A(L)$  presented in equation (5.17), and then solving the model. The estimates of  $\alpha_2$  and  $\beta_2$  obtained above are valid also in the case of the Weymark model. Because the equations are estimated one at a time, dropping the alternative monetary policy reaction functions (5.6') and (5.6'') from the model and assuming that having the sterilization coefficient,  $\lambda$ , equal to zero does not affect the estimates of  $\alpha_2$  and  $\beta_2$  as long as the list of instruments remains unchanged.

Third, the model-independent measures of exchange market pressure and degree of intervention are

$$EMP_t^{erwp} = \Delta e_t + \eta^{erwp} \Delta r_t^p \quad (6.10)$$

and

$$\omega_t^{erwp} = \frac{\eta^{erwp} \Delta r_t^p}{EMP_t^{erwp}}. \quad (6.11)$$

To form the model-independent conversion factor  $\eta^{erwp}$ ,  $\Delta e_t$  is chosen as a reference variable. This means that, to equalize the conditional volatilities of  $\Delta e_t$  and  $\Delta r_t^p$ , the conversion factor is calculated as the ratio of the standard deviations of the time series:

$$\eta^{erwp} = - \left( \frac{\text{var}(\Delta e_t)}{\text{var}(\Delta r_t^p)} \right)^{\frac{1}{2}}. \quad (6.12)$$

As can be seen from table 7, the conversion factors obtained in the Weymark model are at least ten or even many tens of times larger than those obtained in my model or those suggested by Eichengreen and Rose and Wyplosz (1995). Hence whether the monetary policy reaction function is included has a considerable effect on the value of the

conversion factor and on the values of exchange market pressure and degree of central bank intervention.

According to equations (3.1') and (3.3'), the larger the conversion factor, the more the central bank's foreign exchange interventions dominate the measure of exchange market pressure. In practice, the volatility of foreign exchange interventions is typically considerably greater than the volatility of the exchange rate. In their study of twenty-two mostly OECD countries, Eichengreen and Rose and Wyplosz (1996: 205) find the volatility of interventions to be 12.5 times larger than the volatility of the exchange rate. In the Finnish data the volatility of interventions is 11 to 15.5 times larger than that of the exchange rate, depending on the measure of foreign exchange interventions. This means that, absent scaling of the components of the measure of exchange market pressure, the foreign exchange interventions determine the pressure almost completely and the proportion of pressure that is relieved by the intervention activity of the central bank is necessarily nearly 100%. Under these circumstances it is very hard to find degrees of intervention policy,  $\omega_t$ , that are significantly different from unity, ie to find any significant evidence of a floating exchange rate even if the exchange rate is allowed to float quite freely.

This is a problem also in the seminal work of Girton and Roper (1977) where the measure of exchange market pressure is simply the sum of the change in the exchange rate and the central bank's foreign exchange interventions, ie  $EMP_t^{gp} = \Delta e_t + \Delta r_t^p$ . Because in the Weymark model the conversion factor  $\eta^{wp}$  is larger than unity, the dominance of foreign exchange interventions gets even more serious. In fact, one reason that Eichengreen and Rose and Wyplosz (1995) introduced their model-independent measure of exchange market pressure was to solve the problem of widely differing volatilities of the components of the measure and the resulting dominance of foreign exchange interventions.

### 6.6.1 Measurements of exchange market pressure

Figures 3a and 3b and table 8 provide measurements of exchange market pressure using alternative measures of foreign exchange intervention and alternative model constructions. They also clarify the problems arising from a large conversion factor and the resulting dominance of foreign exchange interventions.

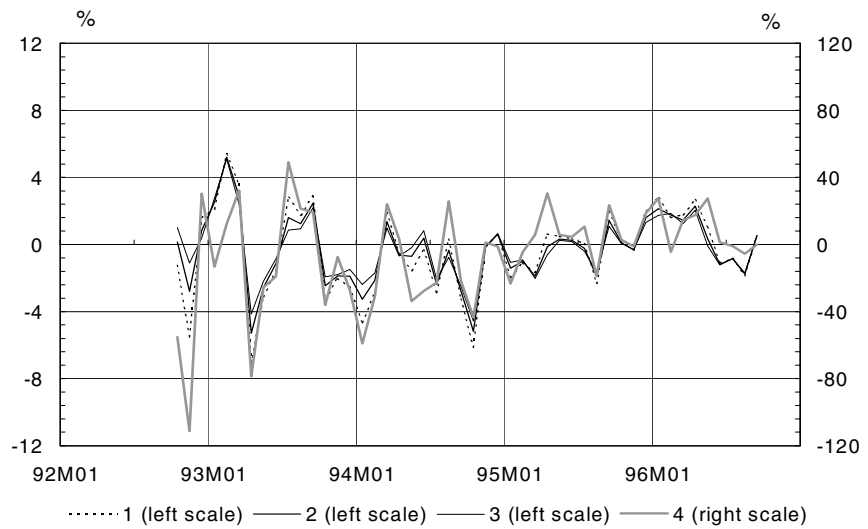
There are three general conclusions that can be drawn on the basis of figures 3a and 3b. First, there are some qualitative differences between the measurements ie the sign of the pressure depends to some extent on

the model. From time to time, the model-consistent measure derived in Weymark (1995) produces measurements which are opposite from those of model-consistent measures derived in this paper and from those of the Eichengreen-Rose-Wyplosz model-independent measure. Second, the measurements using my model-consistent and the Eichengreen-Rose-Wyplosz model-independent measures seem to go more or less hand in hand with each other, especially when the broad measure of foreign exchange intervention is used. Third, and most strikingly, the scale of the Weymark measurement is ten times larger than the scale of the other measurements. While the range of the next volatile Eichengreen-Rose-Wyplosz measurements is from +5.4% depreciation to -7.1% appreciation when the broad measure of foreign exchange intervention is used and from +8.6% depreciation to -6.5% appreciation when the narrow measure is used, the range of the Weymark measurements is from +49.0% depreciation to -111.2% appreciation and from +59.0% depreciation to -66.4% appreciation respectively. It is hard to believe that the magnitude of money market disequilibrium would be so high that the exchange rate should have changed 60% or 100% in order to remove that disequilibrium. Therefore, if the money supply equations and the sterilization of foreign exchange interventions are ignored, the model-consistent measure gives the direction of the pressure but not the actual rate of exchange rate change which would be needed to remove the money market disequilibrium.



Figure 3a.

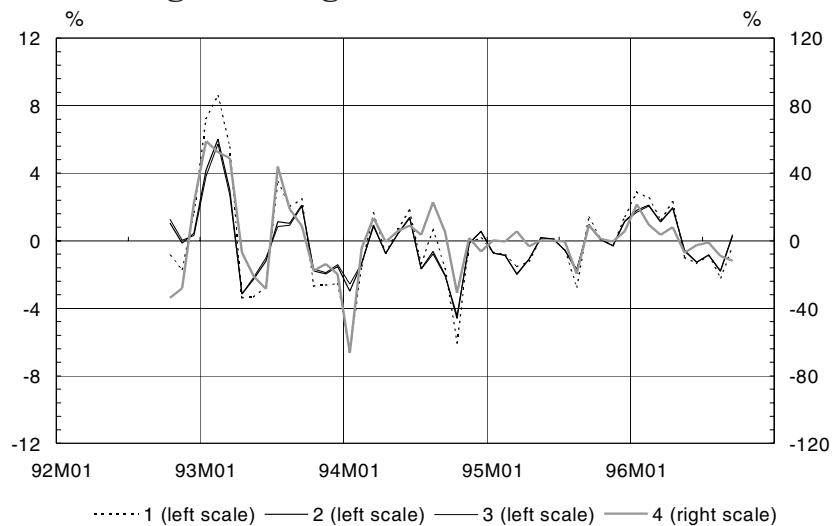
### Exchange market pressure using the broad measure of foreign exchange intervention



- 1 equalized conditional volatilities
- 2 model with endogenous money supply (unrestricted eq.) and sterilization
- 3 model with endogenous money supply (restricted eq.) and sterilization
- 4 model with exogenous money supply and nonsterilization

Figure 3b.

### Exchange market pressure using narrow measure of foreign exchange intervention



- 1 equalized conditional volatilities
- 2 model with endogenous money supply (unrestricted eq.) and sterilization
- 3 model with endogenous money supply (restricted eq.) and sterilization
- 4 model with exogenous money supply and nonsterilization

Table 8.

**Exchange market pressure using alternative  
measures of foreign exchange intervention and  
alternative models**

Date	EMP <sup>erwb</sup>	EMP <sup>1b</sup>	EMP <sup>2b</sup>	EMP <sup>wb</sup>	EMP <sup>erwn</sup>	EMP <sup>1n</sup>	EMP <sup>2n</sup>	EMP <sup>wn</sup>
92M10	-0.012	0.002	0.010	-0.552	-0.009	0.010	0.013	-0.339
92M11	-0.055	-0.028	-0.011	-1.112	-0.017	-0.001	0.000	-0.282
92M12	0.016	0.008	0.004	0.303	0.017	0.004	0.003	0.224
93M01	0.021	0.025	0.028	-0.132	0.072	0.042	0.038	0.590
93M02	0.054	0.052	0.051	0.123	0.086	0.060	0.057	0.523
93M03	0.036	0.029	0.024	0.322	0.056	0.030	0.027	0.490
93M04	-0.071	-0.053	-0.041	-0.786	-0.034	-0.032	-0.031	-0.070
93M05	-0.031	-0.026	-0.022	-0.254	-0.033	-0.023	-0.022	-0.212
93M06	-0.016	-0.011	-0.009	-0.192	-0.027	-0.012	-0.010	-0.284
93M07	0.028	0.016	0.009	0.490	0.035	0.011	0.008	0.439
93M08	0.018	0.013	0.009	0.214	0.020	0.010	0.009	0.188
93M09	0.029	0.025	0.022	0.193	0.025	0.021	0.021	0.088
93M10	-0.033	-0.025	-0.019	-0.361	-0.027	-0.018	-0.017	-0.178
93M11	-0.020	-0.019	-0.018	-0.074	-0.026	-0.020	-0.019	-0.139
93M12	-0.025	-0.019	-0.015	-0.272	-0.026	-0.015	-0.014	-0.199
94M01	-0.047	-0.033	-0.024	-0.590	-0.065	-0.030	-0.026	-0.664
94M02	-0.029	-0.021	-0.017	-0.308	-0.015	-0.014	-0.013	-0.044
94M03	0.019	0.013	0.010	0.241	0.016	0.009	0.009	0.135
94M04	-0.005	-0.006	-0.007	0.032	-0.007	-0.007	-0.007	-0.007
94M05	-0.015	-0.007	-0.002	-0.338	0.007	0.004	0.004	0.056
94M06	-0.003	0.004	0.008	-0.276	0.018	0.014	0.013	0.089
94M07	-0.029	-0.024	-0.021	-0.226	-0.014	-0.016	-0.017	0.035
94M08	0.003	-0.003	-0.008	0.259	0.007	-0.006	-0.008	0.228
94M09	-0.032	-0.028	-0.025	-0.216	-0.017	-0.020	-0.021	0.049
94M10	-0.061	-0.052	-0.046	-0.436	-0.061	-0.046	-0.044	-0.309
94M11	-0.001	-0.001	-0.002	0.012	-0.001	-0.001	-0.002	0.015
94M12	0.006	0.006	0.007	-0.013	0.001	0.005	0.006	-0.064
95M01	-0.020	-0.014	-0.011	-0.233	-0.007	-0.007	-0.007	0.003
95M02	-0.011	-0.010	-0.009	-0.045	-0.008	-0.009	-0.009	-0.004
95M03	-0.017	-0.019	-0.020	0.060	-0.015	-0.020	-0.020	0.056
95M04	0.006	-0.001	-0.006	0.305	-0.012	-0.011	-0.011	-0.033
95M05	0.005	0.003	0.003	0.058	0.002	0.002	0.002	0.002
95M06	0.004	0.002	0.002	0.046	0.001	0.001	0.001	0.001
95M07	0.000	-0.002	-0.004	0.108	-0.006	-0.006	-0.006	-0.006
95M08	-0.023	-0.019	-0.016	-0.190	-0.028	-0.018	-0.017	-0.193
95M09	0.020	0.014	0.011	0.236	0.014	0.009	0.009	0.091
95M10	0.002	0.001	0.001	0.028	0.001	0.001	0.001	0.010
95M11	-0.003	-0.003	-0.003	-0.013	-0.003	-0.003	-0.003	-0.006
95M12	0.020	0.016	0.013	0.188	0.014	0.012	0.011	0.057
96M01	0.028	0.021	0.017	0.273	0.029	0.018	0.017	0.214
96M02	0.016	0.018	0.019	-0.044	0.025	0.021	0.021	0.095
96M03	0.018	0.015	0.012	0.145	0.012	0.011	0.011	0.035
96M04	0.027	0.023	0.020	0.175	0.023	0.020	0.019	0.079
96M05	0.010	0.004	-0.001	0.274	-0.010	-0.006	-0.006	-0.071
96M06	-0.011	-0.012	-0.012	0.014	-0.013	-0.013	-0.013	-0.026
96M07	-0.008	-0.008	-0.008	-0.009	-0.009	-0.008	-0.008	-0.012
96M08	-0.019	-0.018	-0.017	-0.054	-0.022	-0.018	-0.018	-0.089
96M09	0.005	0.005	0.006	0.000	-0.004	0.003	0.004	-0.118

EMP<sup>erwb</sup> = Exchange market pressure with equalized conditional volatility and broad measure of foreign exchange interventions

EMP<sup>erwn</sup> = Exchange market pressure with equalized conditional volatility and narrow measure of foreign exchange interventions

EMP<sup>1b</sup> = Exchange market pressure with endogenous money supply (unrestricted), sterilization and broad measure of foreign exchange interventions

EMP<sup>1n</sup> = Exchange market pressure with endogenous money supply (unrestricted), sterilization and narrow measure of foreign exchange interventions

EMP<sup>2b</sup> = Exchange market pressure with endogenous money supply (restricted), sterilization and broad measure of foreign exchange interventions

EMP<sup>2n</sup> = Exchange market pressure with endogenous money supply (restricted), sterilization and narrow measure of foreign exchange interventions

EMP<sup>wb</sup> = Exchange market pressure with exogenous money supply, nonsterilization and broad measure of foreign exchange interventions

EMP<sup>wn</sup> = Exchange market pressure with exogenous money supply, nonsterilization and narrow measure of foreign exchange interventions

## 6.6.2 Measurements of the degree of intervention

The fact that ignoring the sterilization of foreign exchange interventions results in degrees of central bank intervention close to 1 can be seen in figures 4a and 4b, which show the degrees of intervention using alternative measures of foreign exchange intervention and model constructions. Before drawing any conclusions on the basis of figure 4a and 4b, a technicality should be noted. As derived in chapter 5 above, the degree of central bank intervention can be determined as a function of the central bank's exchange rate policy response coefficient,  $\omega_t = \omega(\rho_t^{kp})$ :

$$\omega_t^{1p} = \frac{(1 - \lambda)\rho_t^p}{(1 - \lambda)\rho_t^p + \gamma_1\alpha_2 + \beta_2} \quad (6.13)$$

$$\omega_t^{2p} = \frac{(1 - \lambda)\rho_t^p}{(1 - \lambda)\rho_t^p + (1 + \gamma_1)\alpha_2 + \beta_2},$$

where superscript k indicates the form of money supply equation used and p the broad or narrow measure of foreign exchange intervention. The equations are also presented in figure 1 above in chapter 5.

When  $\rho_t^p = \infty$ , the central bank uses foreign exchange intervention to hold the exchange rate fixed, ie  $\omega_t^{kp} = 1$ . When  $\rho_t^p = 0$ , the central bank allows the exchange rate to float freely, ie  $\omega_t^{kp} = 0$ ; there are no foreign exchange interventions and hence no changes in the domestic money supply due to foreign exchange interventions. Values  $0 < \rho_t^p < \infty$  characterize intermediate intervention policies where the central bank dampens appreciation and depreciation pressure by purchasing and selling foreign bonds, implying  $0 < \omega_t^{kp} < 1$ . Because the equations are discontinuous, the central bank's intervention policy is interpreted to be completely different depending on whether the response coefficient  $\rho_t^p$  is larger or smaller than the limit value,  $\rho^{kp}$ , at which the denominator is equal to zero. The alternative limit values depend on the model used and on the measure of foreign exchange intervention. When  $\rho^{kp} < \rho_t^p < 0$ , the central bank's actions magnify the change in the exchange rate, implying  $\omega_t^{kp} < 0$ ; the central bank actively depreciates (appreciates) the domestic currency with respect to its free float value when there is excess supply of (demand for) the domestic currency and the exchange rate is already depreciating (appreciating). When  $\rho_t^p < \rho^{kp}$ , the central bank aggressively reverses the exchange rate movement, implying  $\omega_t^{kp} > 1$ ; the exchange rate is observed to move in the opposite direction to what would have

occurred in the absence of central bank intervention. The alternative limit values,  $\rho^{kp}$ , are listed in table 9.

Table 9.

**Discontinuity of the degree of central bank intervention,  $\omega_t^{kp} = \omega(\rho_t^p)$ , using alternative measures of foreign exchange intervention and alternative model constructions**

$\Delta r_t^{\text{broad}}$	$\Delta r_t^{\text{narrow}}$
$\rho^{1b} = -28.4858$	$\rho^{1n} = -38.7589$
$\rho^{2b} = -59.0341$	$\rho^{2n} = -54.6804$
$\rho^{wb} = -0.8326$	$\rho^{wn} = -0.8368$
$\rho^{\text{erwb}} = -15.5050$	$\rho^{\text{erwn}} = -11.0318$

$\rho^{kp}$  where k equals 1 for the model including unrestricted money supply equation, 2 for the model including restricted money supply equation, w for the model excluding the money supply equation, and erw for the model-independent conversion factor.

In practice the non-linearity and discontinuity of equations (5.27) and (5.27') means that if  $\rho_t^p$  is sufficiently close to the relevant limit value,  $\rho^{kp}$ , the degree of central bank intervention becomes very large, which makes the intervention policy difficult to interpret and to visualize. This inconvenience increases as the absolute value of  $\rho^{kp}$  decreases. For example, if the money supply equations (5.6') and (5.6'') are ignored and the central bank is assumed to leave its foreign exchange interventions completely unsterilized as in Weymark (1995), the discontinuity occurs when  $\rho^{wp}$  is very close to zero. This means that the possibility that the central bank magnifies changes in the exchange rate, ie  $\rho^{wp} < \rho_t^p < 0$ , is very small, and if this really happens, the degree of intervention policy,  $\omega_t^{wp}$ , is necessarily a very large number. To avoid this problem the extreme values of  $\omega_t^{kp}$  are replaced by 2 if  $\omega_t^{kp}$  is larger than 2 and by -1 if  $\omega_t^{kp}$  is smaller than -1. The adjusted degrees of central bank intervention using alternative measures of foreign exchange intervention and alternative model constructions are presented in table 10.

Table 10.

**Degree of central bank intervention using  
alternative measures of foreign exchange  
intervention and alternative models**

Date	$\omega^{erwb}$	$\omega^{lb}$	$\omega^{2b}$	$\omega^{wb}$	$\omega^{erwn}$	$\omega^{ln}$	$\omega^{2n}$	$\omega^{wn}$
92M10	<b>2</b>	<b>-1</b>	-0.79	1.03	2	-0.74	-0.43	1.05
92M11	1.09	1.17	1.43	1.00	1.28	<b>2</b>	<b>-1</b>	1.02
92M12	1.03	1.05	1.10	1.00	1.02	1.09	1.13	1.00
93M01	-0.41	-0.19	-0.08	1.23	0.59	0.29	0.22	0.95
93M02	0.07	0.04	0.02	0.59	0.42	0.17	0.13	0.90
93M03	0.45	0.31	0.18	0.94	0.64	0.34	0.27	0.96
93M04	0.57	0.42	0.26	0.96	0.09	0.03	0.02	0.56
93M05	0.40	0.27	0.15	0.93	0.44	0.18	0.14	0.91
93M06	0.63	0.48	0.31	0.97	0.78	0.50	0.42	0.98
93M07	0.94	0.89	0.80	1.00	0.95	0.84	0.79	1.00
93M08	0.63	0.49	0.31	0.97	0.68	0.38	0.30	0.97
93M09	0.32	0.21	0.11	0.90	0.21	0.07	0.05	0.78
93M10	0.56	0.41	0.25	0.96	0.46	0.20	0.15	0.92
93M11	0.15	0.09	0.05	0.77	0.35	0.13	0.10	0.88
93M12	0.55	0.40	0.25	0.96	0.56	0.26	0.20	0.94
94M01	0.66	0.51	0.34	0.97	0.76	0.47	0.38	0.98
94M02	0.55	0.40	0.24	0.96	0.16	0.05	0.04	0.71
94M03	0.66	0.51	0.33	0.97	0.60	0.30	0.23	0.95
94M04	-0.39	-0.18	-0.08	1.24	0	0	0	0
94M05	1.18	1.40	<b>2</b>	1.01	0.58	0.29	0.22	0.95
94M06	<b>2</b>	<b>-1</b>	-0.50	1.04	0.32	0.12	0.09	0.86
94M07	0.39	0.26	0.14	0.92	-0.29	-0.07	-0.05	1.51
94M08	<b>2</b>	<b>-1</b>	-0.50	1.04	<b>2</b>	-0.83	-0.47	1.05
94M09	0.32	0.21	0.11	0.90	-0.32	-0.08	-0.05	1.45
94M10	0.35	0.22	0.12	0.91	0.34	0.13	0.09	0.87
94M11	-0.68	-0.28	-0.12	1.15	<b>-1</b>	-0.25	-0.17	1.12
94M12	-0.19	-0.09	-0.04	1.52	<b>-1</b>	-0.29	-0.19	1.11
95M01	0.62	0.47	0.30	0.97	-0.12	-0.03	-0.02	<b>2</b>
95M02	0.18	0.11	0.06	0.81	-0.05	-0.01	-0.01	<b>-1</b>
95M03	-0.26	-0.12	-0.06	1.36	-0.38	-0.09	-0.06	1.38
95M04	<b>2</b>	<b>-1</b>	-0.73	1.03	0.14	0.04	0.03	0.68
95M05	0.63	0.48	0.31	0.97	0	0	0	0
95M06	0.68	0.53	0.36	0.98	0	0	0	0
95M07	<b>2</b>	<b>-1</b>	-0.40	1.05	0	0	0	0
95M08	0.40	0.27	0.15	0.93	0.49	0.22	0.16	0.93
95M09	0.62	0.47	0.30	0.97	0.45	0.19	0.14	0.92
95M10	0.81	0.70	0.52	0.99	0.68	0.37	0.30	0.96
95M11	0.16	0.09	0.05	0.78	0.08	0.02	0.02	0.54
95M12	0.47	0.33	0.19	0.94	0.25	0.08	0.06	0.81
96M01	0.50	0.35	0.21	0.95	0.52	0.24	0.18	0.94
96M02	-0.21	-0.10	-0.05	1.44	0.23	0.08	0.06	0.79
96M03	0.41	0.27	0.15	0.93	0.15	0.05	0.03	0.70
96M04	0.32	0.20	0.11	0.90	0.20	0.07	0.05	0.77
96M05	1.45	<b>2</b>	<b>-1</b>	1.02	0.52	0.24	0.18	0.93
96M06	-0.13	-0.07	-0.03	1.90	0.07	0.02	0.02	0.51
96M07	0.00	0.00	0.00	0.06	0.03	0.01	0.01	0.27
96M08	0.11	0.06	0.03	0.69	0.25	0.09	0.06	0.81
96M09	-0.05	-0.03	-0.01	<b>-1</b>	<b>2</b>	-0.92	-0.52	1.05

$\omega^{erwb}$  = The degree of intervention policy with equalized conditional volatility and broad measure of foreign exchange interventions

$\omega^{erwn}$  = The degree of intervention policy with equalized conditional volatility and narrow measure of foreign exchange interventions

$\omega^{lb}$  = The degree of intervention policy with endogenous money supply (unrestricted), sterilization and broad measure of foreign exchange interventions

$\omega^{ln}$  = The degree of intervention policy with endogenous money supply (unrestricted), sterilization and narrow measure of foreign exchange interventions

$\omega^{2b}$  = The degree of intervention policy with endogenous money supply (restricted), sterilization and broad measure of foreign exchange interventions

$\omega^{2n}$  = The degree of intervention policy with endogenous money supply (restricted), sterilization and narrow measure of foreign exchange interventions

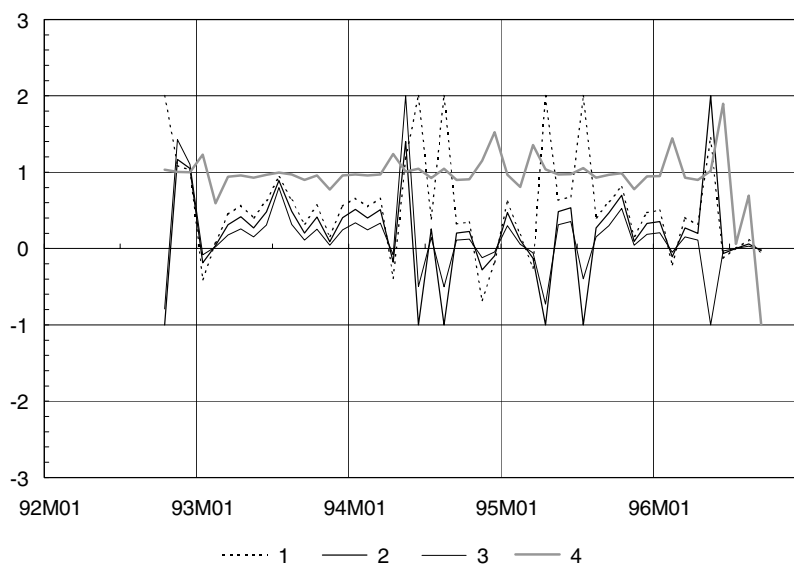
$\omega^{wb}$  = The degree of intervention policy with exogenous money supply, nonsterilization and broad measure of foreign exchange interventions

$\omega^{wn}$  = The degree of intervention policy with exogenous money supply, nonsterilization and narrow measure of foreign exchange interventions

There are four general conclusions that can be drawn on the basis of figures 4a and 4b presenting the alternative degrees of intervention policy. First, if the money supply equations are ignored and the central bank is assumed to leave its foreign exchange interventions completely unsterilized, it is very hard to find degrees of intervention,  $\omega_t^{wp}$ , that are significantly different from unity, especially when the broad measure of foreign exchange intervention is used. This means that any substantial evidence supporting the assumption of a floating exchange rate would be hard to find even if the exchange rate were actually allowed to float quite freely. Second, the non-linearity and discontinuity of the degree of intervention policy is a problem. When the policy response coefficient  $\rho_t^p$  is sufficiently close to the relevant limit value,  $\rho^{kp}$ , it may fall on either side of the limit quite accidentally, depending on the model construction. Therefore, depending on the model construction, the same foreign exchange intervention may be interpreted to reflect totally different intervention policies, ie magnifying or aggressively reversing the exchange rate movement. Third, the narrow measure of foreign exchange intervention seems to give more nicely behaving degrees of intervention than the broad measure of intervention. Fourth, the two model-consistent degrees of intervention derived in this paper,  $\omega_t^{lp}$  and  $\omega_t^{2p}$ , give a rather similar picture of the intervention activity of the central bank.

Figure 4a.

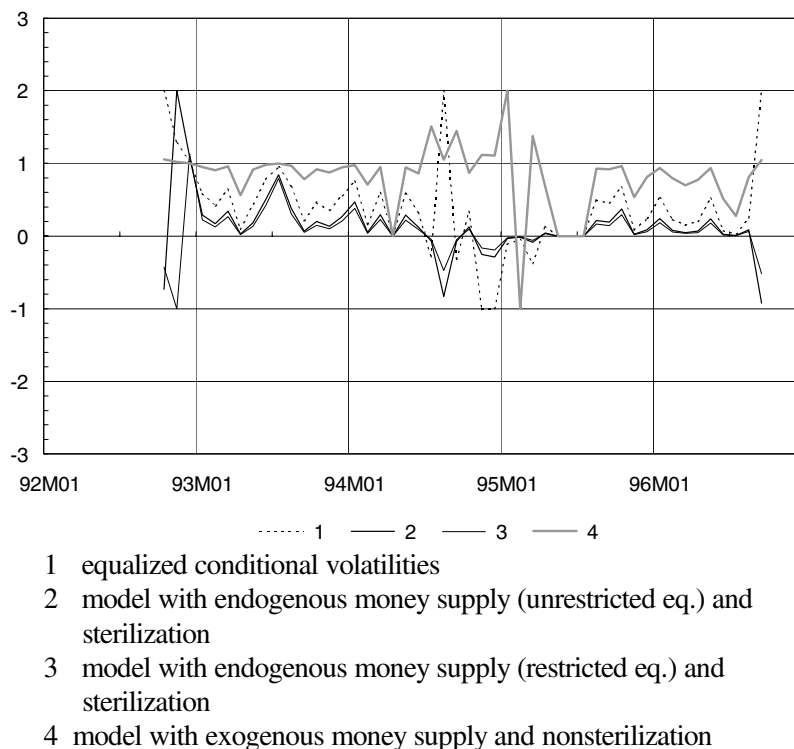
**Degree of intervention using the broad measure of foreign exchange intervention**



- 1 equalized conditional volatilities
- 2 model with endogenous money supply (unrestricted eq.) and sterilization
- 3 model with endogenous money supply (restricted eq.) and sterilization
- 4 model with exogenous money supply and nonsterilization

Figure 4b.

**Degree of intervention using the narrow measure of foreign exchange intervention**



**6.6.3 Effects of alternative measures of foreign exchange intervention**

Figures 5a–5d illustrate the effect of the two alternative measures of foreign exchange intervention on the measurements of exchange market pressure. Figures 5a and 5b give the values of the model-consistent measure in the cases in which the underlying model includes the unrestricted money supply equation (5.6') and the restricted money supply equation (5.6'') respectively. Figure 5c gives the values of the model-independent measure suggested by Eichengreen and Rose and Wyplosz (1995). Finally, figure 5d gives the values of the model-consistent measure in the case in which money supply is assumed to be exogenous and the central bank is assumed to leave its foreign exchange interventions completely unsterilized, as suggested by Weymark (1995).

The main conclusion that can be drawn on the basis of figures 5a–5d is that the smaller the conversion factor,  $\eta$ , in the composite index of exchange market pressure, the smaller the difference between the measurements of the exchange market pressure using the broad and narrow measures of foreign exchange intervention. In other words, the

way in which foreign exchange interventions are measured does not matter as long as conversion factor,  $\eta$ , is small. The reason behind this result is straightforward. As can be seen in figure 2 above, broadly and narrowly defined foreign exchange intervention differ quite considerably from time to time. Now, absent any scaling of the components of the measure of exchange market pressure, the foreign exchange interventions dominate the measure. While the conversion factor,  $\eta$ , reduces the dominance of foreign exchange intervention in the measure, it also reduces the effect of the difference between broadly and narrowly defined interventions on the measure. Therefore, as can be seen from table 7 and figures 5a–5d, the difference between the values of measures of exchange market pressure are the smallest in the case of the smallest conversion factors,  $\eta^{2b}$  and  $\eta^{2n}$ , and the difference is largest in the case of the largest conversion factors,  $\eta^{wb}$  and  $\eta^{wn}$ .

Finally, the effect of the two alternative measures of foreign exchange intervention on the measurements of the degree of intervention are described in figures 6a–6d. Again, figures 6a and 6b give the values of the model-consistent measure in the cases of the unrestricted (5.6') and restricted money supply equation (5.6'') respectively; figure 6c gives the values of model-independent measure and figure 6d the values of model-consistent measure in the case of exogenous money supply and unsterilized foreign exchange interventions.

Figure 5a. **Exchange market pressure with endogenous money supply (unrestricted eq.), sterilization and two alternative measures of foreign exchange intervention**

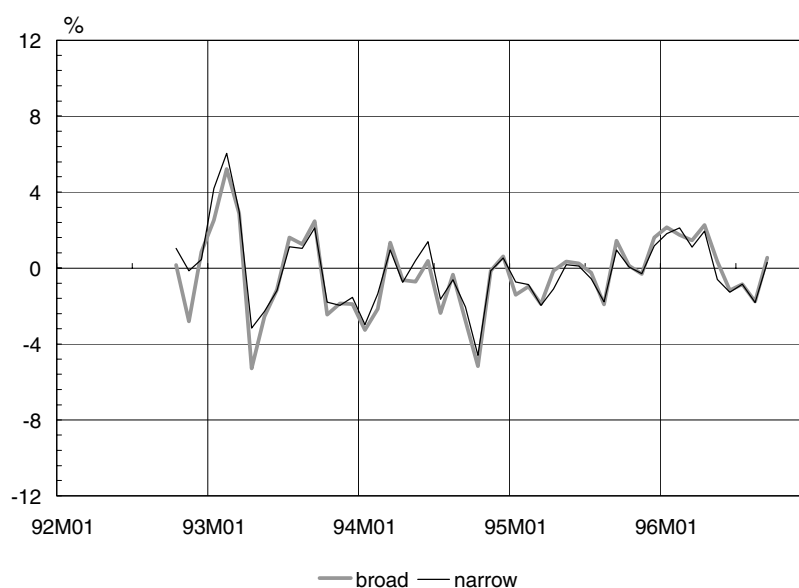




Figure 5b.

**Exchange market pressure with endogenous money supply (restricted eq.), sterilization and two alternative measures of foreign exchange intervention**

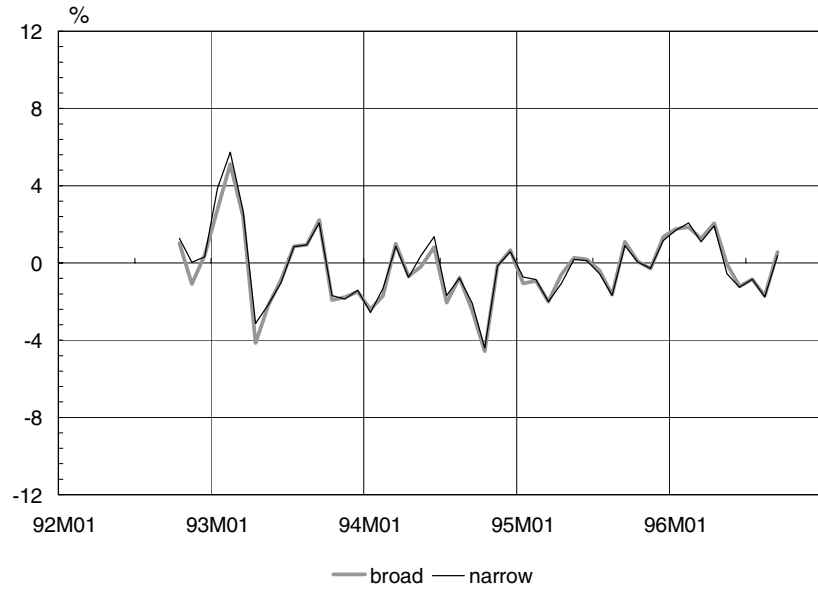


Figure 5c.

**Exchange market pressure with equalized conditional volatility and two alternative measures of foreign exchange intervention**

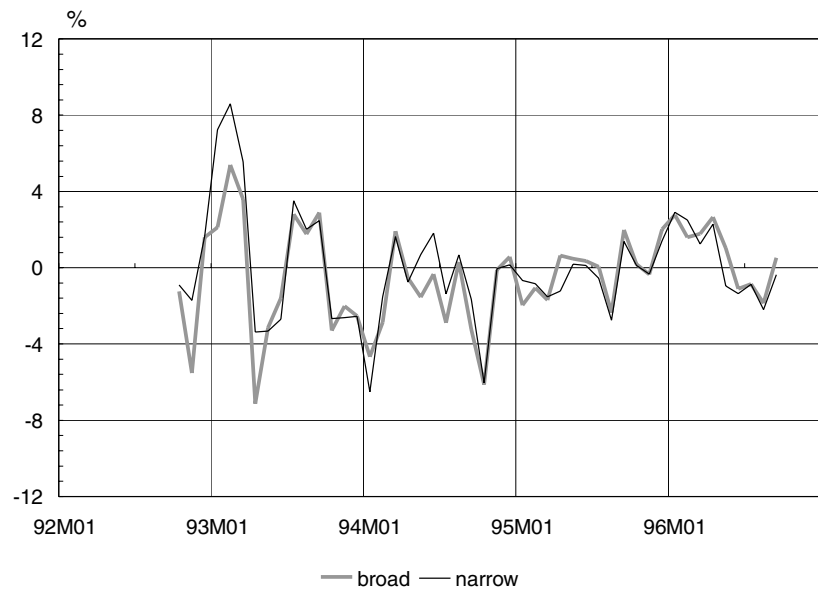
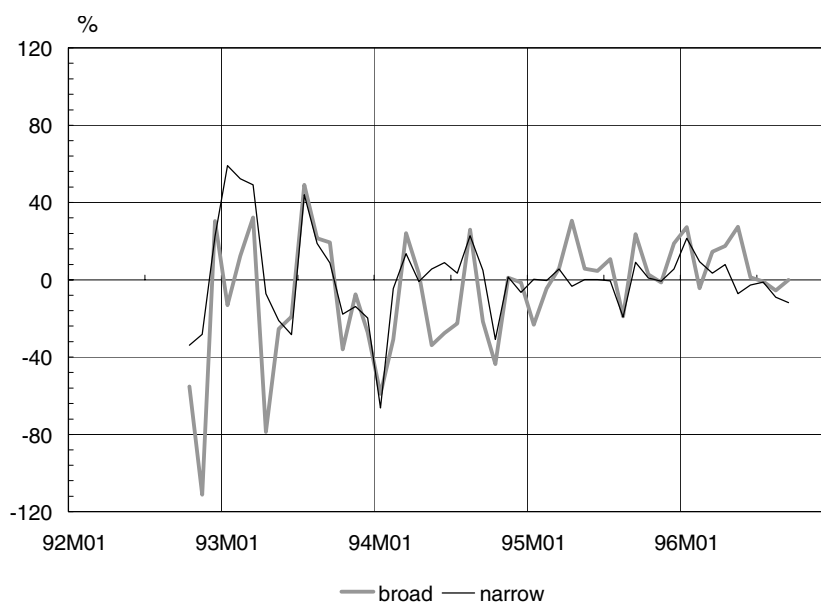


Figure 5d.

**Exchange market pressure with exogenous money supply, nonsterilization and two alternative measures of foreign exchange intervention**



Now, the main conclusion is that the degree of intervention seems to behave more nicely, ie fewer values lie outside the  $[0,1]$  range and also fewer large and small values need to be replaced by adjusted values +2 and -1 respectively, when foreign exchange interventions are defined narrowly than when they are defined broadly. One reason behind this result might be that the central government's foreign exchange transactions with the Bank of Finland are completely independent of foreign exchange policy considerations. If these transactions are conducted according to a prespecified schedule, the likelihood that they do not fit into the overall picture of managing the exchange rate development increases. In practice, this could result in an increased number of foreign exchange interventions which magnify or aggressively reverse the exchange rate movement. This could be one reason to concentrate on the narrow measure of foreign exchange interventions, excluding the central government's foreign exchange transactions with the Bank of Finland. In fact, in what follows, the exchange market pressure and the degree of intervention in Finland during the floating exchange rate regime are analyzed using measures which are estimated with narrowly defined foreign exchange interventions.

Figure 6a.

**Degree of intervention with endogenous money supply (unrestricted eq.), sterilization and two alternative measures of foreign exchange intervention**

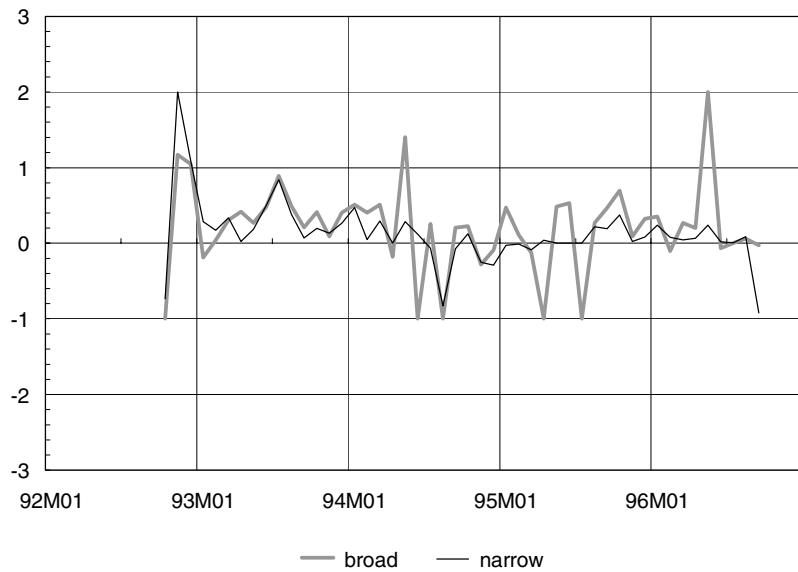


Figure 6b.

**Degree of intervention with endogenous money supply (restricted eq.), sterilization and two alternative measures of foreign exchange intervention**

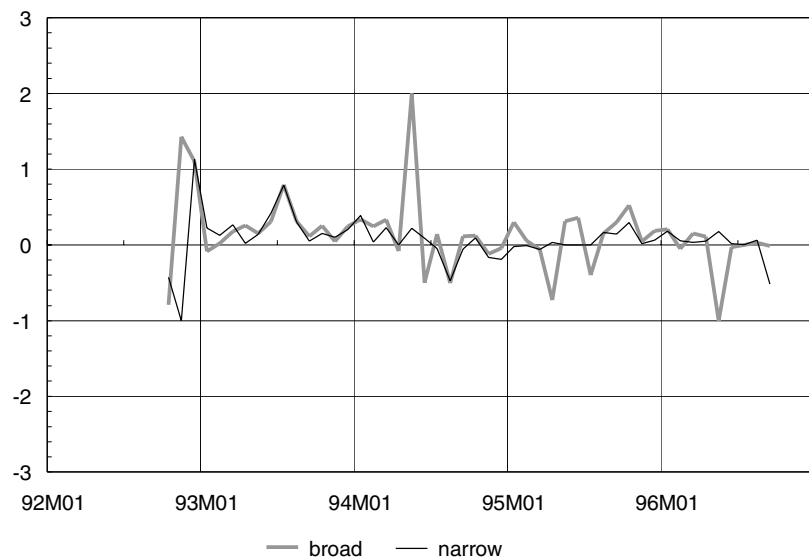


Figure 6c.

**Degree of intervention with equalized conditional volatility and two alternative measures of foreign exchange intervention**

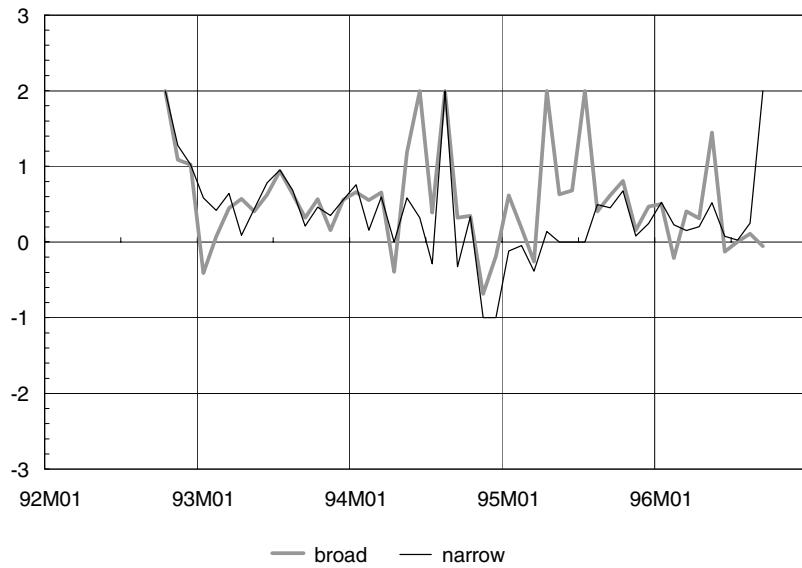
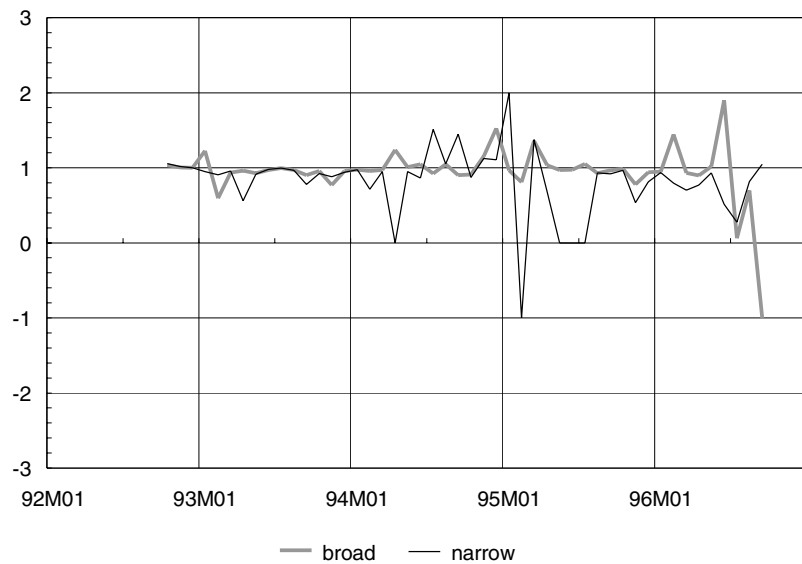


Figure 6d.

**Degree of intervention with exogenous money supply, nonsterilization and two alternative measures of foreign exchange intervention**



## 7 Exchange market pressure and the Bank of Finland's intervention policy during the float of the markka

The Finnish markka was allowed to float from 8 September 1992 to 11 October 1996. During these four years, the Bank of Finland publicly maintained that it purchased and sold foreign currency in the foreign exchange market and influenced the exchange rate of markka only to smooth large day-to-day or intraday fluctuations, which would imply a degree of intervention in the range  $[0,1]$ . In this chapter, the pressure on the markka and the Bank of Finland's reaction to that pressure are analyzed using the measures derived and estimated respectively in chapters 5 and 6 above. To some extent, the analysis is also based on Pösö and Spolander (1996). The main objective is to determine how clean or dirty the float was and whether the Bank of Finland's reactions to appreciation and depreciation pressures were symmetric or asymmetric.

The development of the trade-weighted currency index shown in figure 7 and the development of the Bank of Finland's foreign exchange reserves plus forward position shown in figure 8 describe the overall context of measuring exchange market pressure during the markka float. After the decision to float in September, the markka continued to depreciate and was at its weakest in March 1993. In April 1993, the trend reversed and the markka started to appreciate. Excluding temporary depreciation periods, the markka appreciated until November 1995. From December 1995 to April 1996 the markka depreciated again but this depreciation was reversed almost completely before the markka entered the ERM in October 1996.

Figure 7.

### Trade-weighted currency index during the markka float

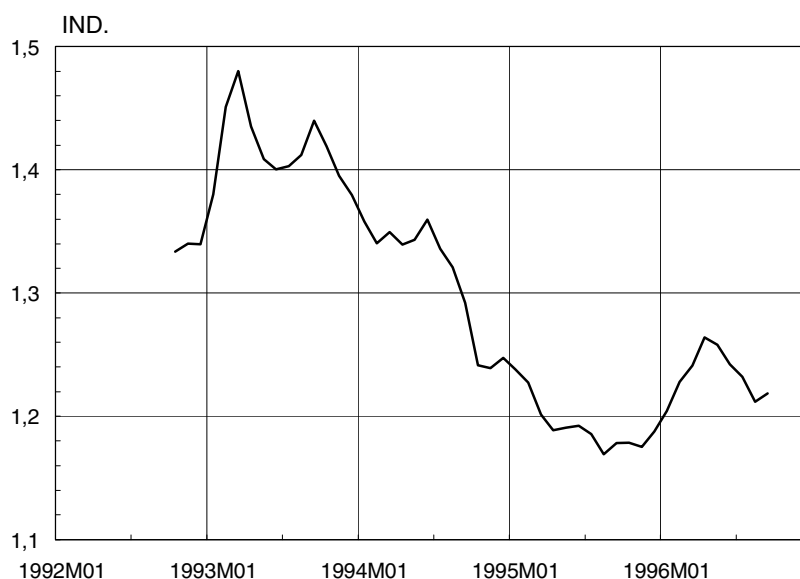
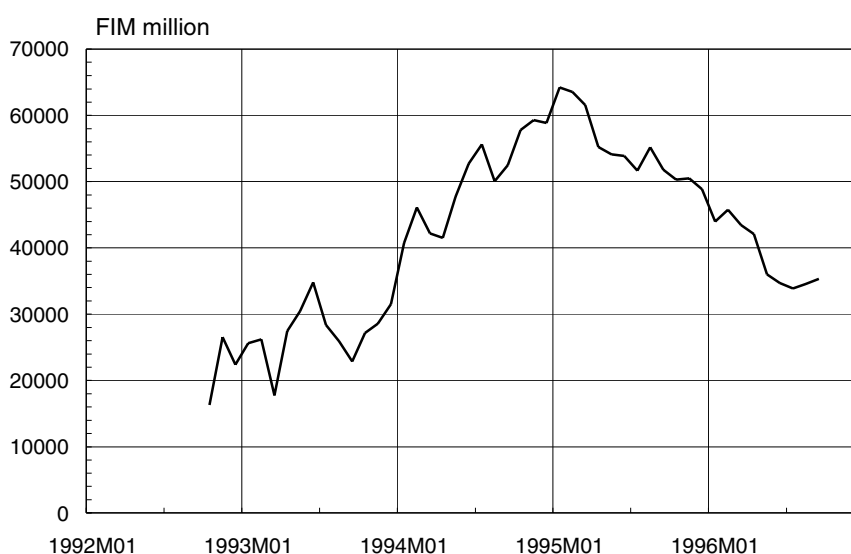


Figure 8.

### Bank of Finland's foreign exchange reserves plus forward position during the markka float



Two distinctive trends can be seen in the development of the Bank of Finland's foreign exchange reserves plus forward position, ie the broad reserves. During the first months of the float the broad reserves remained quite stable but from September 1993 to January 1995, they increased continuously. Especially, the peak in the end of 1994 and start of 1995

was due to forward purchases of foreign bonds. From February 1995 onward, the broad reserves decreased for the rest of the float period. The last forward contracts matured in November 1995, after which no new contracts were made.

The level of foreign reserves, which is measured in markkaa, is affected by purchases and sales of foreign bonds and by changes in the external value of the markka. The level of reserves is also affected by decisions of the central bank concerning the optimal amount of reserves. The question of optimal amount of reserves is related to the credible conduct of exchange rate policy. In other words, if the central bank wants to manage the exchange rate by intervening in the foreign exchange market, it must have enough reserves to do so in a credible way. A natural assumption is that the choice of the optimal amount depends on exchange market pressure, ie the larger the depreciation pressure, the larger the credible level of reserves. In the Finnish case, this means that the optimal amount may have changed during the markka float. This is one reason why actual foreign exchange interventions are a better measure of the central bank's reactions to exchange market pressures than are changes in foreign reserves.

The alternative model-consistent and model-independent measures of exchange market pressure and degree of intervention are summarized in figures 9a–9d and in tables 11 and 12, in which some summary statistics are presented. Only the measures which are estimated with narrowly defined foreign exchange interventions are presented. The bars indicate the exchange market pressure and the line the degree of intervention. Negative bars indicate appreciation and positive bars depreciation pressure. When the line is inside the [0,1] range, the Bank of Finland dampens appreciation or depreciation pressure by respectively purchasing or selling the foreign currency from its reserves. When the degree of intervention is negative, the Bank of Finland's intervention magnifies changes in the exchange rate, ie it purchases (sells) the foreign currency when there is excess supply (demand) of the markka and the exchange rate is already depreciating (appreciating). When the degree of intervention policy exceeds unity, the Bank of Finland's intervention reverses the exchange rate movement, ie the exchange rate moves in the opposite direction to that which would obtain in the absence of the intervention.

Figure 9a.

**Exchange market pressure and degree of intervention with endogenous money supply (unrestricted eq.), sterilization and narrow measure of foreign exchange intervention**

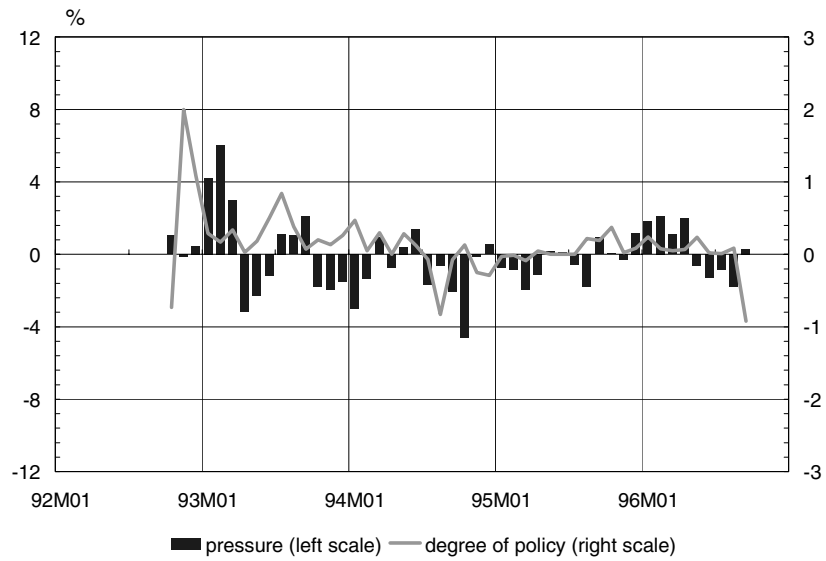


Figure 9b.

**Exchange market pressure and degree of intervention with endogenous money supply (restricted eq.), sterilization and narrow measure of foreign exchange intervention**

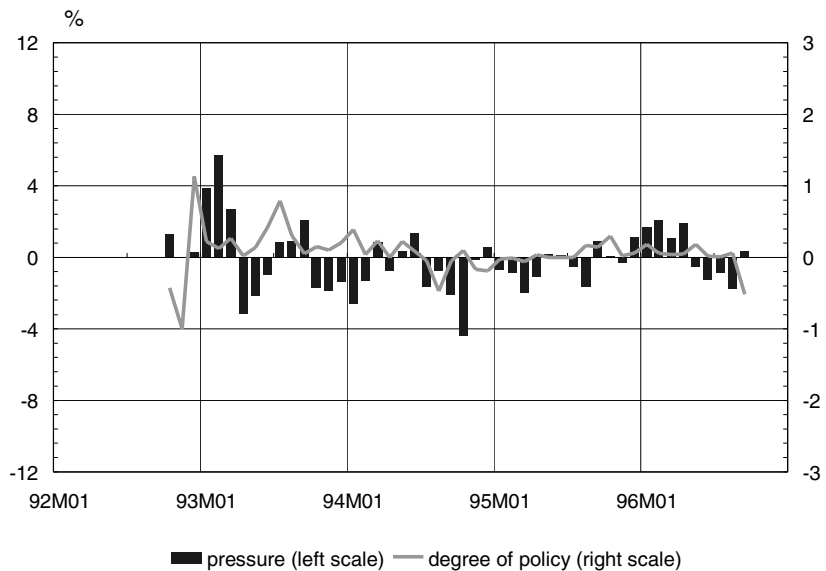




Figure 9c.

**Exchange market pressure and degree of intervention with equalized conditional volatility and narrow measure of foreign exchange intervention**

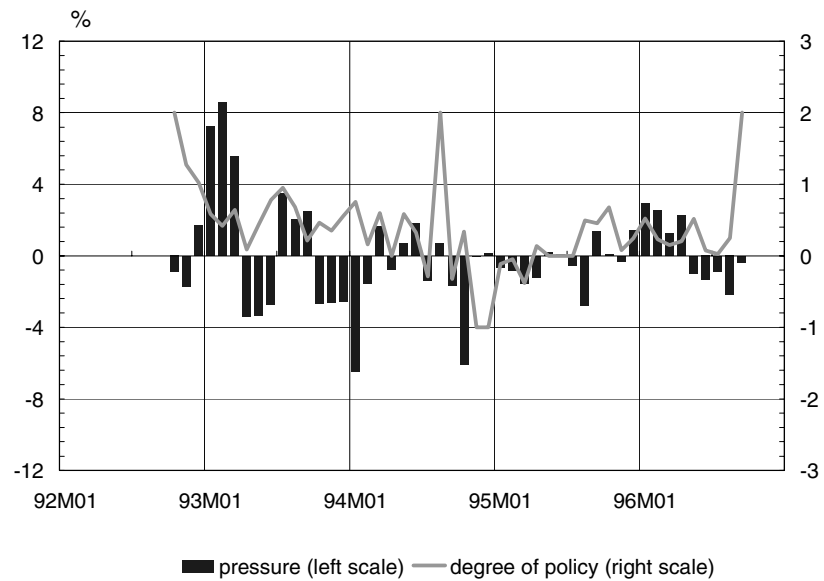


Figure 9d.

**Exchange market pressure and degree of intervention with exogenous money supply, nonsterilization and narrow measure of foreign exchange intervention**

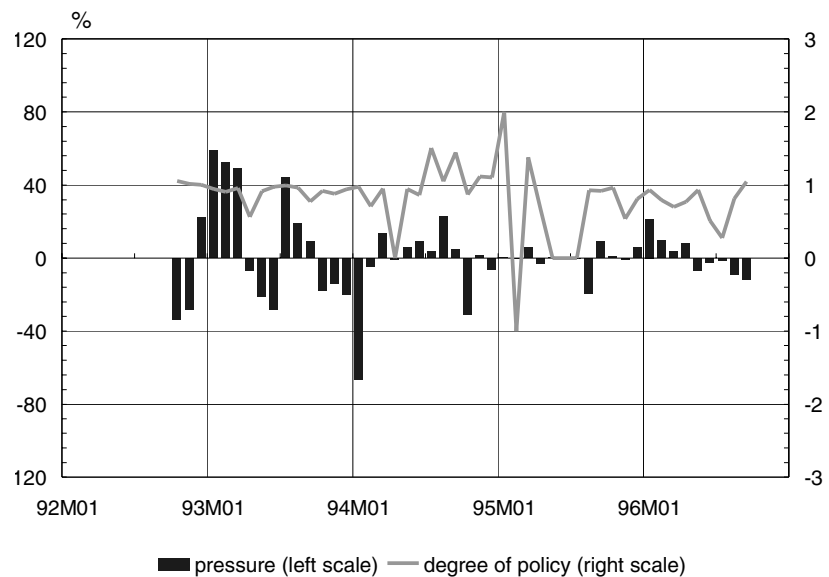


Table 11.

**Exchange market pressure (%), degree of intervention, exchange rate change (%) and the Bank of Finland's narrow foreign exchange interventions during the markka float**

Date	EMP <sup>1</sup>	$\omega^1$	EMP <sup>2</sup>	$\omega^2$	EMP <sup>erw</sup>	$\omega^{erw}$	dE	dR
1992M10	1.05	-0.74	1.27	-0.43	-0.89	<b>2</b>	1.82	5970
1992M11	-0.15	<b>2</b>	0.03	<b>-1</b>	-1.70	1.28	0.47	4530
1992M12	0.44	1.09	0.30	1.13	1.66	1.02	-0.04	-3470
1993M1	4.20	0.29	3.85	0.22	7.24	0.59	2.99	-9840
1993M2	6.03	0.17	5.73	0.13	8.59	0.42	5.01	-9300
1993M3	3.00	0.34	2.70	0.27	5.55	0.64	1.98	-7470
1993M4	-3.17	0.03	-3.14	0.02	-3.38	0.09	-3.08	600
1993M5	-2.28	0.18	-2.16	0.14	-3.33	0.44	-1.87	3130
1993M6	-1.19	0.50	-1.02	0.42	-2.70	0.78	-0.59	5030
1993M7	1.12	0.84	0.85	0.79	3.50	0.95	0.18	-7400
1993M8	1.04	0.38	0.92	0.30	2.02	0.68	0.64	-3070
1993M9	2.10	0.07	2.06	0.05	2.48	0.21	1.96	-1170
1993M10	-1.80	0.20	-1.69	0.15	-2.68	0.46	-1.44	2690
1993M11	-1.97	0.13	-1.89	0.10	-2.63	0.35	-1.70	2200
1993M12	-1.53	0.26	-1.41	0.20	-2.55	0.56	-1.13	3720
1994M1	-2.99	0.47	-2.58	0.38	-6.50	0.76	-1.59	12550
1994M2	-1.35	0.05	-1.33	0.04	-1.52	0.16	-1.29	560
1994M3	0.94	0.30	0.86	0.23	1.63	0.60	0.66	-2200
1994M4	-0.75	0	-0.75	0	-0.75	0	-0.75	0
1994M5	0.40	0.29	0.37	0.22	0.69	0.58	0.29	-920
1994M6	1.39	0.12	1.34	0.09	1.81	0.32	1.22	-1350
1994M7	-1.65	-0.07	-1.68	-0.05	-1.37	-0.29	-1.76	-930
1994M8	-0.62	-0.83	-0.77	-0.47	0.68	<b>2</b>	-1.14	-4270
1994M9	-2.05	-0.08	-2.09	-0.05	-1.66	-0.32	-2.20	-1440
1994M10	-4.59	0.13	-4.42	0.09	-6.05	0.34	-4.01	4890
1994M11	-0.15	-0.25	-0.16	-0.17	-0.05	<b>-1</b>	-0.18	-310
1994M12	0.53	-0.29	0.57	-0.19	0.14	<b>-1</b>	0.68	1330
1995M1	-0.73	-0.03	-0.73	-0.02	-0.67	-0.12	-0.75	-190
1995M2	-0.86	-0.01	-0.86	-0.01	-0.83	-0.05	-0.87	-90
1995M3	-1.96	-0.09	-2.01	-0.06	-1.54	-0.38	-2.13	-1440
1995M4	-1.11	0.04	-1.09	0.03	-1.23	0.14	-1.06	400
1995M5	0.17	0	0.17	0	0.17	0	0.17	0
1995M6	0.11	0	0.11	0	0.11	0	0.11	0
1995M7	-0.56	0	-0.56	0	-0.56	0	-0.56	0
1995M8	-1.78	0.22	-1.67	0.16	-2.76	0.49	-1.40	3250
1995M9	0.94	0.19	0.89	0.14	1.39	0.45	0.76	-1520
1995M10	0.06	0.37	0.05	0.30	0.11	0.68	0.04	-180
1995M11	-0.30	0.02	-0.30	0.02	-0.32	0.08	-0.29	60
1995M12	1.18	0.08	1.15	0.06	1.43	0.25	1.08	-820
1996M1	1.81	0.24	1.69	0.18	2.90	0.52	1.38	-3970
1996M2	2.10	0.08	2.06	0.06	2.51	0.23	1.94	-1330
1996M3	1.11	0.05	1.10	0.03	1.24	0.15	1.06	-440
1996M4	1.95	0.07	1.92	0.05	2.29	0.20	1.82	-1100
1996M5	-0.61	0.24	-0.56	0.18	-0.97	0.52	-0.46	1200
1996M6	-1.28	0.02	-1.27	0.02	-1.35	0.07	-1.25	240
1996M7	-0.85	0.01	-0.84	0.01	-0.86	0.03	-0.84	60
1996M8	-1.81	0.09	-1.77	0.06	-2.21	0.25	-1.66	1350
1996M9	0.29	-0.92	0.37	-0.52	-0.38	<b>2</b>	0.56	2310

EMP<sup>1</sup> = Exchange market pressure with endogenous money supply (unrestricted) and sterilization.

$\omega^1$  = The degree of intervention policy with endogenous money supply (unrestricted) and sterilization.

EMP<sup>2</sup> = Exchange market pressure with endogenous money supply (restricted) and sterilization.

$\omega^2$  = The degree of intervention policy with endogenous money supply (restricted) and sterilization.

EMP<sup>erw</sup> = Exchange market pressure with equalized conditional volatility of dE and dR.

$\omega^{erw}$  = The degree of intervention policy with equalized conditional volatility of dE and dR.

dE = Exchange rate change

dR = Bank of Finland's narrow foreign exchange interventions

Table 12.

**Appreciation and depreciation pressures, Bank of Finland's foreign exchange interventions and degree of intervention during each year of the markka float**

Date	EMP <sup>1</sup>		EMP <sup>2</sup>		EMP <sup>erw</sup>		Exchange rate	
	appreciation	depreciation	appreciation	depreciation	appreciation	depreciation	appreciation	depreciation
92M10–M12	-0.15	1.49	0.00	1.61	-2.59	1.66	-0.04	2.29
93M01–M12	-11.94	17.49	-11.32	16.11	-17.28	29.38	-9.81	12.76
94M01–M12	-14.15	3.25	-13.79	3.13	-17.90	4.95	-12.92	2.85
95M01–M12	-7.30	2.46	-7.23	2.37	-7.90	3.22	-7.05	2.16
96M01–M09	-4.54	7.27	-4.44	7.12	-5.77	8.94	-4.21	6.76
Total	-38.07	31.97	-36.78	30.35	-51.45	48.15	-34.03	26.82
Average	-1.46	1.45	-1.47	1.32	-1.91	2.29		

	$\omega^1$		$\omega^2$		$\omega^{erw}$		Currency	
	appreciation	depreciation	appreciation	depreciation	appreciation	depreciation	sold	purchased
92M10–M12	N/A	1.09	N/A	1.13	1.28	1.02	-3470	10500
93M01–M12	0.22	0.35	0.17	0.29	0.45	0.58	-38250	17370
94M01–M12	0.16	0.24	0.13	0.18	0.32	0.50	-11420	19330
95M01–M12	0.07	0.13	0.05	0.10	0.18	0.28	-4240	3710
96M01–M09	0.09	0.11	0.07	0.08	0.22	0.28	-6840	5130
Average	0.14	0.26	0.11	0.22	0.36	0.45	-64220	56070

EMP<sup>1</sup> = Exchange market pressure with endogenous money supply (unrestricted) and sterilization.

$\omega^1$  = The degree of intervention policy with endogenous money supply (unrestricted) and sterilization.

EMP<sup>2</sup> = Exchange market pressure with endogenous money supply (restricted) and sterilization.

$\omega^2$  = The degree of intervention policy with endogenous money supply (restricted) and sterilization.

EMP<sup>erw</sup> = Exchange market pressure with equalized conditional volatility of dE and dR.

$\omega^{erw}$  = The degree of intervention policy with equalized conditional volatility of dE and dR.

dE = Exchange rate change

dR = Bank of Finland's narrow foreign exchange interventions

The last quarter of 1992 is one of the most interesting periods during the float. After the Bank of Finland allowed the markka to float in September 1992, the pent-up depreciation pressure was released, causing a rapid devaluation of the markka. By October and through November, the markka was confronting either slight depreciation pressure or appreciation pressure, depending on the measure used. Clear depreciation pressure emerged again in December. However, the most interesting result is that the degree of intervention remained outside the [0,1] range for the whole quarter. As can be seen in table 11, whether there was depreciation or appreciation pressure in October and November, the Bank of Finland purchased foreign currency and sold the markka so heavily that the markka depreciated.

The most important reason for the large purchases of foreign currency in the last quarter of 1992 was the maturing of forward contracts in a situation where the foreign exchange reserves were already

exceptionally small. These forward contracts had been entered into just before the decision to float, in order to sterilize any large sales of foreign currency and postpone the effect of such sales on the markka supply and official foreign exchange reserves. The temporary settling down of the foreign exchange market gave the Bank of Finland an opportunity to increase its foreign exchange reserves by purchasing currency directly from the markets without depreciating the value of markka significantly. The government also raised capital imports to increase official foreign exchange reserves. From 18 to 20 November 1992, the government imported FIM 13 billion worth of foreign currency from abroad.

The depreciation pressure that emerged in December 1992 prevailed through the first quarter of 1993. This pressure was partly due a troubled Swedish economy and pressure on the Swedish krona. The Bank of Finland dampened the depreciation of markka by selling FIM 26.6 billion worth of foreign currency and thus managed to remove some 20 to 60% of the depreciation pressure. The 10% depreciation of the markka removed the rest of the pressure.

Positive news regarding Finland's export industries increased the appreciation pressure in the second quarter of 1993. The Bank of Finland's reaction to this pressure changed quite considerably within the quarter. In April 1993, the Bank of Finland let the markka float (and appreciate) almost freely. As the appreciation continued, the Bank of Finland started to intervene more heavily and eventually removed some 20 to 40% of the appreciation pressure in May 1993 and 40 to 80% in June.

In the third quarter of 1993, the picture was reversed. Speculation against ERM currencies in late July, the widening of ERM fluctuation bands in early August, and depreciation pressure on the Swedish krona all influenced the value of the markka. The Bank of Finland dampened markka depreciation by selling FIM 11.6 billion worth of foreign currency. The Bank of Finland's reaction was at its strongest in July 1993 when it eliminated the depreciation pressure almost totally and kept the exchange rate stable. In August 1993 the Bank of Finland's intervention policy eased somewhat, and in September it allowed the markka to float quite freely again.

After a quarter of depreciation pressure, the markka faced appreciation pressure in October 1993. This pressure remained fairly strong until February 1994 as foreign investors increased their investments in Finnish government bonds and in Finnish industry shares and investors sold foreign currency. The threat of a strike by bank employees in November 1993 induced the export industry to repatriate their export incomes faster than usual. The Bank of Finland intervened

only to smooth the widest fluctuations and removed some 15 to 50% of the pressure in the last quarter of 1993. However, in January 1994, as the pressure intensified further, the Bank suddenly purchased FIM 12.5 billion worth of foreign currency and tightened its intervention policy considerably. In February, as the pressure diminished again, the Bank of Finland refrained from intervening and let the markka float almost freely.

The trend was reversed in March 1994 as US investment funds started to sell markkaa. The Bank of Finland sold foreign currency and removed 25 to 60% of the pressure. In April 1994 the markka appreciated without the Bank of Finland trying to dampen the appreciation. In May and June 1994 the pressure was slightly positive again and the Bank of Finland again sold foreign currency. In July 1994 the pressure was negative, but instead of purchasing the Bank of Finland sold foreign currency and hence magnified the change in the exchange rate. Three reasons can be found for this. First, as the volume of intervention was small and the degree of intervention policy very close to zero, the negative figure could be due to the aggregation of daily interventions and exchange rate changes into monthly figures; when the central bank intervenes only once or twice a month but the exchange rate changes every day, relating a cumulative sum of interventions to an average change in the exchange may give awkward results, which may not reflect any actual change in the central bank's intervention policy. Second, the Bank of Finland could have reacted to depreciation pressure but, at the same time, a decrease in the money multiplier could have reduced money market liquidity, appreciated the markka and turned pressure positive. As a result, it would seem as if the Bank of Finland had tried to magnify the markka's appreciation by squeezing money market liquidity. Unfortunately, however, there were no major changes in the money multiplier during that period. Finally, it is of course possible that the Bank of Finland changed its intervention policy, introduced an implicit exchange rate target and, in this case, tried to support the markka by selling foreign currency from its reserves. Of the alternative explanations, the first would seem the most acceptable. On the whole, from February to July 1994 the depreciation and appreciation pressures were moderate and the Bank of Finland settled for dampening only the few largest interday and intraday changes.

The mid-August depreciation of the Swedish krona affected the markka. The Bank of Finland reacted aggressively by selling FIM 4.1 billion worth of foreign currency within two days and neutralized the pressure. According to measures presented in figures 9c and 9d, this sale turned depreciation pressure into actual appreciation of the markka. According to the other measures, this sale only magnified the change in

the exchange rate. With the completion of successful budget talks and the increased likelihood of Finland's membership in the European Union, the markka appreciated further in September and October 1994. In December 1994 the markka depreciated slightly. To some extent, this development seems to have been desirable because the Bank of Finland eased its intervention activity and let the markka appreciate. On the other hand, the Bank of Finland purchased almost FIM 5 billion worth of foreign currency in October 1994 in order to dampen markka appreciation. For some reason, however, this removed only a small part of the prevailing appreciation pressure.

The Mexican crisis in early 1995 had little impact on the external value of the markka. In March the Spanish peseta and Portuguese escudo were devalued in the ERM, but according to the alternative exchange market pressure indices, depreciation pressure on markka did not emerge. Instead, the foreign exchange pressure was slightly negative from January to April 1995. At the same time, the Bank of Finland seems to have mainly sold foreign currency as if it had tried to dampen depreciation pressure, resulting in negative measurements of the degree of intervention. Again, as above, the most reasonable explanation is that aggregating daily interventions and exchange rate changes into monthly figures when the central bank interventions are few in number may distort the degree of intervention. In May and June 1995 exchange market pressure remained small and the Bank of Finland let the markka float freely.

The pressure turned negative again in July 1995 as the government credit rating remained untouched, bond auctions succeeded well and foreign and Finnish investors started to buy markkaa. The appreciation pressure intensified in August 1995, but the Bank of Finland broke the spiral by purchasing FIM 3.3 billion worth of foreign currency, which removed some 20 to 50% of the appreciation pressure. In September 1995, there was restlessness in the international foreign exchange market as the doubt concerning Italy's ERM/EMU situation had been raised by comments made by the German finance minister, Theo Waigel. The markka started to depreciate, with the Bank of Finland attempting to dampen the largest intraday movements.

In October and November 1995 the pressure was minor, but it became clearly positive again in December 1995. This depreciation pressure remained fairly strong until April 1996. The pressure on the markka reached its acme in late January and early February 1996 as rumours spread as to the willingness of the Bank of Finland to depreciate the markka. The Bank of Finland tried to kill these rumours by selling FIM 4 billion worth of foreign currency in January 1996, which removed

some 25 to 50% of the depreciation pressure. After that, intervention activity diminished and the Bank of Finland again settled for dampening only the largest intraday depreciations.

Appreciation pressure on the markka started to emerge in May 1996 with positive news about the Finnish economy and ERM speculation claiming that the markka exchange rate should have been clearly stronger than it was. This speculation intensified during the summer months of 1996. During the summer, the Bank of Finland let the markka appreciate quite freely but in September 1996 it purchased so much foreign currency that the resulting increase in the supply of markka not only neutralized the appreciation pressure but in fact depreciated the markka somewhat.

Looking at the float period as a whole, we cannot say that depreciation or appreciation pressure was clearly dominant. The result depends on the particular model behind each measure. The model-consistent measure with unrestricted money supply equation indicates that average monthly appreciation pressure was equal to average monthly depreciation pressure but that there were 26 months of appreciation pressure vs 22 months of depreciation pressure. As a result, the sum of monthly appreciation pressure (-38.07%) was slightly greater than the sum of monthly depreciation pressure (31.97%). According to the model-consistent measure with the restricted money supply equation, the average appreciation pressure was somewhat higher than the average depreciation pressure and there were 25 months of appreciation pressure vs 23 months of depreciation pressure. Total appreciation (-36.78%) and depreciation (30.35%) pressure did not differ significantly from that of the preceding measure. Finally, according to the Eichengreen-Rose-Wyplosz model-independent measure, the average appreciation pressure was somewhat smaller than the average depreciation pressure but there were 27 months of appreciation pressure vs 21 months of depreciation pressure and hence total appreciation pressure (-51.45%) was again slightly greater than depreciation pressure (48.15%). These figures are also considerably larger than the respective figures for the model-consistent measures above. However, the reason for this is straightforward: the larger the conversion factor  $\eta$ , the more influence the foreign exchange interventions have on the measurement of exchange market pressure and the more this value differs from the actual change in the exchange rate. This can clearly be seen from table 12.

Table 12 also shows that exchange market pressure decreased over time during the markka's float. In 1993, both appreciation and depreciation pressures were strong and depreciation pressure was dominant. In 1994, exchange market pressure turned negative as

depreciation pressure decreased considerably. The overall pressure remained negative but continued to fall in 1995. At the beginning of 1996, depreciation pressure increased momentarily. Later in 1996, ERM speculation caused the pressure to become increasingly negative.

The degree of intervention depends also on the particular model behind the measure. The model-consistent measure with unrestricted money supply equation shows that the average degree of intervention for the entire float was 0.20.<sup>55</sup> For the model-consistent measure with the restricted money supply equation, the figure is 0.17 and for the Eichengreen-Rose-Wyplosz model-independent measure 0.41. This indicates that the Bank of Finland limited month-to-month changes in the external value of markka only to a minor extent, allowing the markka to drift toward its underlying free-float equilibrium value.

It is, however, more interesting to look at the Bank of Finland's reaction to appreciation and depreciation pressure separately as presented in table 12. Again, the actual figures depend on the particular model. For the model-consistent measure with the unrestricted money supply equation, the average degree of intervention for depreciation pressure months was 0.26, exceeding the corresponding figure of 0.14 for appreciation pressure months. For the model-consistent measure with the restricted money supply equation, the average degree of intervention was 0.22 for depreciation and 0.11 for appreciation pressure months. For the Eichengreen-Rose-Wyplosz model-independent measure, the corresponding figures were 0.45 and 0.36. The same pattern can be detected when the average degrees of intervention are compared within every year. When the end of 1992 is excluded, the average degree of intervention decreased over time, but every year the degree for depreciation pressure months was larger than the degree for appreciation pressure months. This suggests that the Bank of Finland reacted more to depreciation than to appreciation pressure on the markka during its float, although total appreciation pressure was slightly greater than depreciation pressure. It is also interesting to see that the degree of intervention was negative, indicating that the Bank of Finland magnified changes in the exchange rate more often when exchange market pressure was negative than when it was positive. Overall this can be interpreted to suggest that markka appreciation was considered desirable.

Given the simplicity of the model, the estimates obtained must be viewed with caution. First, the exchange market pressure should perhaps be viewed more as a measure of the size of external imbalance and not so

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<sup>55</sup> That is, the average for those months in which the degree of intervention was positive but not replaced by the adjusted value, +2.



much as a required percentage change in the exchange rate. Second, monthly averages smooth changes in the exchange rate and hence hide variation perhaps too well. However, monthly data hides variation considerably less than quarterly data, which has been used in some previous studies on exchange market pressure and degree of intervention. Third, when daily foreign exchange interventions are netted into monthly cumulative sums, any small net figures obtained do not necessarily mean low intervention activity; the wind may change in the middle of the month so that interventions in one direction are neutralized by interventions in the other direction resulting in a small cumulative sum. This becomes a problem as the frequency of data decreases. In the case of monthly data, the possibility of this problem should at least be taken into account. Finally, given the definition of the supply of money in the model,  $\Delta m_t^s$ , only autonomous changes in domestic credit,  $\Delta d_t^a$  and foreign exchange interventions,  $\Delta r_t$ , affect the supply of money. In practice, however, also changes in the money multiplier affect the supply of money, ie  $\Delta m_t^s$  may change even in the absence of central bank reaction. A change in the money multiplier changes the supply of money and may cancel out the intended effect of central bank intervention. In practice, therefore, the degree of intervention is not totally under the control of the central bank, which may result in strange measurements of degree of intervention.

## 8 Summary and conclusions

The previous chapters have discussed the measurement of excess demand for domestic currency. The aim was to find an acceptable framework to measure exchange market pressure in a system of floating currency and partly sterilized foreign exchange interventions. Following the methodology introduced by Weymark (1995), a model-consistent measure of exchange market pressure and the degree of central bank intervention were calculated in the context of a small open-economy monetary model in which the central bank's monetary and foreign exchange policies were explicitly defined, foreign exchange interventions partly sterilized, and expectations rational. The model was applied to Finnish data in order to obtain the parameter values needed to calculate the actual measures of exchange market pressure and the degree of intervention. Finally, given the estimated model-consistent measures, the development of exchange market pressure and the degree of intervention during the period of the markka float was discussed.

The idea behind the measure of exchange market pressure is that the imbalance between the demand and supply of the domestic currency in the international foreign exchange market is removed by a change in the exchange rate or in the supply of money. Given the money multiplier, the change in money supply depends on the money and foreign exchange market interventions of the domestic central bank. If monetary policy is assumed to be completely independent of foreign exchange policy, ie if money market interventions except for sterilizing operations, are not assumed to be instruments of foreign exchange policy, the total international excess demand or supply of the domestic currency, ie exchange market pressure, can be measured quantitatively by forming a summary statistic from observed changes in the exchange rate and foreign exchange reserves of the domestic central bank. The degree of intervention can then be characterized by the proportion of exchange market pressure that is relieved by the intervention activity of the central bank.

In principle the general definition of exchange market pressure is applicable to any model in which foreign exchange market intervention has a direct and contemporaneous effect on at least one domestic market through its effect on exchange rate. In this paper, measures of exchange market pressure and degree of intervention are derived from an empirically-oriented small open economy monetary model with rational expectations. The effect of a foreign exchange intervention on the exchange rate is derived under the assumption that the intervention does

not change the expected future exchange rate policy. In this way, an empirical measure of exchange market pressure can be formed by using data on exchange rates and foreign exchange interventions.

To yield the estimates of the conversion factor, which converts the central bank's foreign exchange interventions into exchange rate equivalent units, the relevant equations of the model – money demand, domestic price level and money supply – were estimated. Two alternative monetary policy rules and measures of the central bank's foreign exchange intervention were used. According to the unrestricted rule, the central bank is assumed to increase the liquidity of the banking sector as the domestic economy grows and prices rise but to squeeze the liquidity if actual inflation is higher than the target or the actual level of real output above its long-term non-inflationary trend. According to the restricted rule, the central bank is assumed to try to influence economic activity and the demand for money only by setting a target for inflation and reacting to deviations from that target. The choice between alternative measures of foreign exchange interventions depends on the voluntariness of the customer transactions of the central bank with the central government. Including the central government's foreign exchange transactions with the central bank in the measure implies that, to some extent, these transactions are assumed to be at the discretion of the central bank. Excluding these transactions from the measure implies that the central bank is assumed to have absolutely no choice but to execute orders from the central government.

Two reference measures were also calculated. First, the measure used by Weymark (1995) was estimated by ignoring monetary policy reaction functions and assuming that the central bank always leaves its foreign exchange interventions completely unsterilized. Second, the model-independent measure suggested by Eichengreen, Rose and Wyplosz (1995) was calculated by equalizing the conditional volatilities of the change in the exchange rate and the unsterilized foreign exchange interventions.

According to the estimation results, the conversion factors obtained in the Weymark model were at least ten times higher than the factors obtained in the model presented in this paper or factors suggested by Eichengreen, Rose and Wyplosz (1995). Hence, the inclusion of the monetary policy reaction function and especially the sterilization of foreign exchange intervention had a considerable impact on the value of the conversion factor.

Now, the larger the conversion factor, the more the central bank's foreign exchange interventions dominate the measure of exchange market pressure. This means that, without any scaling of the components of the

measure of exchange market pressure, the foreign exchange interventions determine the pressure almost completely, and since the volatility of foreign exchange interventions is considerably greater than the volatility of the change in the exchange rate, the values of the measure of exchange market pressure become relatively large. This is a problem in the seminal work of Girton and Roper (1977), where the measure of exchange market pressure is a simple sum of the change in the exchange rate and the central bank's foreign exchange interventions. Because in the Weymark model the conversion factors were larger than unity, the dominance of foreign exchange interventions was even more serious. Therefore, if the money supply equations and the sterilization of foreign exchange interventions are ignored as in Weymark (1995), the model-consistent measure gives the direction of the pressure but not the rate of the exchange rate change which would be needed to remove the money market disequilibrium. In this sense, the values of model-consistent measures derived in this paper are more realistic. The values of the Eichengreen-Rose-Wyplosz model-independent measure seem to go more or less hand in hand with these model-consistent values, especially when the broad measure of foreign exchange intervention is used. As mentioned before, however, the main deficiency of the Eichengreen-Rose-Wyplosz measure is that it does not take into account the structure of the economy.

Another implication of the heavy dominance of foreign exchange interventions in the measure of exchange market pressure is that the proportion of pressure that is relieved by the intervention activity of the central bank is necessarily near 100%. Under these circumstances it is very hard to find degrees of intervention that are significantly different from unity, ie any significant evidence on any degree of floating exchange rate, even if the exchange rate were allowed to float quite freely. This is exactly what happens with the Weymark-measure in Finnish data, especially when the broad measure of foreign exchange intervention is used. This is not a problem if the sterilization of foreign exchange intervention is taken into account as in the measure derived in this paper.

When the effects of the two alternative measures of foreign exchange intervention on the values of exchange market pressure are analysed, the main conclusion is that the smaller the conversion factor, the smaller the difference between the values of the exchange market pressure using the broad and narrow measures of foreign exchange intervention. In other words, the way in which foreign exchange interventions are measured does not matter as long as the conversion factor is small. Furthermore, the alternative degrees of intervention seem to behave better when the

foreign exchange interventions are defined in the narrow way than when they are defined in the broad way. One reason behind this result might be that the occurrence of the central government's foreign exchange transactions with the Bank of Finland has been truly completely independent of foreign exchange policy considerations. If these transactions are conducted according to a prespecified schedule, the probability that they do not fit into the overall picture of managing exchange rate developments increases. In practice, this could result in an increased number of foreign exchange interventions which magnify or aggressively reverse the exchange rate movement.

Finally, the pressure on the floating markka and the Bank of Finland's reaction to that pressure was analysed. The main objective was to determine how clean or dirty the float was and whether the Bank of Finland's reactions to appreciation and depreciation pressures were symmetric or asymmetric. Only the measures which were estimated with narrowly defined foreign exchange interventions were used.

Looking at the float period as a whole, neither depreciation nor appreciation pressure was clearly dominant. Exchange market pressure decreased over time during the markka's float. In 1993, both appreciation and depreciation pressure were high and depreciation pressure was dominant. In 1994, the exchange market pressure turned negative as depreciation pressure decreased considerably. The overall pressure remained negative but continued to fall in 1995. At the beginning of 1996, depreciation pressure increased momentarily. Later in 1996, ERM speculation caused the pressure to become increasingly negative.

The alternative degrees of intervention indicate that the Bank of Finland limited month-by-month changes in the external value of the markka only to a minor extent, allowing the markka to drift toward its underlying free-float equilibrium value. When the Bank of Finland's reactions to appreciation and depreciation pressures are analysed separately, the main conclusion is that the average degree of intervention decreased over time but that every year the degree for depreciation pressure months was larger than the degree for appreciation pressure months. This suggests that the Bank of Finland reacted more to depreciation than to appreciation pressure on the markka during its float although total appreciation pressure was slightly larger than depreciation pressure. In sum, it seems that the Bank of Finland let the markka float quite freely, reduced its intervention activity gradually as the exchange market pressure diminished and considered markka appreciation more desirable than depreciation during the markka float.

The major problem with the model-consistent measure presented in this study is the model itself. As a result of its analytical simplicity, some

of its empirical relevance is lost. Unfortunately, changing the model would not do much good since finding statistical support for empirical models which would link macroeconomic variables to the exchange rate is difficult. As far as the instruments of foreign exchange policy are concerned, unsterilized foreign exchange intervention – as monetary policy in general – is generally assumed to have significant effects on the exchange rate, but evidence on the effectiveness of sterilized foreign exchange intervention is unclear. In this sense, therefore, it was important for calculating exchange market pressure that empirical evidence be found on the imperfect sterilization of the Bank of Finland's foreign exchange intervention.

Another deficiency is that the model employed in this study and hence the consistent measure of exchange market pressure and degree of intervention ignore the signaling effect of the central bank's actions. If market participants believe that a central bank uses official statements or sterilized foreign exchange interventions to signal the future course of monetary policy, an official statement or a sterilized foreign exchange intervention could alter market participants' expectations of future domestic monetary policy and absorb part of the current exchange market pressure. This means that the degree of intervention would be larger than without the recognition of the signalling channel and the float more managed. A large part of recent empirical work has concentrated on the signalling effects of sterilized foreign exchange interventions and the effect of news regarding economic fundamentals on exchange rate determination. Therefore, incorporating the signalling channel in the measure of exchange market pressure and the degree of central bank intervention would be an excellent, albeit demanding, topic for further research.

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# Appendix

## Operational counterparts of theoretical variables

Below the theoretical variables and their operational counterparts are presented. All data are monthly, from October 1992 to September 1996.

$p_t$	Consumer price index (log). Source: [P9500.M] in the Bank of Finland Database.
$p_t^*$	Trade-weighted average of consumer price indices in the currency basket countries (log). $p_t^*$ has fixed weight structure for each calendar year. Source: [XUVIRALL.CP] in the Bank of Finland Database.
$e_t$	Trade-weighted currency index (log). $e_t$ has fixed weight structure for each calendar year. Source: [XNVIRALL.M] in the Bank of Finland Database.
$c_t$	Seasonally adjusted wholesale volume index (log). Source: [C110.K] in the Bank of Finland Database.
$y_t$	Monthly indicator of real GDP (log). Source: [GDPM.M95] in the Bank of Finland Database.
$y_t^{\text{trend}}$	An estimate of the long-term trend component of $y_t$ , obtained using Hodrick-Prescott filter with smoothing parameter $\lambda=14400$ . The choice of $\lambda$ has a significance influence on the smoothness of the trend. Choosing a low value results in a trend that follows $y_t$ very closely whereas choosing a high value reduces the sensitivity of the trend to short-run changes in $y_t$ . Hodrick and Prescott (1980) suggest the use of $\lambda=14400$ for monthly data. The HP-trend is estimated for the period 1980:1–1998:11. The estimation period is extended beyond September 1996 in order to avoid the end-point problem.
$i_t$	Three-month HELIBOR (Helsinki interbank offered rate). Source: [EHEL3.TER] in the Bank of Finland Database.
$i_t^*$	Trade-weighted average of three-month interest rates in the currency basket countries. $i_t^*$ has fixed weight structure for each calendar year. Source: [EK12V3.M] in the Bank of Finland Database.
$m_t$	M1 money (log). Source: [M1.M] in the Bank of Finland Database.
$B_t$	Monetary base. $B_t = \text{CASH}_t + \text{FR}_t + \text{RR}_t$ .

<b>CASH<sub>t</sub></b>	Notes and coin in circulation. Source: [S1000.M] in the Bank of Finland Database.
<b>FR<sub>t</sub></b>	Banks' free reserves at the Bank of Finland. FR <sub>t</sub> equals banks' call money deposits [S1322.M] till September 1995 and banks' excess reserves [S1323Y.M] thereafter. Source: Bank of Finland Database.
<b>RR<sub>t</sub></b>	Banks' required reserves at the Bank of Finland. RR <sub>t</sub> equals banks' cash reserve deposits [S1323.M] till June 1993 and banks' minimum reserve deposits [S1323V.M] thereafter. The data is adjusted with reserve requirement ratio [S6005.K] so that changes in reserve requirement do not affect the data. The ratio of 1.65%, effective in July 1993 when the current minimum reserve system was introduced, is chosen the constant reserve requirement. Source: Bank of Finland Database.
<b>R<sub>t</sub></b>	Foreign exchange reserves [S1290.M] plus forward position [VT008.MU] of the Bank of Finland. Source: Bank of Finland Database.
<b><math>\Delta R_t^{\text{narrow}}</math></b>	Monthly sum of Bank of Finland's daily foreign exchange interventions. $\Delta R_t^{\text{narrow}}$ consists of ordinary spot transactions [M03.D–M04.D], changes in forward position [S82.D–S84.D] including both outright forwards and forwards in swap contracts, and spot transactions connected with swap contracts [M03S.D–M04S.D+S84.D]. Source: Bank of Finland Database.
<b><math>\Delta R_t^{\text{broad}}</math></b>	$\Delta R_t^{\text{narrow}}$ plus the central government's nett foreign exchange transactions with the Bank of Finland [S85.D] due to the central government's foreign debt management. Source: Bank of Finland.
<b>DUMDEC<sub>t</sub></b>	Dummy variable indicating a seasonal increase in M1 <sub>t</sub> in every December. DUMDEC <sub>t</sub> equals +1 in December 1992, 1993, 1994, 1995 and 0 elsewhere. A temporary December effect means that CASH <sub>t</sub> , FR <sub>t</sub> and M1 <sub>t</sub> rise in December because of Christmas sales and tax refunds and respectively fall in January. Hence, $\Delta DUMDEC_t$ should be used as a seasonal dummy in money demand equation expressed in difference form. In the actual data, a temporary December effect can be seen in CASH <sub>t</sub> and FR <sub>t</sub> but not in M1 <sub>t</sub> ; rises in M1 <sub>t</sub> in December 1992, 1993, 1994, 1995 are not followed by respective falls in January 1993, 1994, 1995, 1996. Therefore, DUMDEC <sub>t</sub> is used

instead of  $\Delta\text{DUMDEC}_t$  in change in money demand equation.

- DUM9301<sub>t</sub>** Dummy variable indicating a upward shift in price level due to an increase in indirect taxation in January 1993.  $\text{DUM9301}_t$  equals 0 till December 1992 and +1 thereafter. In domestic inflation equation  $\Delta\text{DUM9301}_t$  is used.
- DUM9302<sub>t</sub>** Dummy variable indicating a one-month prolonged December effect at the turn of the year 1992/1993. Hence,  $\text{DUM9302}_t$  equals +1 in February 1993 and 0 elsewhere. The increase in  $M1_t$  in December 1992 is caught by  $\text{DUMDEC}_t$ .
- DUM9406<sub>t</sub>** Dummy variable indicating an increase in price level due to an increase in value added tax in June 1994.  $\text{DUM9406}_t$  equals 0 till May 1994 and +1 thereafter. In domestic inflation equation  $\Delta\text{DUM9406}_t$  is used.
- DUM9409<sub>t</sub>** Dummy variable indicating a cancellation of a temporary increase in  $RR_t$  and  $FR_t$  in August 1994. The increase in  $RR_t$  and  $FR_t$  does not show in M1 money in August 1994 but the decrease does in September 1994. Hence,  $\text{DUM9409}_t$  equals +1 in September 1994 and 0 elsewhere.