Objectives and Effectiveness of Foreign Exchange Market Intervention. A Survey of the Empirical Literature *

1. Introduction

Disagreement can be observed in the literature as to whether there remains a need for central bank intervention in the case of a freely floating exchange rate system. According to Wallace (1979) demands for different currencies are almost exclusively determined by speculation. In the absence of legal restrictions on (international) asset holdings (anticipated) official intervention is needed to stabilize the exchange rates. Mayer (1982), by contrast, contends that intervention in markets for foreign exchange can be dispensed with on the implicit assumption that demands for individual currencies are well behaved. A stable economic environment thus guarantees stable exchange rates. Furthermore, Krugman (1988) states that a target zone for exchange rates is only sustainable for a limited period of time. Repeated intervention by central banks will result in a loss of reserves which is large enough to trigger off a speculative attack. For a survey of the literature on target zones see Frenkel & Goldstein (1986).

This controversy is not at the heart of this article [see, on the need for central bank intervention, Mussa (1981) and Mayer (1982)]. We treat the functioning of the current exchange rate system as given and assume that discontent with its outcomes, probably caused by destabilizing speculation in the foreign exchange market has caused

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the marked increase in the volume of central bank intervention since the mid 1980s.

In what follows we will briefly discuss the definition of exchange market intervention and the different kinds of intervention that are distinguished. Furthermore, we will summarize the objectives a central bank may pursue by carrying out exchange market intervention and the channels through which intervention can influence the development of the exchange rates. Finally, we will give a survey of the results of empirical research that has been carried out to assess which objectives the central bank did in fact pursue and whether the interventions were effective after all. Our aim is to present the most relevant empirical studies. Therefore, we do not pretend to give a fully complete survey.

2. Definition

We define an exchange market intervention as a sale or a purchase of foreign currencies by the monetary authorities with the aim of changing the exchange rate of their own currency *vis-à-vis* one or more foreign currencies. The distinction that is being made between "active intervention" on the one hand and "passive intervention" on the other hand does not seem very helpful to us as far as empirical research is concerned. By definition passive intervention is distinguished from active intervention in that the transactions are carried out outside instead of inside the exchange market. It is of course at the discretion of a central bank to carry out a sale of foreign exchange inside or outside the market depending on the strength of its own currency.

For example, the buying of troop dollars and the steady inflow of interest earnings on its dollar reserves cause the Bundesbank's international reserves to increase autonomously. The Bundesbank has stabilized its reserve position by selling foreign currencies inside the market in periods when the DM was weak and outside the market in periods when the DM was strong against the US dollar. By counteracting the autonomous growth in reserves in this way the Bundesbank, *ceteris paribus*, supports the level of the DM-dollar exchange rate.

The empirical investigation of objectives and effectiveness of exchange market intervention is hampered by a lack of data with respect to this division. Most researchers try to concentrate on data series covering transactions in foreign currencies which have been undertaken with the sole aim of influencing the development of the exchange rate.

3. Different kinds of intervention

By far the larger part of exchange market intervention is carried out in the spot market. While "analytically there is no distinction between the effects of forward market and sterilized spot market transactions on the spot exchange rate" [Smith & Madigan (1988, p. 189)] the reason for this seems to be that an intervention operation derives a great deal of its effect from the announcement of the operation itself. Highly visible spot market operations confirm the announcement.

A purchase (sale) of foreign exchange by a central bank leads, *ceteris paribus*, to an increase (decrease) in the reserve position of the private banking system as a whole (unsterilized foreign exchange market intervention). To prevent the money stock from increasing (decreasing) the monetary authorities can sterilize the effect of the exchange market intervention by selling (buying) short-term domestic assets to (from) the banking system leaving the monetary base of the country unchanged. The monetary base (MB) consists of currency in the hands of the public and reserves in the banking system. By definition it equals the sum of net foreign assets (NFA) and domestic assets (DA) in the hands of the central bank:

$$MB \equiv NFA + DA \tag{1}$$

The effect of the exchange market intervention on the monetary base is completely neutralized when:

$$\blacktriangle DA = - \blacktriangle NFA \tag{2}$$

A central bank can publicly announce that a certain level of its own currency in terms of a third currency will be defended. This intervention method is productive when it gains the exchange market

participants' confidence and stops speculation against the currency. If, in contrast, speculators view the particular exchange rate level that the central bank is willing to defend as too high, seemingly infinite speculative capital flows will force the central bank to review its policy. To avoid this counterproductivity a central bank can intervene in the market for foreign exchange anonymously. It can instruct a private bank to buy or sell a certain amount of foreign exchange when a particular exchange rate level is reached. Of course, depending on the signal the central bank wants to give, it may instruct more than one bank and/or currency broker.

Furthermore a distinction can be made between intervention carried out within the domestic exchange market and intervention undertaken at a moment when the domestic market for foreign exchange in country A is closed. The former sort of intervention can be considered as an ordinary transaction in foreign currencies with the only exception that country A's central bank is involved. The latter sort of intervention can take two forms. Firstly, the central bank in country A can act as a domestic market participant of last resort for a private bank in country A which, outside country A's market times, is faced with an excess demand for or supply of a certain currency. Given the current state of information technology the private bank will otherwise enter the world market for foreign exchange in the time zone where it is open at that particular moment. Secondly, when the central bank in country A wants to counteract unfavourable exchange rate movements taking place at a moment when the market for foreign exchange in country A is closed, it can instruct another central bank, situated in the time zone where the market is open to carry out a certain transaction in the foreign exchange market.

In an attempt to stabilize the spot exchange rate, the central bank could enter the foreign exchange options market. A depreciation of the domestic currency can in principle be stopped when agents that had planned to sell amounts of the currency buy put-options that have been written by the central bank, instead. The pressure on the exchange rate, however, is not lessened when options are only bought by options-traders. Furthermore, whereas currency speculators are faced with a two-sided exchange rate risk, the options-traders' risk is only one way. Moreover, the influence of the options-market on the underlying spot and forward market still is not clear.

4. Objectives of exchange market interventions; theory

In the theoretical literature two divisions of objectives can be found. In the Jurgensen-report (Working Group on Exchange Market Intervention, 1983) the objectives are classified according to whether the central bank pursues them on a long-term or a short-term basis, whereas the kind of objective underlying the intervention forms the division criterion for German economists like Lehment (1980) and Sommer (1983). The latter division criterion distinguishes four categories of interventions. "Anpassungs"-interventions (in English corresponding with "smoothing"-interventions) *grosso modo* refer to interventions undertaken on account of a leaning against the wind policy. The central bank tries to resist large short term exchange rate movements without affecting the underlying trend. Interventions carried out to alter the trend in the development of the exchange rate for economic or political reasons are called "Erhaltungs"-interventions ("trend breaking"-interventions), whereas "Gestaltungs"-interventions ("direction indicating"-interventions) apply to the situation where the exchange rate is moving out of control. Finally, the category "other interventions" covers sales and purchases of foreign currencies aimed at the management of the volume and composition of the foreign exchange market reserves of the central bank.

In our view, the extent of the division of objectives in the Jurgensen-report is not in accordance with what the central banks try to do to counteract unwanted exchange rate movements. To formulate medium-term and long-term objectives is one thing. To carry out exchange market interventions aimed at realizing those objectives while one is not even able to control the exchange rate movements in the short run is something totally different.

An intervention reaction function can be derived by combining a policy loss function with a set of equations describing the determination of the exchange rate of currency B in terms of currency A (S_t). The policy loss function reflects the hypothesis that the central bank of country A wishes to limit deviations from a target level for the exchange rate (S_t^T):

$$L_t = (\log S_t - \log S_t^T)^2 = (s_t - s_t^T)^2 \qquad (3)$$

with $s_t = \log S_t$ and $s_t^T = \log S_t^T$. To capture intervention carried out on account of a leaning against the wind policy, the target level for

the exchange rate can be thought of as representing past levels of the exchange rate. This follows immediately from the definition of smoothing exchange rate fluctuations: whether or not the exchange rate was considered to be at a desirable level in the previous period(s), deviations from this target level will be countered. The determination of the exchange rate can be modelled by implementing a simplified flow market interpretation as in Neumann (1984). The market for currency A is in equilibrium when the net supply of currency A by the central bank of country A (I_t^A) equals the change in the net stock demand for assets denominated in currency A by residents of country B ($\blacktriangle AA_t^B$) plus the net flow demand for currency A resulting from current account transactions (CA_t):

$$I_t^A = \blacktriangle AA_t^B + CA_t \tag{4}$$

whereby

$$AA_t^B = (1/cV_t)\ (s_t - E_t s_{t+1} + i_t^A - i_t^B) \tag{5}$$

In equation (5), c represents the coefficient of relative risk aversion ($c>0$), V_t the variance of unanticipated changes in the exchange rate ($V_t>0$), E_t is the expectation operator conditional on information at time t, and i_t^A and i_t^B are the one-period interest rates in country A and B respectively. The current account surplus is assumed to depend on lagged values of the real exchange rate. In this context it needs no further specification.

By minimizing the loss function (3) with respect to the constraints given by the equations (4) and (5), whereby $\delta s_t/\delta I_t^A = -cV_t$, and by making use of the definition for the expected risk premium on assets denominated in currency A, RP_t^A

$$RP_t^A = f_t - E_t s_{t+1} \tag{6}$$

in which f_t denotes the log of the one-period forward rate (F_t), and of the interest arbitrage condition:

$$i_t^A - i_t^B = f_t - s_t \tag{7}$$

the intervention reaction function can be obtained:

$$I_t^A = (1/cV_t)\ (\blacktriangle RP^A - s + s^T)_t + CA_t \tag{8}$$

From this model it appears that the central bank of country A will supply amounts of currency A to the foreign exchange market ($I_t^A>0$) when the exchange rate of currency B in terms of currency A is lower than the target value ($s_t<s_t^T$); when an increase in the expected risk premium on assets denominated in currency A raises speculative demand for that currency ($\blacktriangle RP_t^A>0$); and when there is a current account surplus for country A ($CA_t>0$).

5. Effectiveness of exchange market intervention; theory

Following the approach taken by Loopesko (1984) and Humpage (1986) a number of channels can be distinguished through which the exchange rate can be influenced. Figure 1 gives a representation of the three main channels.

Non-sterilized purchases and sales of foreign exchange are said to have an impact on the exchange rate via the monetary channel. A purchase of foreign currency by the central bank for example leads to a loosening of the domestic money market and, *ceteris paribus*, results in an increase in the money stock. In most economic models a depreciation of the currency is the immediate consequence.

In the monetarist exchange rate model for instance, the money demand functions of countries A and B are the basic components. Here they are assumed to be identical:

$$\dot{M}o_t = \dot{P}_t + \alpha_1 \dot{Y}r_t - \alpha_2 \blacktriangle i_t \tag{9}$$

The relative change in the demand for money ($\dot{M}o_t$) is a function of the relative change in the price level ($\dot{P}_t$) and the production level ($\dot{Y}r_t$), and the absolute change in the interest rate ($\blacktriangle i_t$). If the production level is determined exogenously, if there is perfect capital mobility, and the expectations are formed rationally, and if it is assumed that purchasing power parity holds for tradeables, the long-term solution for the monetarist exchange rate model runs as follows:

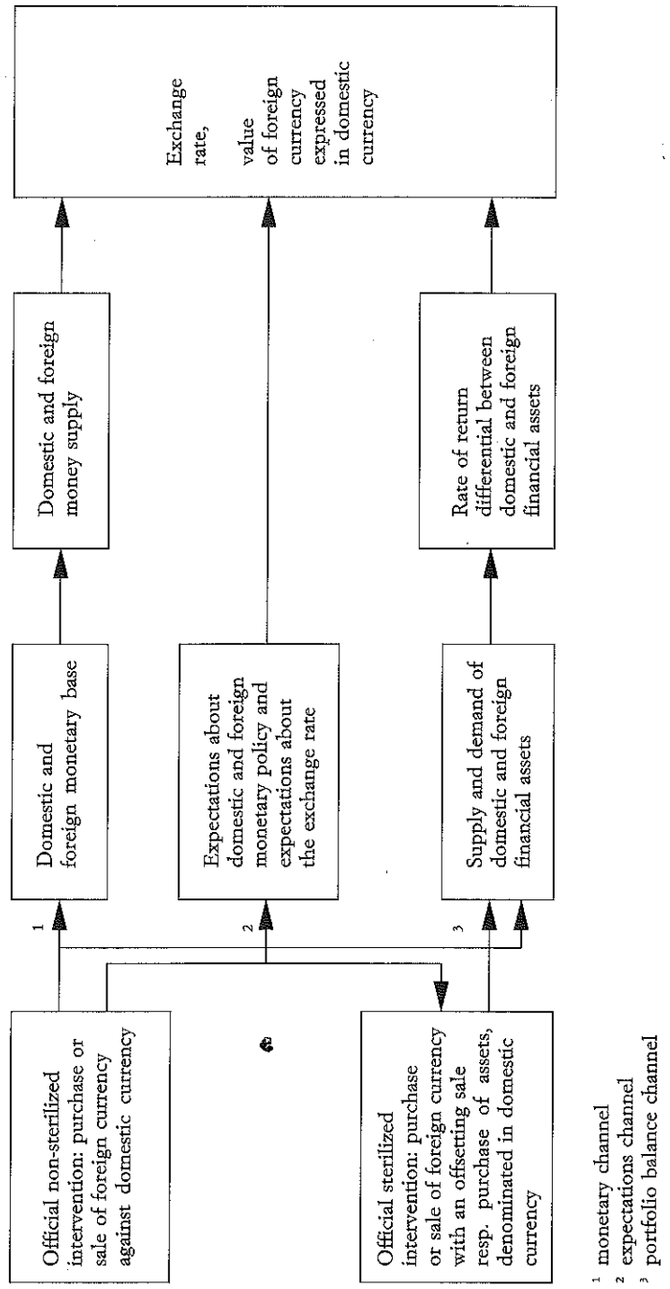
$$\dot{S}_t = (\dot{M}o_A - \dot{M}o_B)_t - \alpha_1(\dot{Y}r_A - \dot{Y}r_B)_t \tag{10}$$

An increase in the money supply in country A leads to a proportional depreciation of currency A with respect to currency B.

Nearly all empirical investigations disregard the monetary channel because it can be argued that this channel applies to mon-

FIGURE 1

THREE CHANNELS OF INFLUENCE OF OFFICIAL INTERVENTION



etary policy rather than exchange rate policy. Of course, this argument may be arbitrary.

Theoretically, sterilized purchases and sales of foreign exchange can have an impact on the exchange rate. Loopesko distinguishes three possible channels. In the portfolio-balance model it is assumed that risk-averse wealth holders diversify their portfolios across assets denominated in different currencies. When wealth holders do not view otherwise identical government bonds denominated in currency A and currency B as perfect substitutes, a disturbance of the portfolio-balance caused by a sterilized exchange market intervention carried out by the central bank of country A will, *ceteris paribus*, lead to a change in the spot exchange rate (S_t) of currency B in terms of currency A. The level of the risk premium on government bonds denominated in currency B (RP_t^B) can be defined as:

$$RP_t^B = (i_B - i_A)_t - (s_t - E_t s_{t+1}) \qquad (11)$$

Now suppose that, in an attempt to support currency B, the central bank of country A buys an amount of currency B whereby an offsetting sale of short-term government bonds denominated in currency A leaves the monetary base and thus the money stock in country A unchanged. The open market sale induces a rise in i_A and an excess demand for foreign securities by the investors, who try to rebalance their portfolios. However, an inducement to switch their assets denominated in currency A for assets denominated in currency B is required: a *depreciation* of currency A in terms of currency B restores portfolio-balance by lowering the risk premium on government bonds denominated in currency B [see equation (11)], and by increasing the value of government bonds denominated in currency B in terms of currency A.

Besides the portfolio-balance channel, two other channels are distinguished by which sterilized interventions can affect the exchange rate. The market-efficiency channel implies that the central bank can "[focus] the attention of the public on neglected information that is germane to exchange rate determination" [Loopesko (1984, p. 258)]. It must be noted that in our opinion it is very hard for the central bankers to establish the market inefficiencies with certainty. The superior-information channel corresponds with what we call the expectations channel. By providing the market with new information or a signal about the future course of the exchange rate

or of monetary policy, the exchange rate can be expected to change immediately after the intervention. Notably, supporters of the asset market view of exchange rates see this as the main channel through which interventions can affect the exchange rate.

6. Objectives of exchange market intervention: empirical investigations

In section 4 we summarized the objectives a central bank may pursue by carrying out exchange market intervention. An intervention reaction function was derived from a simple model containing a policy loss function. In this section we will give an overview of the results of empirical research that has been undertaken in this field since the transition, in 1973, to a system of floating exchange rates. From the estimated reaction functions it can be judged which of the objectives that can be distinguished in theory were in fact pursued.

The dramatic increase of the exchange market turnovers has caused a proper timing of the interventions and the use of the correct intervention technique to become of growing importance in the exchange rate policy of the central banks. The estimated reaction functions however only give an explanation for the volume and direction of intervention transactions. This, of course, detracts from the explanatory power of the estimated relations. All investigations under review are concerned with spot market interventions only. In the estimated reaction functions the volume of intervention in subsequent periods (I_t) is the dependent variable that has to be explained by the independent variables of which the difference between the actual level of the exchange rate (S_t) and the target level of the exchange rate (S_t^T) is the most important one. Obviously when the estimation is carried out using monthly data the exchange rate change in one month (independent variable) will be simultaneously determined by the interventions undertaken in the same month. In an attempt to reduce the simultaneity bias, some studies use the two stages least squares (2SLS) or the instrumental variables (IV) estimation technique. Nevertheless, the estimation results have to be interpreted carefully. It should be stressed that the empirical tests of the objectives of intervention policy are rather indirect in the sense

that estimates of the reaction functions assume the underlying model to be the true model. Therefore, estimation results may not only be an indication of objectives of intervention policy, but also of the strength of the underlying model.

Henceforth we will discuss a number of empirical investigations into the objectives of exchange market intervention. Their main characteristics are summarized in table 1.

Artus (1976) studies the intervention policy of the Bundesbank (DBB) over the period March 1973-July 1975. He finds evidence of a leaning against the wind policy. A rise (fall) by one percentage point in the value of the DM in terms of the US dollar ($\dot{S}_t$) during one month gave rise to the buying (selling) of 0.359 billion DM worth of foreign exchange over the same one-month period. Furthermore the German central bank on average bought (sold) 463 million DM of foreign exchange "for each US $ 0.01 of discrepancy between the current value of the Deutsche Mark in US cents", (S_t), "and its target value", (S_t^T) (p. 329). The target level of the exchange rate is based on relative prices in the Federal Republic of Germany (P_G) and the United States (P_{US}). The structural equations with standard errors in parentheses look as follows:

$$I_t = \underset{(0.093)}{0.463}\ (S_t - S_t^T) + \underset{(0.057)}{0.359}\ \dot{S}_t \qquad (12)$$

$$S_t^T = 40.2 - 54.8\ (P_G/P_{US} - 1) \qquad (13)$$

The findings of Quirk (1977) with respect to the intervention behaviour by the Bank of Japan (BOJ) show a great deal of correspondence with those of Artus' study of the German intervention policy. Quirk however is not able to relate the interventions to the deviation from a target level for the yen exchange rate. Instead, the total volume of spot transactions on the Tokyo foreign exchange market and the lagged endogenous variable are significant independent variables in explaining the intervention response. A one percent exchange rate change of the yen with regard to the US dollar was accompanied on average by intervention amounting to $ 156 million in the month the exchange rate change occurred and $ 78 million thereafter. Quirk ascertained that the interpretation of the OLS-estimates was not hampered by a simultaneity-bias after comparing the results with those of a 2SLS-estimate.

Branson, Halttunen and Masson (1977, 1979) try to apply the asset-market model empirically to the US dollar – DM exchange

TABLE 1

	Period	Data	Estimation technique	Definition of intervention	Exchange rate	Intervening central bank
Artus (1976)	March '73-July '75	monthly	2SLS	change in the net foreign assets of the Bundesbank (in billions of D Mark) (p. 319)	spot rate of the Deutsche Mark in terms of US dollars	DBB
Quirk (1977)	March '73-Oct. '76	monthly	OLS & 2SLS	changes in the Foreign Exchange Fund account (in millions of dollars) (p. 650)	spot rate of the yen in terms of US dollars	BOJ
Branson *et al.* (1977) Branson *et al.* (1979)	Aug. '71-Dec. '76 Aug. '71-March '78	monthly	2SLS	international reserves of Germany (in US dollars) minus cumulated SDR allocations (p. 323)	spot rate of the Deutsche Mark in terms of US dollars index 1970=100	DBB
Dornbusch (1980)	July '73-Dec. '79	quarterly	OLS	changes in reserves (except for interest earnings) as a fraction of lagged reserves (p. 713)	1) effective spot rate of the US dollar 2) spot rate of the DM in terms of US dollars 3) spot rate of the yen in terms of US dollars	DBB, BOJ, Bank of Canada, Banque de France and Bank of England
Lehment (1980)	April '73-Dec. '78	monthly	OLS	average monthly changes of the adjusted net reserve position of the Bundesbank (p. 220)	change in the spot rate of the DM in terms of US dollars	DBB
König & Gaab (1982)	April '73-Jan. '82	monthly	OLS	changes in the stock of foreign exchange reserves in billions of DM (p. 190)	change in the spot rate of the US dollar in terms of DM	DBB
Neumann (1984)	March '74-Dec. '81	monthly	OLS	Bundesbank direct transactions in the US dollar/DM market (p. 237)	(log of the) spot rate of the DM in US dollars	DBB
Gaiotti *et al.* (1989)	April '73-Dec. '87	monthly	OLS & IV	Germany: interventions on the DM/dollar market affecting the net external position of the Bundesbank. Japan: total net official sales of the national currency (p. 31)	spot rate of the DM and the yen in terms of the US dollar	DBB & BOJ
Eijffinger & Gruijters (1989a)	Feb. '85-Sept. '88	daily	OLS	"active" intervention inside the US dollar/DM exchange market (p. 2)	spot rate of the US dollar in terms of DM	DBB & FED

rate. To obtain consistent results a reaction function for intervention is estimated simultaneously with an equation determining the level of the exchange rate. Branson, Halttunen and Masson relate Germany's reserve position in period t to the reserve position in period t−1 and the change in the index of the US dollar/DM exchange rate that occurred between the end of period t−1 and the end of period t. A rise (fall) of the $/DM-exchange rate index by one point caused the Bundesbank to lean against the wind by means of purchasing (selling) $ 83 million when estimated over the period 1971:8-1976:12, and $ 180 million when estimated over the period 1971:8-1978:3.

Dornbusch (1980) assumes that central banks calculate the unanticipated depreciation of the US dollar ($\dot{S}^{UA}_t$), defined as the difference between the actual depreciation of the US dollar with respect to their own currencies ($\dot{S}_t$) and the depreciation that investors had already anticipated upon by demanding a risk premium on assets denominated in U.S. dollars:

$$\dot{S}^{UA}_t = \dot{S}_t - (i^{\$}_t - i^{*}_t) \qquad (14)$$

The intervention behaviour of the major industrial countries taken as a whole (I_t) is explained rather poorly by the unanticipated depreciation of the effective exchange rate of the US dollar, indicating perhaps that one or more important explanatory variables have been left out of the estimated reaction function. The main result of the estimations is, with t-values in parentheses:

$$I_t = \underset{(104.8)}{1.00} + \underset{(3.22)}{0.003}\ \dot{S}^{UA}_t + \underset{(1.68)}{0.001}\ \dot{S}^{UA}_{t-1} \qquad (15)$$

$$R^2 = 0.38 \quad DW = 1.81 \quad SEE = 0.05$$

For example, an unanticipated depreciation of the nominal effective exchange rate of the US dollar during a quarter by one percentage point, led to a cumulative intervention of 0.4 percent of foreign net claims on the United States (in 1980: $600 million).

Lehment (1980) distinguishes two estimation periods. For the first period, April 1971-December 1975, the results show a significant proportional relationship between changes in the exchange rate of the DM in terms of US dollars and changes in the reserve position of the Bundesbank. However, for the period January 1976-December 1975, there are no signs of a leaning against the wind policy. Lehment supposes that this is caused by the fact that the Bundesbank aimed its interventions at keeping the $/DM exchange rate within a certain target zone. He does however not test this presumption.

The explanatory power of the reaction functions estimated in König and Gaab (1982) over the period April 1973-July 1975 is satisfactory. The estimation results furthermore correspond for the greater part with those of the studies discussed above. However, estimates over later periods (1974-1979, 1980-1981) lose power dramatically.

Neumann (1984) takes up the challenge of trying to formulate and estimate an intervention reaction model which explains a considerable portion of observed Bundesbank intervention. Unlike König and Gaab (1982), Neumann (1984) has data at his disposition which give a precise coverage of the foreign exchange operations undertaken with the sole aim of influencing the exchange rate. Furthermore, Neumann estimates a non-linear model in which he tries to establish whether or not the Bundesbank shifts its priority to controlling the money stock when the uncertainty in the DM/US dollar market increases. Neumann supposes that the Bundesbank buys US dollars if the spot rate of the DM in terms of US dollars goes beyond the target level and if the expected risk premium on DM-assets increases [see equation (11)]. The target level-specification giving the reaction function the highest explanatory power looks as follows:

$$\log S_t^T = \delta \log F_{t-1} + (1-\delta) \log S_t^{ppp} + \blacktriangle RPt + \mu_t \qquad (16)$$

As in Artus (1976), purchasing power parity considerations (S_t^{PPP}) are taken into account. This of course comes down to stabilizing the real exchange rate. In an attempt to fight private speculation *ex ante* the Bundesbank tries to compress the risk premium. This is done by revising the target rate in accordance with increases in the expected risk premium and movements in the lagged forward rate (F_{t-1}). It appears that for the more turbulent subperiod, September 1977-December 1981, Neumann's supposition of a shift in the trade-off in favor of money control is confirmed.

Gaiotti, Giucca and Micossi (1989) try "...to ascertain whether the intervention policies of 1985-87 entailed a departure from past practices..." (p. 21). Their estimations cover the period 1974:4-1987:12 or subperiods within this sample using monthly data. The estimating equation is obtained by substituting the equation which explains movements in the target exchange rate S_t^T, equation (13) above, into

the actual intervention reaction function. The intervention data Gaiotti, Giucca and Micossi use are not very detailed. To account for changes in the reserve position of a central bank (I_t) that do not directly result from interventions in the foreign exchange market, the trade balance (TB_t) is included as an explanatory variable in the reaction function. This is the main difference from the approach taken by Artus (1976). The main IV estimation results look as follows, with t-values in parentheses:

for the Deutsche Bundesbank

$$I_t = \underset{(-4.28)}{-1413.1} + \underset{(3.12)}{1479}\,(P_{GER}/P_{US}-1) + \underset{(0.44)}{17.96}\,TB_t + \underset{(3.77)}{2603.8}\,S_t + \underset{(3.46)}{169.44}\,\dot{S}_t \qquad R^2=0.30 \qquad DW=1.83 \qquad (17a)$$

for the Bank of Japan

$$I_t = \underset{(-4.24)}{-3715.4} + \underset{(3.08)}{3148.7}\,(P_{JAP}/P_{US}-1) + \underset{(2.63)}{150.74}\,TB_t + \underset{(3.78)}{6974.8}\,S_t + \underset{(2.03)}{189.34}\,\dot{S}_t \qquad R^2=0.39 \qquad DW=1.69 \qquad (17b)$$

The leaning against the wind behaviour of the Bundesbank appears to have been stable throughout the period. From the IV-estimates it follows that the German central bank on average bought (sold) 169 million US dollars for every one percent appreciation (depreciation) of the Deutsche Mark *vis-à-vis* the US dollar during one month. However, the steady appreciation of the US dollar from March 1980 until February 1985 was accompanied by a more than average intervention effort by the Bundesbank. The estimated coefficient for the variable capturing the leaning against the wind intervention by the Bank of Japan is larger (189 million US dollars) than that of the Bundesbank. Moreover, the Japanese central bank intervened significantly less than average during the period of US dollar appreciation mentioned earlier. Furthermore, Gaiotti, Giucca and Micossi find that the Bank of Japan from the midst of 1986 onwards rigidly tried to hold on to the prevailing exchange rate level. The reported IV-estimates of the leaning coefficients are significantly higher than the ones obtained with OLS. This can be explained by the fact that the former method accounts for the negative correlation between $\dot{S}_t$ and I_t while the latter does not. In view of the frequency

of the data one wonders whether the percentage rate of change of the spot rate from one period (month) to another (S_t) can capture the leaning against the wind character of the interventions adequately. A dummy variable accounting for the coordinated interventions following the Plaza Agreement enters the estimated reaction functions of both the Bundesbank and the Bank of Japan with a coefficient significantly different from zero. This indicates that the concerted action in October 1985 is one without precedent in the post-Bretton Woods era.

Eijffinger and Gruijters (1989a) have daily data of intervention by the Bundesbank and the Federal Reserve System at their disposal. This makes possible the testing of a second intervention strategy: countering erratic fluctuations and leaning against the wind over shorter periods than one month. To take account of exchange rate movements which take place during a day, Eijffinger and Gruijters include in their estimation the opening-, fixing-, and closing-rates of every trading day at the Frankfurt foreign exchange market. These variables are indicated by S_t^P, S_t^F and S_t^U, respectively. It appears that on average one fifth of the Bundesbank and Federal Reserve interventions taken as a whole were directed at minimizing the difference between the spot rate and the five days moving average of the opening, fixing and closing rate of the US dollar in terms of DM. For September 1985 estimation results indicate that the Bundesbank pursued a leaning *with* the wind policy. A closer inspection of the data revealed that all observed US dollar sales were carried out after the establishment of the Plaza agreement had shifted the market sentiment in favor of a depreciation of the US dollar. The coordination of exchange market intervention by the Bundesbank and the Federal Reserve System is investigated by adding intervention by the Federal Reserve as an extra explanatory variable of the Bundesbank's reaction function. The estimated coordination coefficient is significantly different from zero in five out of eight months in which both central banks intervened. However its value is unstable indicating a divergent degree of coordination. To test the effect of exchange market uncertainty on interventions the smoothing coefficient is adjusted for the variance of the opening, fixing and closing rates of the US dollar in terms of the DM in the past five days. The estimation results for the reaction function of the Bundesbank's interventions (I_t^{DBB}) in October 1987 are as follows, with t-values in parentheses

$$I_t^{DBB} = \underset{(-0.10)}{-0.003} - \underset{(-5.47)}{1321.7}\ \sigma_5^2[S_t^P - 1/15 \sum_{n=1}^{5} S_{t-n}^{P/F/U}] \qquad (18)$$

with $\sigma_5^2 = \sum_{n=1}^{5} [S_{t-n}^{P/F/U} - 1/15 \sum_{n=1}^{5} S_{t-n}^{P/F/U}]^2$

$\bar{R}^2 = 0.580$ DW=1.760

Eijffinger and Gruijters find that in months with large exchange rate fluctuations the smoothing coefficient as well as the explanatory power of the reaction function are larger than in months with small fluctuations. This indicates that the Bundesbank and the Federal Reserve System take their responsibility and do not pull back when the uncertainty grows, contrary to the empirical findings of Neumann (1984).

7. Effectiveness of exchange market intervention: empirical investigations

In this part we will summarize the results of empirical research carried out to ascertain the effectiveness of foreign exchange market intervention undertaken since 1973. As noted earlier, the effectiveness of non-sterilized interventions has not been investigated empirically. Attention has been paid to the effectiveness of interventions via the portfolio balance channel because this channel, if operative, constitutes an independent tool of monetary policy. However, the enormous growth in financial market turnovers during the last decade has diminished the potential for central banks to cause a significant imbalance in wealth holders' portfolios. For this reason current research focusses more on the expectations channel.

As we argued in the theoretical discussion the portfolio balance channel can only be effective if the risk premium (RP_t) in equation (11) does not equal zero. Problems arise however when one wants to calculate the risk premium. Various attempts have been made using different kinds of expectations formations [see, on the problem of estimating econometrically the portfolio-balance model, Tryon (1984) and Weber (1986)]. Another complication lies in the fact that the

effect of central bank interventions is absorbed in the movements of the exchange rate immediately. To get a clear view of the actual effectiveness one should be able to compare these movements with the fluctuations in the exchange rate that would have occurred in the absence of intervention. Furthermore, it can be argued that the estimations are rather partial as most of the time intervention will be accompanied by other measures of monetary policy, for instance interest rate policy [see, on the relative importance of intervention determining exchange rates during the period 1985-88, Obstfeld (1988)].

The main characteristics of the empirical studies we will discuss below are summarized in table 2.

In Branson, Halttunen and Masson (1977, 1979) movements in the spot rate of the Deutsche Mark in terms of US dollars (S_t) are related to movements in US and German stocks of money ($M1_t^{US}$, $M1_t^{G}$) and stocks of net foreign assets (FP_t^{US}, FP_t^{G}). Sterilized foreign exchange market interventions have an impact on the volume of a country's net foreign assets, but leave the money stock unchanged. Thus, it is possible to detect the effect of such interventions without having the problem of finding a proxy for the expected exchange rate movements. Consistent estimates look as follows, with t-values in parentheses:

$$S_t = \underset{(-0.1)}{-4.852} - \underset{(-1.7)}{0.062}\, M1_t^{G} + \underset{(2.8)}{0.092}\, M1_t^{US} + \underset{(1.7)}{0.676}\, FP_t^{G} - \underset{(-1.9)}{0.398}\, FP_t^{US} \qquad (19)$$

$$\bar{R}^2 = 0.937 \qquad DW = 1.349 \qquad RHO = 0.868\ (14.0)$$

All coefficients have the correct sign. From a point estimate in Branson *et al.* (1977) it can be derived that a sterilized purchase by the Bundesbank of $ 1 billion on average caused the DM to depreciate by 0.185 cent. Comparing Branson *et al.* (1977) with Branson *et al.* (1979) however, leads one to conclude that the results are unstable.

Loopesko (1984) constructs a series for realized foreign exchange market profits, r_t:

$$r_t = (i_t^{US} - i_t^{*}) - (S_{t-1} - S_{t-2}) \qquad (20)$$

S is the logarithm of the spot rate of a G-7 currency in terms of the US dollar, i^{US} and i^{*} are overnight US dollar and G-7 currency Eurodeposit rates, respectively. Realized profits calculated this way reflect both the expected risk premium and any spot rate forecast

TABLE 2

	Period	Data	Estimation technique	Definition of intervention	Exchange rate	Intervening central bank
portfolio balance channel						
Branson *et al.* (1977) Branson *et al.* (1979)	Aug. '71-Dec. '76 Aug. '71-March '78	monthly	2SLS	international reserves of Germany (in US dollars) minus cumulated SDR allocations (p. 323)	spot rate of the Deutsche Mark in US dollars terms, index 1970=100	DBB
Loopesko (1984)	May '75-Nov. '81	daily	OLS	interventions of the individual G-7 countries (in millions of US dollars), more precise definition unknown (p. 270)	log of the spot rate of the G-7 currencies in terms of the US dollar	Central banks of the G-7 countries
Rogoff (1984)	March '73-Dec. '80	weekly	2S 2SLS	changes in the Canadian Exchange Fund account, SDR allocations and bookkeeping valuation effects netted out (p. 148)	log of the spot rate of the US dollar in terms of Canadian dollars	Bank of Canada
portfolio balance – and expectations channel						
Dominguez & Frankel (1990)	Nov. '82-Dec. '87	daily	IV	Bundesbank interventions: 'active interventions' aimed at influencing the US dollar/DM spot rate. Fed & Treasury interventions: constructed intervention series from Fed publications (p. 3)	log of the spot rate of the Deutsche Mark in terms of the US dollar	DBB FED Treasury
expectations channel						
Humpage (1988)	Aug. '84-Aug. '87	dummies with value one on days the Fed intervened and with value zero on days the Fed did not intervene	OLS	"Intervention dummies are constructed from internal documents on US intervention" (p. 4)	- log of the spot rate of the US dollar in terms of DM - log of the spot rate of the US dollar in terms of yen	FED
Eijffinger & Gruijters (1989b)	Feb. '85-Aug. '88	daily	OLS	active intervention inside the US dollar/DM market aimed at influencing the spot rate of the US dollar in DM (in billions of DM, p. 2)	spot rate of the US dollar in terms of DM	DBB & FED

error. The joint hypothesis of perfect substitutability of assets denominated in different currencies and of the 'efficient' working of the foreign exchange market is rejected because previously observable variables (*e.g.* cumulated interventions, lagged values of realized profits and the exchange rate) proved to be significant determinants of realized profits. The results of a second (F-)test lead Loopesko to conclude that "...the predictable component of realized profits can be identified with a risk premium, and hence that sterilized intervention can affect the exchange rate through a portfolio balance channel" (p. 267). However, interventions are only one out of many factors that determine demand and supply conditions on the foreign exchange market and therefore changes in the risk premium. Loopesko's investigation of the 'extra effectiveness' of coordinated interventions is hindered by a lack of data as well as difficulties in interpreting the data. She finds some evidence of a more than proportionate effect of coordinated US and narrowly defined German intervention.

Rogoff (1984) expects the risk premium on assets denominated in Canadian dollars to be positively correlated with the relative supply of Canadian dollar (A_t) *versus* US dollar (A_t^*) denominated outside assets, both including the monetary base:

$$(i_t^{CAN} - i_t^{US} - \blacktriangle S_t^e) = \alpha_0 + \alpha_1 (A_t/S_t A_t^*) + \mu_t \qquad (21)$$

He supposes that expectations are formed rationally. This enables him to replace the expected exchange rate change by the *ex post* exchange rate change:

$$S_{t+1} = S_{t+1}^e + e_{t+1} \qquad (22)$$

where e_{t+1} is a forecasting error which is uncorrelated with any information dated period t or earlier. The very disappointing estimation results are accompanied by the "plausible interpretation ... that there is a time-varying exchange risk premium but one that cannot be affected by sterilized intervention" (p. 141).

The goal of Dominguez and Frankel (1990) is to disentangle the influence of the portfolio- and the expectations-channel. Dominguez and Frankel do not "invoke the methodology of rational expectations" (p. 9). Instead, they "measure expectations of the future spot exchange rate by means of survey data on the forecasts of market participants" (p. 3).[1] As we argued in the theoretical part, sterilized

[1] This method is open to question because survey data do not have to correspond with market expectations. Market participants may be interested in masking their actual expectations.

interventions are effective if they are able to change the risk premium. As the expected exchange rate change is a crucial component of the risk premium Dominguez and Frankel try to establish the impact of publicly known intervention and interventions carried out anonymously on market participants' expectations:

$$\hat{S}_{t+k}^e - S_t = \alpha_0 + \alpha_1 (S_{t-j} - S_t) + \alpha_2 NEWS_t + \alpha_3 REPI_t + \mu_t \qquad (23)$$

where $\hat{S}_{t+k}^e$ is the log of the k-days-ahead expectation for the \$/DM spot rate. It is supposed that investors expect the trend in exchange rate movements over the previous j days to carry on during the following k days. Furthermore investors are expected to redress their expectations when it becomes known that central banks change their exchange rate policy. The dummy variable NEWS captures this effect. The dummy variable REPI is multiplied by the amount of Intervention REPorted in the newspapers to account for the effect of discrete interventions. Consistent estimates are obtained by replacing variables which cause simultaneity by instrumental variables (IV) that are exogenous but do, at least partly, explain the endogenous variables. Estimation results for the period October 1982-October 1984 are not very interesting. As is well known the monetary authorities in the US hardly intervened during that period. For the period October 1984-December 1987 it appears from the estimation results that "newspaper reports of prospective intervention in support of the dollar ... tend[ed] to lower expectations of the future \$/DM exchange rate" (p. 18) by 0.005 per cent on average. When measured on the day before the survey, intervention, expressed as a percent of wealth, is a statistically significant determinant of the risk premium on DM denominated assets. This leads Dominguez and Frankel to conclude that over the period considered sterilized interventions were effective. In an attempt to quantify the effects they carry out some tentative calculations. On the assumption that interest rates in Germany and the United States are held constant an intervention not known publically has no effect on the risk premium. The effect on the spot rate is in proportion to the total reserve money supplied to the banking system by the Bundesbank. A \$ 100 million non-sterilized intervention thus represents an exchange rate change of 0.079 per cent (in 1987). The change in the spot rate caused by a sterilized intervention of the same amount is smaller (because of the larger denominator that applies here) but is nonetheless not zero. The calcu-

lated exchange rate effect of a publically known intervention is far greater. The level of the risk premium on DM assets is affected. This leads investors to reallocate their portfolios. In the absence of expectations with an extrapolating character and of induced interest rate changes, the exchange rate change amounts to 2.4 per cent.

In the analysis of Humpage (1988) it is not the volume of intervention that counts but the mere fact that the Federal Reserve Bank did intervene. To emphasize the search for the "news"-effect of interventions Humpage makes a distinction, with the aid of dummy variables, between initial intervention, which he defines as intervention carried out following a period of at least five days without intervention on the one hand and subsequent intervention defined as the complement of the former type on the other hand. For the period August 1984-August 1987 Humpage distinguishes three estimation periods in which the attitude of the Federal Reserve System towards intervention showed fundamental differences. Initial purchases of DM and yen directly following the Plaza meeting (represented by the dummy variables D^1 and D^3) significantly contributed to a depreciation of the US dollar against the DM and the yen respectively. Subsequent intervention (represented by the dummy variables D^2 and D^4) did not produce a significant effect:

$$S(DM/\$)_t = \underset{(-6.455)}{-0.052\ D_t^1} + \underset{(0.824)}{0.002\ D_{t-1}^2} + \underset{(1003.3)}{0.999\ S(DM/\$)_{t-1}} \qquad (24)$$

$$S(Yen/\$)_t = \underset{(-4.996)}{-0.027\ D_t^3} - \underset{(-0.101)}{0.0002\ D_{t-1}^4} + \underset{(5272.1)}{0.999\ S(Yen/\$)_{t-1}} \qquad (25)$$

Initial intervention carried out as a consequence of the Louvre agreement did not have an effect on the opening rates of the US dollar *vis-à-vis* the DM [$S(DM/\$)_t$] and the yen [$S(yen/\$)_t$] in New York due to conflicting statements on the direction of US policy. Humpage concludes that intervention can have an effect on exchange rate movements taking into account that "the size and duration of any announcement effect seems to depend on the extent to which the intervention creates expectations of changes in monetary and fiscal policies" (p. 15).

Eijffinger and Gruijters (1989b) assume the market for foreign exchange to be highly efficient. For that reason they relate the closing rate of the US dollar in DM at the Frankfurt foreign exchange market on day t to the opening rate of the same day, to the lagged closing

rate, to changes in the interest differential between one-month Euro-DM and Eurodollar deposits in London during day t and to spot market intervention by the Bundesbank and by the Federal Reserve respectively during day t. Interventions appear to have influenced the US dollar-DM exchange rate significantly during only one out of eight estimated periods of about six months. US dollar-sales of one billion DM during the six months just before the establishment of the Plaza agreement on average led the \$/DM rate to drop 0.65 per cent. The announcement of unexpected US trade balance figures proves to have outweighed the effect of interventions in other periods. Eijffinger & Gruijters do however find that "a selective intervention strategy and a careful timing of the interventions" (p. 20) can improve the effectiveness. Coordinated interventions and initial interventions, defined similarly as in Humpage (1988) appear to have a larger announcement effect.

8. Conclusions

Given the turbulent developments on the markets for foreign exchange, it takes fine data which give a precise description of intervention carried out primarily to influence the spot rate of the currency under review to establish the objectives a central bank pursued during the estimation period and to detect the actual effectiveness of the interventions undertaken. From the more dated as well as from the more recent studies it appears that countering large exchange rate movements is the most important objective central banks pursue with their interventions in the market for foreign exchange. Obviously, the realisation of a target level of the exchange rate is also a matter of concern for the central banks. However, because the target level the central bankers have in mind is not known and because it evolves over time, to relate interventions to it is not easy.

A careful interpretation of the estimated reaction functions leads to doubt about the relevance of a very extensive subdivision of objectives as for example made in the Jurgensen-report. A broad subdivision with two categories seems reasonable to us: interventions carried out on account of a leaning against the wind policy whereby

the central banks' sales and purchases are aimed at dampening exchange rate movements without altering the underlying trend on the one hand, and interventions undertaken to alter the trend in the exchange rate because of the development of the 'fundamentals' or political reasons on the other hand.

The effectiveness of the first category of interventions is fairly negligible whereas interventions of the second category if embodying a sufficient 'news'-content appear to have a larger chance of affecting the exchange rate significantly. Several attempts have been made to detect the components of which the announcement effect is made up. In this context the extra-effectiveness of intervention carried out after a certain period of no intervention and coordinated intervention is investigated. The results are rather mixed indicating perhaps that whether or not market participants pay attention to the interventions also depends on the availability of other 'news'. Statements of politicians and monetary authorities which accompany the intervention can lend support to or detract from its effectiveness. Influencing the exchange rate by means of intervention must run by the expectations channel. With that it can be ascertained that interventions do not constitute an independent tool of monetary policy.

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