A Positive Theory of Central Bank Intervention

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A POSITIVE THEORY OF CENTRAL BANK INTERVENTION*

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Abstract

This paper analyzes an exchange rate policy game between a central bank and rational speculators under symmetric information. The central bank tries to counteract shocks to the exchange rate by means of sterilized intervention working through the expectations channel. Private speculators resist to be fooled. They anticipate the interventions. An 'intervention bias' results with an inefficiently high equilibrium volume of intervention which does not reduce the impact of shocks to the exchange rate. Cross-country evidence lends support to the propositions derived from the model that the more independent the central bank the smaller and the more consistent the intervention efforts.

Keywords: exchange rates, foreign exchange intervention, central bank independence.

JEL Classification: E58, F31.

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1. Introduction

Since the breakdown of the Bretton Woods fixed exchange rate system in the early seventies, the exchange value of the major currencies in the industrialized world is in principle determined by market forces. However, in the present system of managed floating the exchange rate is not the outcome of supply and demand by private market participants only. The monetary authorities of many countries have frequently been trying to influence the relative value of their currencies by means of exchange market interventions. To comply with Article IV of the Articles of Agreement of the International Monetary Fund (IMF) as amended in 1978 central banks are obliged to promote a stable exchange rate system and hence to "counter disorderly exchange market conditions". It is a fact of observation that central banks do indeed enter the market for foreign exchange in case of strains.

The aim of this paper is to investigate the motives and constraints facing central banks when they decide to engage in foreign exchange intervention. To influence exchange rate movements interventions basically have to alter the balance of supply and demand for foreign exchange. However, average central bank transactions in foreign exchange are very small compared to the daily turnover on the world foreign exchange market. Furthermore, the monetary authorities of most large countries give priority to domestic policy objectives. They routinely neutralize the money market effect of their transactions in foreign exchange. Due to the sterilization of the money market effect the interventions, in essence, involve nothing but a shift in the currency composition of private investment portfolios. Henderson and Sampson (1983) set out how sterilized interventions eventually exert an effect on the exchange rate through the portfolio balance channel by causing an imbalance in investors' portfolios. Bhattacharya and Weller (1992, p.4) note that "it is implausible to suppose that the impact of such tiny changes in the worldwide asset mix would have a significant effect on exchange rates".[1] According to them, the introduction of strategic behaviour by central banks can alter the scope for intervention dramatically. This paper explores the strategic interaction between the central bank on the one hand and private speculators on the other hand.

The paper is organized into four remaining sections. In section 2 central bank intervention is modeled as a game against rational speculators. The following argument is developed. Typical intervention efforts are very tiny compared to the average daily turnover in the foreign exchange market. In order to maximize the effect of interventions carried out to counteract shocks to the

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[1] Almekinders and Eijffinger (1991) and Edison (1993) provide a comprehensive survey of empirical investigations into the effectiveness of intervention. They conclude that, in general, interventions working through the portfolio balance channel have no economically significant impact on exchange rates. For a different view see Dominguez and Frankel (1993a,b). The estimation results in the latter studies are subject to simultaneity bias and/or involve testing the effectiveness of intervention indirectly through a risk premium.

demand for foreign exchange, central banks will engage in surprise-interventions. Actual higher-than-expected central bank interventions may catch private foreign exchange traders off balance leading them to revise their forecasts of future exchange rates. In the efficient foreign exchange market this will lead to an immediate correction of the exchange rate. However, speculators resist to be fooled by the central bank. Consequently, they base trading in the foreign exchange market on the anticipation of central bank intervention. It is shown in the paper that the strategic interaction between the central bank and private speculators introduces an 'intervention bias': the equilibrium volume of intervention is *ceteris paribus* larger in absolute value without reducing the impact of shocks to the exchange rate. This is the case if the central bank systematically tries to counteract realized shocks to the exchange rate and if the private sector has full information about the shape of the policy loss function which underlies the intervention behavior of the central bank. Section 3 investigates the sensitivity of the equilibrium volume of intervention to changes in the central bank's aversion to non-fundamental exchange rate changes. Furthermore, two propositions are derived with regard to the link between central bank independence and the magnitude and variability of the volume of intervention. Section 4 investigates whether these propositions are supported by cross-country evidence. Section 5 concludes.

2. Central bank intervention as a game against rational speculators.

By now, an extensive body of literature exists which analyses monetary policy games (for surveys, see *e.g.* Blackburn and Christensen (1989) and Cukierman (1992)). A game theoretic analysis of the incentives facing monetary authorities when managing the external rather than the internal value of the domestic currency has only recently attracted attention. Horn and Persson (1988), Holden (1991), Alogoskoufis (1993) and Rasmussen (1993) go beyond refining the familiar inflation-unemployment tradeoff. Holden (1991, p. 1543) recognizes that "... a government may feel tempted to exploit the short run rigidity of wages, and devalue in order to obtain a short run gain in terms of improved competitiveness". However, for countries which committed themselves to the Articles of Agreement of the International Monetary Fund (IMF) competitive devaluations do not seem to be a feasible policy option.[2] In general, the monetary authorities of large industrialized countries give priority to domestic policy objectives. The instruments of monetary policy are basically used to attain these objectives. Therefore, throughout this paper it is assumed that central banks only try to influence the course of the exchange rate by means of sterilized interventions which by definition lack a money market effect.

A systematic analysis of exchange rate policy requires an appropriate model of the

[2]Principle A of the Principles and Procedures for Surveillance which came into effect in March 1978 provides that 'a member shall avoid manipulating exchange rates (...) in order to (...) gain an unfair competitive advantage over other members' (*IMF Survey*, April 3, 1978).

exchange rate. Furthermore, some assumptions regarding the behaviour of the central bank and private exchange market participants need to be made.

The exchange rate

The general failure of structural models of the exchange rate in empirical tests is well documented (for a survey see MacDonald and Taylor (1992)). In recent years many economists have adopted new research strategies in exploring the field of exchange rate economics. Within a short time an extensive literature has developed which aims to describe the mere statistical properties of the time series of exchange rates. In this literature short-term exchange rate returns are thought of as resulting from the interaction among the various sorts of exchange market participants and their reaction to the 'news' which hits the market almost continuously. However, all of this is mostly left unspecified ('black box'). In this paper the popular random walk model of the exchange rate is amended to allow for an effect of intervention.

Consider the following stochastic exchange rate equation:

$$\Delta s_t = a + \delta^V INV_t + \delta^E (INV_t - INV_t^e) + \epsilon_t, \qquad \epsilon_t \sim N(0, \sigma_\epsilon^2) \qquad (1)$$

where s_t is the log of the foreign exchange rate (units of domestic currency per unit of foreign currency).[3] INV_t and INV_t^e denote the actual volume of intervention (purchases of foreign currency by the domestic central bank) and private exchange market participants' expected volume of intervention, respectively. It is important to note that speculators determine INV_t^e upon observation of ϵ_t, the stochastic shock to the exchange rate.[4] When the actual and expected volume of intervention are both zero (*i.e.*, in case $INV_t = INV_t^e = 0$) and when the stochastic shock to the exchange rate ϵ_t takes on a value of zero, the domestic currency experiences a constant a per cent depreciation ($a > 0$) or appreciation ($a < 0$) *vis-à-vis* the foreign currency per time period. In the remainder of the paper this a per cent exchange rate change is assumed to be implied by a difference between the inflationary biases of monetary policy in the domestic and the foreign country.[5] Obviously, if a is positive (negative) the domestic inflationary bias is higher

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[3]Following the empirical literature (see, *e.g.* Meese and Singleton (1982) and Baillie and Bollerslev (1989)), the exchange rate is assumed to contain a unit root.

[4]The shock to the exchange rate may exhibit persistence according to $\epsilon_t = \epsilon_{t-1} + b + \chi_t$, where χ_t is a normally distributed random variable with mean zero and variance σ_χ^2 and b, the drift of the ϵ-process, is the constant and predictable part of the shock. In the present paper the exact specification of the shock is not important as speculators are supposed to form expectations after its realization.

[5]Similar monetary policy games at home and abroad may lead to different optimal time-consistent inflation rates for the domestic and foreign economy. In monetary policy games productivity is usually assumed to be constant and the same across countries. By contrast, the responsiveness of output to changes

(lower) than the foreign one.

Compared to individual private currency dealers, the central bank may be viewed as a relatively big player in the market. However, intervention volumes are very tiny compared to the total daily turnover on the foreign exchange market.[6] Consequently, the course of the exchange rate is not likely to be affected by the very volume of intervention. In spite of that, equation (1) does allow sterilized interventions to affect the exchange rate through the portfolio balance channel.[7] This effect is measured by the coefficient δ^V. If δ^V is positive the volume of intervention itself matters with purchases (sales) of foreign currency affecting the exchange rate positively (negatively). The negligibility of intervention volumes compared to the average daily turnover on the foreign exchange market implies that $\delta^V = 0$. Equation (1) also leaves open the possibility that central bank intervention works through the expectations channel. Actual higher-than-expected interventions may catch private speculators off balance and, hence, lead to a correction in the exchange rate. The expectations channel is operative if $\delta^E > 0$. This implies that actual larger-than-expected purchases (sales) of foreign currency affect the exchange rate positively (negatively).[8]

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in the real wage, the difference between the market clearing level of output and its socially optimal level and/or monetary authorities' preferences may be different in any pair of countries (see, *e.g.* Cukierman 1992, p. 29). Purchasing power parity (*PPP*) implies that the rate of exchange-rate depreciation is equal to the difference between the domestic and foreign rate of inflation, $\hat{\pi}_t$ and $\hat{\pi}_t^*$, respectively:

$$\Delta s_t^{PPP} = \hat{\pi}_t - \hat{\pi}_t^* \equiv a$$

[6]What stands out from Dominguez and Frankel (1993, Figures 5.1 and 5.4 - 5.13) is that the Bundesbank, the Federal Reserve and the Swiss National Bank refrain from intervening on the majority of trading days. More importantly, typical intervention efforts by these central banks are of the order of $100 to $300 million. In April 1992, the daily average of global spot market turnover net of double-counting arising from both local and cross-border interbank operations was estimated to be $ 400 billion. This implies a 15 percent rise from the corresponding estimate of $350 billion for April 1989 (Bank for International Settlements, 1993).

[7]Henderson and Sampson (1983) and Pilbeam (1991) set out how intervention operations that, for example, increase the current relative supply of German mark to U.S. dollar assets which private investors are obliged to accept into their portfolios, force a decrease in the price of German mark assets.

[8]It can easily be seen from equation (1) that the effect of (unexpected) purchases of foreign currency may not be large enough to *fully* compensate for the downward pressure on the exchange rate, *i.e.* when $0 < \delta^V INV_t + \delta^E (INV_t - INV_t^e) < |a + \epsilon_t|$. In that case, casual observation of the resulting exchange rate movement, Δs_t, leads one to conclude that the interventions were not effective. This touches upon the familiar methodological problem that, in practice, the rate of appreciation $a + \epsilon_t$ that would have occurred in the absence of intervention is not known.

Central bank behaviour

The central bank is assumed to make a tradeoff between the costs of interventions in the spot market for foreign exchange and the losses from fluctuations in the exchange rate. The central bank policy loss function looks as follows:

$$L_t^{CB} = \frac{1}{2}(c\ INV_t)^2 + \frac{\alpha}{2}(\Delta s_t - a)^2 \tag{2}$$

The first term on the right hand side of (2) proxies the costs of intervention. The value of the central bank loss function increases more than proportionally with the volume of intervention. The higher the volume of intervention the higher the potential financial losses on the net foreign currency position of the central bank caused by purchases (sales) of foreign currency which turn out to be not successful at preventing the domestic currency from appreciating (depreciating). Of course, potential financial gains from interventions which turn out to be effective also increase with the volume of intervention. However, if central banks are risk averse and if they are aware of the relative negligibility of interventions on the balance of supply and demand in the foreign exchange market, they will limit the chance of losing money by intervening too heavily.[9] It seems that, the more predictable the actions of the central bank the higher *ceteris paribus* the potential losses from intervention and the higher the cost coefficient c.

In principle, exchange rate stability is a public good. The second term on the right hand side of (2) reflects that central bank losses increase more than proportionally with changes in the exchange rate which are not caused by the differential inflationary biases at home and abroad. Above it was argued that the different outcomes of the monetary policy games between the central bank and workers in the domestic and the foreign economy initially resulted in an a per cent per period depreciation of the domestic currency (of course, when a is negative the domestic currency appreciates). This depreciation may be at odds with for instance the monetary authorities' attempts to stabilize the exchange rate and to maintain external equilibrium of the domestic economy. However, it is assumed that the central bank gives priority to domestic monetary policy and that it will not direct exchange rate policy at counteracting exchange rate movements which are a direct result of the outcome of the monetary policy game.

Rational speculators

The foreign exchange market is hit by 'news' almost continuously. This frequent arrival of new information causes currency traders' positions to be in a permanent state of flux. Each

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[9]Apart from financial costs of intervention, it can be argued that there are reputational costs involved as well. The latter costs will not be analyzed in the present paper, however.

exchange market participant bases position taking on his prediction of the market's interpretation of, and reaction to news and rumors. This translates into a stochastic shock to the exchange rate ϵ_t. Obviously, this stochastic shock is the outcome of a kind of information game among well-informed private exchange market participants (Lyons (1991)). However, for the present exchange rate policy game issues of intra-private sector behaviour, addressed in Blackburn and Christensen (1989, p. 12) in a general game theoretic context, are of no concern.

By assumption, strategic interaction between the central bank on the one hand and private exchange market participants on the other hand comes into play only after the shock ϵ_t has materialized.[10] Consequently, for the exchange rate policy game, the diverse group of foreign currency traders can be treated as one representative agent. The loss function of the representative speculator looks as follows:

$$L_t^{PS} = \frac{1}{2} (INV_t^e - INV_t)^2 \tag{3}$$

where INV_t^e denotes the speculator's expectation regarding the volume of intervention to be carried out by the central bank in period t. To make sure, the realization of the shock ϵ_t is contained in the information set of the representative speculator when he computes this expectation. The loss function in (3) reflects speculators' aversion to be fooled by the central bank.

The Nash equilibrium of the exchange rate policy game

The strategic interaction between the central bank and the representative speculators takes place after the shock to the exchange rate has occurred. Hence, although there is a stochastic element in the exchange rate model, the exchange rate policy game is deterministic. Upon the observation of the speculative shock to the exchange rate, the monetary authorities attempt to minimize period t's policy loss, taking the expectations of private exchange market participants, INV_t^e, as given (the Nash assumption). The central bank's reaction function to the expectations of other exchange market participants is obtained from the first order condition for a minimum of (2), *i.e.* $\partial L_t^{CB}/\partial INV_t = 0$, after substituting equation (1) into it:

$$INV_t = \frac{\alpha(\delta^V + \delta^E)}{c^2 + \alpha(\delta^V + \delta^E)^2} [\delta^E \, INV_t^e - \epsilon_t] \tag{4}$$

[10] In Krugman's (1991) target zone model the anticipation of unlimited *unsterilized* interventions by the central bank at the edges of the band induces an S-shaped exchange rate pattern inside the band, the so-called honeymoon effect. There is no such effect in the model here. This is because the central bank is assumed to use monetary policy instruments only for domestic policy objectives. This assumption, which seems realistic for most large industrialized countries, diminishes the scope for central bank intervention rather dramatically. Private speculators know that interventions have no significant impact on the exchange rate as long as they do not come by surprise. Hence the absence of a honeymoon-effect.

According to equation (4) the domestic central bank partly accomodates private exchange market participants' expectations regarding the volume of intervention.[11] Clearly, private exchange market participants minimize period t's losses by setting

$$INV_t^e = INV_t \tag{5}$$

An expression for equilibrium intervention is obtained by substituting this reaction function in (4):

$$INV_t = -B\,\epsilon_t\,, \quad where \;\; B = \frac{\alpha(\delta^V + \delta^E)}{c^2 + \alpha\delta^V(\delta^V + \delta^E)} \tag{6}$$

[Insert Figure 1]

Figure 1 shows the central bank's reaction function for the case of a negative shock to the domestic-currency value of foreign currency, i.e. $\epsilon_t < 0$.[12] Thus it depicts the volume of intervention as a function of the expected volume of intervention in a situation in which purchases of foreign currency are called for. The only point at which expectations are rational is at point N, the intersection of the central bank's reaction function and the 45°-line through the origin. This represents the Nash equilibrium. This equilibrium which is also called the 'discretionary equilibrium' or the 'time consistent solution' in the 'rules versus discretion' literature is unique in this one-shot game. If private exchange market participants expected a lower volume of intervention, in absolute terms, than what is implied by (6), the central bank would have an incentive to carry out surprise interventions. Thus, expectations would not turn out to be rational.[13] Intervention expectations rise to the point where there are no further incentives for the central bank to create surprise interventions. Analogous to the well known 'inflationary bias' of discretionary monetary policy analysed by Barro and Gordon (1983a,b) and Alogoskoufis (1994) this is the 'intervention bias' of discretionary exchange rate policy. The volume of intervention at point N is given by equation (6). However, what stands out from equation (5) and Figure 1 is that in equilibrium intervention is fully anticipated. Substituting (5) in the exchange rate equation (1) gives

$$\Delta s_t = a + \delta^V INV_t + \epsilon_t \tag{7}$$

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[11] $\dfrac{\alpha\delta^E(\delta^V + \delta^E)}{c^2 + \alpha(\delta^V + \delta^E)^2}$ is smaller than one as long as $c^2 > -\alpha\,\delta^V(\delta^V + \delta^E)$. This holds by assumption.

[12] This figure is based on a similar one in Blanchard and Fischer (1989, p. 597).

[13] At points to the left (right) of N, the private sector chooses INV_t^e and the central bank responds by actually carrying out INV_t such that $INV_t > INV_t^e$ ($INV_t < INV_t^e$).

Equations (6) and (7) highlight the time inconsistency of optimal intervention policy. The intervention policy of the central bank described by equation (4) is time-consistent in the sense that at each point in time the volume of intervention selected is best, given the current situation. However, as can be seen from equation (6) and (7), the resulting policy is sub-optimal. It is sub-optimal since it produces an intervention bias with no gains in the form of systematically smaller exchange rate changes unless the portfolio balance channel is operative, *i.e* unless $\delta^V > 0$.

3. The sensitivity of intervention policy to changes in the preferences of the central bank

This section investigates the effect of changes in the weight assigned by the central bank to limiting fluctuations in the exchange rate around the purchasing power parity-implied fundamental trendline. Throughout the paper it is assumed that the monetary authorities of the domestic country give priority to domestic policy objectives. Monetary policy, *i.e.* the choice of domestic inflation is used to attain these objectives. A basic assumption in monetary policy games is that due to existing distortions the market-clearing level of output is lower than the monetary authorities' target level. The parameter which denotes the relative weight the central bank places on output compared to inflation is of crucial importance in the monetary policy game. A well-known result in the literature on monetary policy games is that the higher the central bank's weight on output, the greater the incentive to create surprise inflation. In many studies the parameter for the central bank's weight on output is interpreted as the inverse of the degree of central bank independence (Rogoff (1985), Eijffinger and Schaling (1993b), Debelle (1993)). The idea behind this is that a central bank knows that in the long run it can not systematically stimulate output by means of surprise inflation. Consequently, a central bank will only engage in larger-than-expected monetary expansions if it is forced to do so by politicians and if it is not protected from their influence by law.

In the previous section it was established that the central bank is not able to systematically limit the impact of realized shocks to the exchange rate by means of interventions which work through the expectations channel. Consequently, a central bank which is independent from political incumbents will in general not stubbornly resist these shocks to the exchange rate. As shown by for instance Cukierman (1992) and Eijffinger and Schaling (1993a) in most countries central banks are highly dependent on the government in general and the minister of finance in particular. As a result, the policies implemented by central banks are not independent from the general political process. For instance, a persistent appreciation of the domestic currency will lead domestic exporters to complain to the minister of finance about their declining competitiveness on the world market. A central bank which lacks autonomy in the field of exchange rate policy may be forced by the ministry of finance to engage in highly visible foreign exchange intervention; political incumbents will want to show that they are really concerned with the competitiveness of domestic exporters. The converse of this argument is as follows. The greater the independence given to the central bank by law, the smaller the political influence on exchange rate policy and the smaller the pressure on the central bank to systematically counteract speculative shocks to the exchange rate. Analogous to the monetary policy game, the notion of central bank independence can be incorporated in the present exchange rate policy game by taking the weight α in the central bank loss function in (2) to measure the inverse of the independence of the central bank.

Regarding the intervention reaction coefficient in (6) it can be shown that $\partial B / \partial \alpha > 0$ and $\partial^2 B / \partial \alpha^2 < 0$. Consequently, the higher the weight given by the central bank to reducing changes in the exchange rate which are larger in absolute value than those implied by purchasing power parity, *i.e.* the higher the value of α, the larger the intervention bias. From this proposition 1 can be derived.

Proposition 1: The more independent the central bank, the smaller the average volume of intervention

From

$$\lim_{\alpha \to \infty} B = \lim_{\alpha \to \infty} \frac{\alpha(\delta^E + \delta^V)}{c^2 + \alpha \delta^V(\delta^V + \delta^E)} = \frac{1}{\delta^V} \tag{8}$$

it follows that when the central bank is averse to non-fundamental exchange rate changes the intervention reaction coefficient in (5) converges to the inverse of the coefficient which measures the "volume effect" of intervention. It can be shown that this is the same intervention reaction coefficient as in the game against nature in which $\delta^E = 0$. Figure 2 shows how the intervention reaction coefficient in (5) changes with an increasing aversion of the central bank to speculative shocks to the exchange rate. When α goes to infinity the central bank (or the politicians which determine its policy) is not bothered by the costs of intervention. In a full information exchange rate policy game private speculators know the value of α. Consequently, when α is very high they know that the central bank is going to counteract realized shocks to the exchange rate (ϵ_t) as fiercely as possible. As a result, the expectations channel of influence of interventions does not work at all. The mere "volume effect" of intervention has to do the job. This implies that the central bank will have to try to affect the exchange rate through the portfolio balance channel of intervention. Clearly, when δ^V is very small the average volume of intervention goes to infinity.

[Insert Figure 2]

The variability of the volume of intervention is also sensitive to changes in the central bank's aversion to non-fundamental changes in the exchange rate. Taking variances of (5) gives $Var\ (INV_t) / \sigma_\epsilon^2 = B^2$. From

$$\lim_{\alpha \to \infty} \frac{Var\ (INV_t)}{\sigma_\epsilon^2} = \lim_{\alpha \to \infty} B^2 = \lim_{\alpha \to \infty} \left[\frac{\alpha(\delta^E + \delta^V)}{c^2 + \alpha \delta^V(\delta^V + \delta^E)}\right]^2 = \frac{1}{(\delta^V)^2} \tag{9}$$

it follows that, if the central bank gives an infinite weight to stabilizing the exchange rate around *PPP*-levels, the variance of the volume of intervention is positively related to the variance of shocks to the exchange rate, σ_ϵ^2, and inversely related to the effectiveness of interventions via the portfolio balance channel. Obviously, $\partial B^2 / \partial \alpha > 0$. This implies that a higher weight to limiting changes in the exchange rate leads to a higher variance of the volume of intervention relative to the variance of the shock to the exchange rate. From this proposition 2 can be derived.

Proposition 2: The more independent the central bank, the lower the variance of the volume of intervention.

Equating to zero the second derivative of B^2 with respect to α obtains a point of inflection at $\alpha = c^2/(2\ \delta^V(\delta^V + \delta^E))$. Figure 3 shows how the relative variability of the intervention volume changes with an increasing aversion of the central bank to speculative shocks. From equation (5) it follows that the higher the costs of intervention, *c*, the smaller *ceteris paribus* the equilibrium volume of intervention. When the weight α increases, the central bank is relatively less concerned with the costs of intervention. This leads to a catch-up effect with the variability of intervention (compared to σ_ϵ^2) initially rising fast. When α is above the value corresponding to the point of inflection the shape of the central bank loss function in (2) implies that the costs of intervention start to weigh more heavily again. Consequently, a rise in α leads to a slower rise in the relative variability of the volume of intervention.

[Insert Figure 3]

4. The link between intervention efforts and central bank independence: some cross-country evidence

Section 2 presented a simple game-theoretic model of exchange rate policy. In section 3 it was established that the model implies a negative correlation between the degree of central bank independence and the magnitude and variability of the volume of intervention. In this section it will be investigated whether these negative correlations are supported by cross-country evidence. The Eijffinger-Schaling (ES) index of policy independence developed in Eijffinger and Schaling (1993a) will be used as a measure of central bank independence.[14] This index is available for

[14]Eijffinger and Schaling (1993a) showed that the Alesina (1988, 1989) synthetic indicator of central bank independence is internally inconsistent and does not qualify as an index. Grilli, Masciandaro and Tabellini (GMT) (1991) developed an index of political and economic independence which is very broad. Because they use eight criteria in determining the degree of independence, the essential characteristics of central bank independence are watered down. Alesina and Summers (1993) averaged the Alesina index and the GMT index of political and economic independence.

twelve major industrialized countries. For each of the twelve central banks the magnitude of the intervention efforts is proxied by the average absolute percentage change in the foreign exchange reserves of the respective central bank. The variability of the volume of intervention is proxied by the variance of the absolute monthly percentage change in the central bank's foreign exchange reserves.[15] The data on central bank independence and intervention efforts are depicted in Table 1.

The relationship between the degree of central bank independence and the magnitude and variability of the volume of intervention is analyzed for the post-Bretton Woods period from February 1973 through to January 1993. Under the Bretton Woods system of fixed exchange rates all countries were fully committed to maintaining a fixed price of the U.S. dollar in terms of their own currency. In the model in section 2 it was assumed that central banks are free to choose the actual volume of intervention, *i.e.* they are not bound by international exchange rate arrangements. Therefore, the propositions derived from this model can not be tested with data covering a period during which central banks were obliged to conduct unsterilized interventions in case of strains on the foreign exchange market.

Figure 4 shows a negative relation between the average absolute percentage change in foreign exchange reserves and the ES index of central bank independence. Switserland is a clear outlier in the figure. There are two obvious explanations for that. Firstly, Switserland plays a central role in international banking. Moreover, international investors often regard it as a safe heaven. Consequently, foreign currency flows into the Swiss economy can at time be very large. The Swiss National Bank, like many other central banks, sometimes tries to limit the upward pressure on the external value of the Swiss frame by absorbing some of the foreign currency coming in from abroad. Secondly, it is an idiosyncracy of Swiss commercial banks that they wish to exhibit higher end-of-quarter liquidity in terms of Swiss francs than they wish to maintain over the entire period. In order to smooth out the resulting daily money market rate peaks, the Swiss National Bank offers end-of-quarter swaps to commercial banks (Gärtner (1987, p. 443)). These swaps are completely unrelated to developments in the foreign exchanges. Yet, they are included in the monthly reserves data used in this section.

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[15]The data are taken from the International Financial Statistics of the IMF, *Foreign exchange reserves in millions of U.S. dollars, line 1 D.D.* Upon denoting this monthly variable by R_t, the average monthly absolute percentage change in the foreign exchange reserves of country i is given by

$$DRes_i = \left[\frac{1}{240} \sum_{t=1973:2}^{1993:1} (|R_t - R_{t-1}|)/R_{t-1} \right]_i$$

The variance of the monthly absolute percentage change in foreign exchange reserves of country i is given by

$$VarRes_i = \left[Var(|R_t - R_{t-1}|/R_{t-1}) \right]_i = \frac{1}{240} \sum_{t=1973:2}^{1993:1} ((|R_t - R_{t-1}|/R_{t-1}) - DRes_i)^2$$

With Switserland excluded from the sample, the negative correlation between the volume of intervention and the degree of central bank independence is supported by the results of a simple OLS regression depicted in the top row of Table 2.

The negative relation between the variability of the volume of intervention and the degree of central bank independence can be seen from Figure 5. The result of an OLS regression shown in the bottom row of Table 2 confirm this (again Switserland is left out of the sample).

5. Conclusions

This paper investigates the motives and constraints facing central banks when they decide to engage in foreign exchange intervention. It analyzes an exchange rate policy game between a central bank and rational speculators under symmetric information. The central bank systematically tries to counteract realized shocks to the exchange rate by means of sterilized interventions which presumably work through the expectations channel. Private speculators resist to be fooled. They anticipate the interventions. As a result an 'intervention bias' emerges with the equilibrium volume of intervention *ceteris paribus* being larger in absolute value without reducing the impact of shocks to the exchange rate. The equilibrium volume of intervention is sensitive to changes in the central bank's aversion to non-fundamental exchange rate changes. The paper argues that the greater the independence given to the central bank by law, the smaller the political influence on exchange rate policy and the smaller the pressure on the central bank to systematically counteract speculative shocks to the exchange rate. Analogous to the monetary policy game, the notion of central bank independence is incorporated in the exchange rate policy game by taking the central bank's aversion to non-fundamental exchange rate changes to measure the inverse of the independence of the central bank. In section 3 it is established that the simple game-theoretic model of exchange rate policy implies a negative correlation between the degree of central bank independence and the magnitude and variability of the volume of intervention.

For the post-Bretton Woods period from February 1973 through to January 1993 a cross section of twelve industrialized countries lends support to the propositions derived from the model that the more independent the central bank the smaller and the more consistent the intervention efforts.

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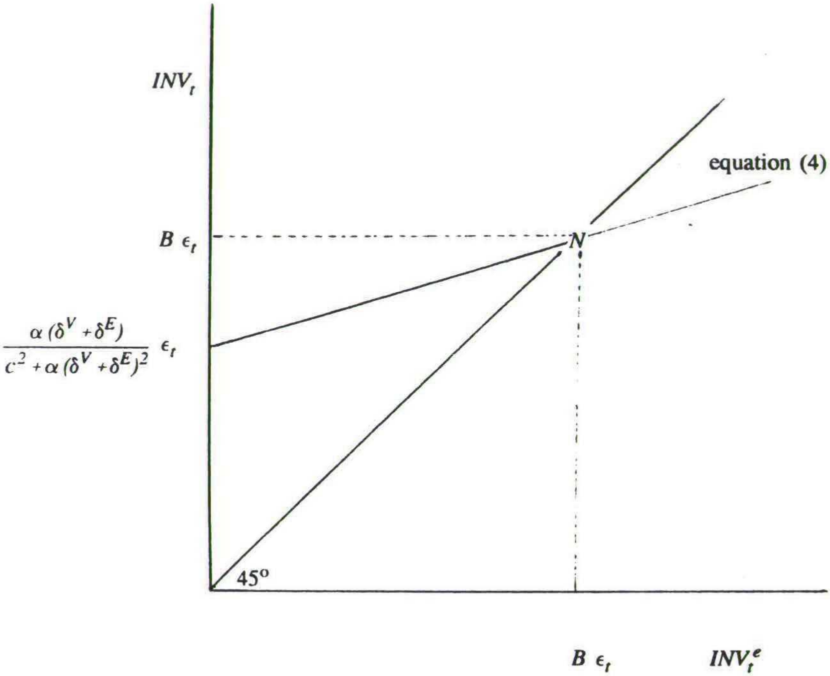

Figure 1 Actual and expected intervention in the presence of positive shocks to the demand for domestic currency which the domestic central bank wants to counteract.

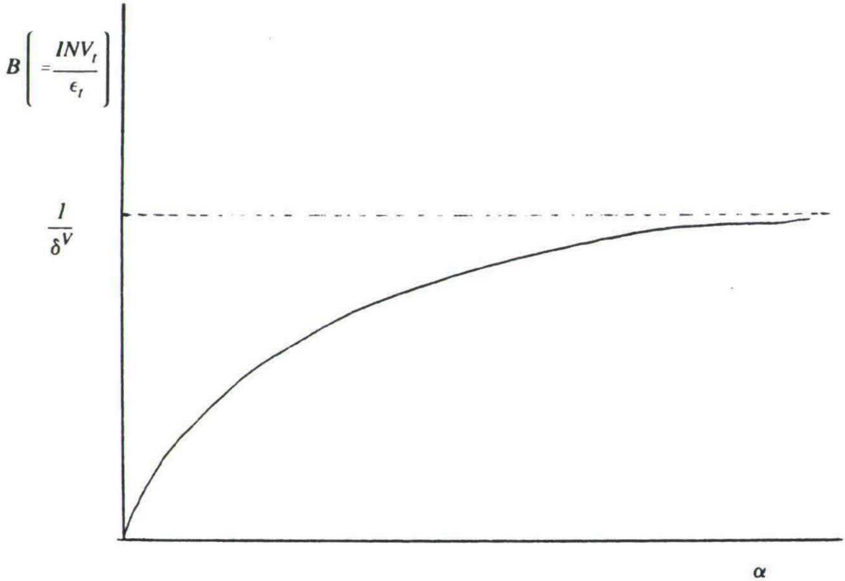

Figure 2 The central bank's aversion to shocks to the exchange rate and the intervention reaction coefficient.

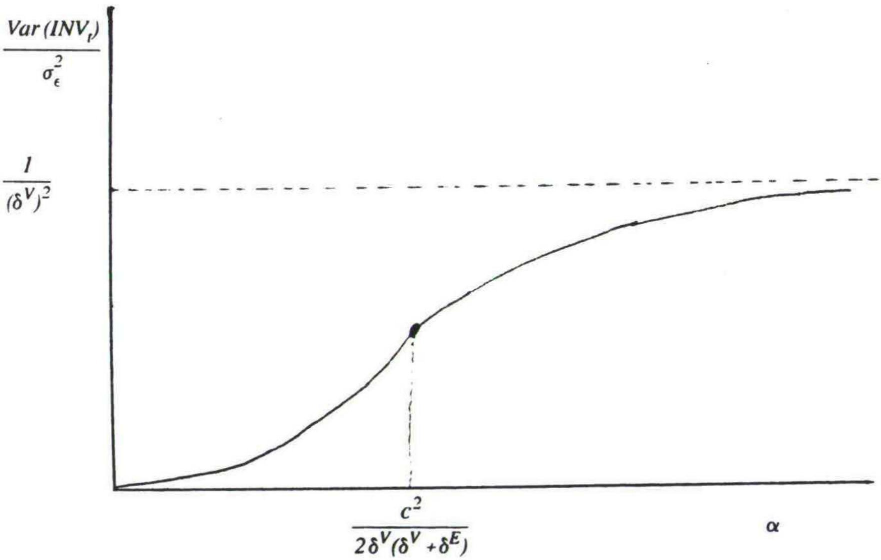

Figure 3 The central bank's aversion to shocks to the exchange rate and the variability of the volume of intervention.

Figure 4 Central bank independence and the average volume of intervention

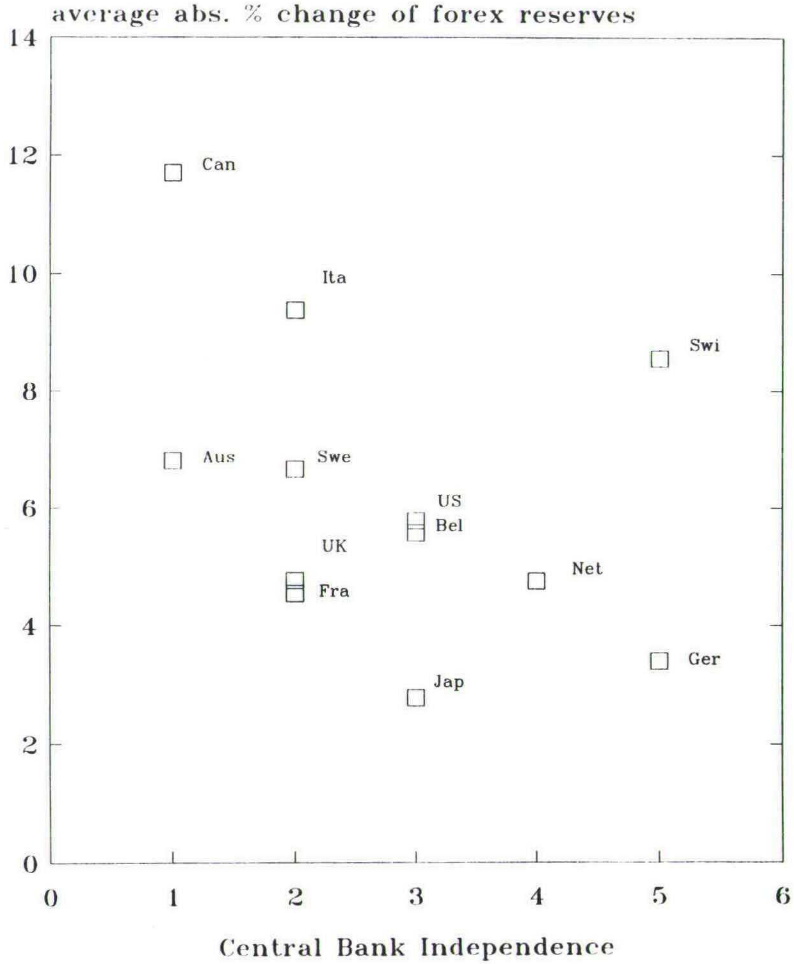

Figure 5 Central bank independence
and the variability of intervention

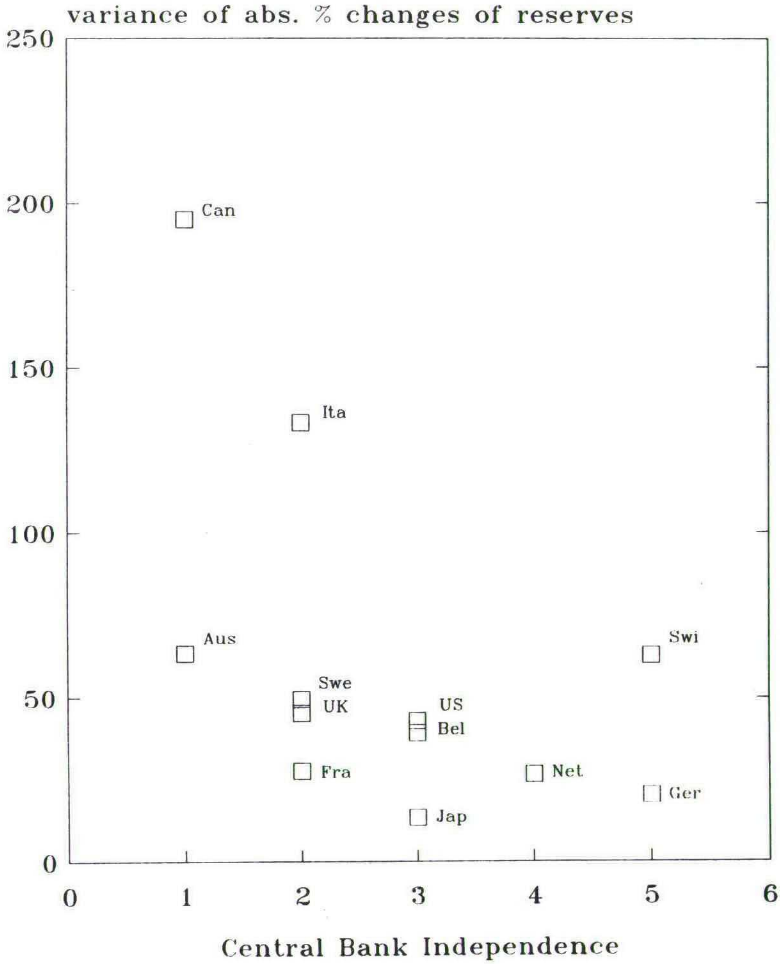

Table 1 *Central Bank Independence and Intervention Efforts:* February 1973-January 1993.[16]

Country	Eijffinger-Schaling Index of Central Bank Independence	Average Monthly Absolute Percentage Change in Forex Reserves	Variance of Monthly Absolute Percentage Change in Forex Reserves
	ES-index$_i$	DRes$_i$	VarRes$_i$
Australia	1	6.80	63.27
Canada	1	11.69	194.91
France	2	4.53	27.31
Italy	2	9.37	133.16
Sweden	2	6.65	49.25
United Kingdom	2	4.75	44.96
Belgium	3	5.56	38.99
Japan	3	2.77	13.13
United States	3	5.77	42.76
The Netherlands	4	4.74	26.42
Germany	5	3.39	20.13
Switzerland	5	8.54	62.67

Table 2 *Central Bank Independence and the magnitude and variability of intervention: OLS estimation results:* February 1973-January 1993.[17]

independent variable / dependent variable	constant	ES-index$_i$	$\bar{R}^2$
DRes$_i$	9.59 (6.37)	-1.41 (-2.62)	0.37
VarRes$_i$	129.82 (3.84)	-27.63 (-2.29)	0.30

[16]For the United States the sample period chosen covers the period November 1978 through to January 1993. Immediately after the demise of the Bretton Woods system the published foreign exchange reserves of the U.S. were very small. Under those circumstances, small absolute changes in the reserves are equivalent to very large percentage changes.

[17]The number of observation is eleven. T-statistics are in parentheses. $\bar{R}^2$ is the squared multiple correlation coefficient adjusted for degrees of freedom.

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