Central bank intervention
and exchange rate dynamics with a regime switching VAR

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Abstract

The present paper offers a new strategy for the empirical assessment of the conditions for the effectiveness of sterilised central bank intervention in the foreign exchange market. This aims at testing in a unified framework the validity of two alternative versions of the signalling approach to central bank intervention. The proposed empirical strategy consists in three steps. First a Probit model is used in order to isolate the part of intervention which is systematically related to the deviation of the exchange rate from its target level. Second, a regime switching VARX is estimated in order to differentiate regimes on the basis of the role played by interventions. Third, simulations are used to examine the respective effects on the exchange rate of the proxy for expected and unexpected intervention both co-ordinated and uncoordinated. Such an approach is applied to the DM-dollar exchange rate after the Louvre accord.

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Central bank intervention in the foreign exchange market has attracted renewed attention over the last year among both academics and policymakers for two reasons. First the large-scale (for many, surprising) depreciation in the euro vis a vis other major currencies since its inception early 1999, has led some observers to argue in favour of a support for the new currency through dollar sales by the European Central Bank. The latter was for long reluctant[1] but finally tried it both in a co-ordinated way in September and then unilaterally in November 2000, when it judged that the bottom of the trough in the dollar value of the euro had finally been reached. This was not accompanied by any new major theoretical work supporting such a policy against the pre-existing near consensus among empirical researchers on the lack of effectiveness of central bank intervention in changing the level of the exchange rate in a desired direction, except possibly in exceptional circumstances (see the survey by Girardin, 2000).

The second reason is linked to the renewed strength of the yen, and (mostly) independent from it, to the persistent sluggishness of the Japanese economy with an apparently ineffective monetary policy at near-zero interest rates (for evidence, see Girardin and Horsewood, 2000). These two stylised facts have led the leading theoreticians in the field of monetary policy to turn their eyes towards Bank of Japan (BOJ) intervention to weaken the yen as the new "foolproof" (Svensson, 2000) way out of lasting stagnation. These new theoretical developments have not set themselves in the track of developments in the theory of the effectiveness of central bank intervention in the foreign exchange market. They have rather mostly appealed to a transmission channel that specialists of the study of central bank intervention had thought long ago discredited i.e. the portfolio-balance effect. Conventional wisdom in the nineties implied that the scale of intervention (typically a couple of billion dollars at most) was too tiny to trigger any substantial reshuffling of portfolios between domestic and foreign assets. The most frequent reply of the advocates of the 'foolproof' way consists in drawing the full lesson from this argument and advise the BOJ to flood the market with yens (Bernanke, 2000; McCallum, 2000; Meltzer, 2000). In their mind, such flooding would at some stage generate non-linearities in the effect of central bank intervention, such that portfolio-balance effects would eventually start to operate.

However Svensson (2000) goes farther by considering that, in the absence of a portfolio-balance effect, aggressive foreign exchange intervention might affect exchange rate expectations and thus the exchange rate. In a complementary way he advocates the adoption by the BOJ of an exchange rate target giving way in the future to an inflation target. Thus Svensson's argument mostly relies on the view of intervention signalling future monetary

[1] Girardin and Boinet (2001) document the prominent role of interest rate policy in the weakness of the euro. On the reaction function part in interest rate decisions by the ECB as a response to such depreciation since late 1999, see Girardin and Taylor (2001).

policy, i.e. the second transmission channel of central bank intervention. The latter is explicitly emphasised by Clouse et al. (2000). Such a transmission channel is often considered as the only alternative channel through which central banks should rely in the hope of their intervention to have any effectiveness.

Given the difficulties met by the empirical validation of the predictions of models based on the second channel, the present paper will offer a new unified framework aimed at testing the relevance of this second channel compared to a third channel. Such a channel is based on the release by the central bank through its interventions of information on its exchange rate target. The novelty of this interpretation of the strategic approach, as applied to foreign exchange market intervention, is that the effectiveness of interventions arises only from the extent to which the central bank, by means of such interventions, conveys some information on its exchange rate objectives, which remain partly secret. The latter theoretical framework implies that only unexpected intervention should have an impact on the exchange rate. This result may seem relevant in the case of the February 1987 Louvre Accord which adopted exchange rate targets for G3 currencies, without publicising the level of such targets.

A novel empirical implication of this third channel is that one should extract the unexpected or non-systematic part of intervention. This is similar to the well-known literature on the effects of monetary policy shocks. The now standard approach to the study of the latter, as popularised by Christiano et al. (1998) has relied on vector autoregressive (VAR) models. Using a VAR model instead of focusing solely on an exchange rate equation is particularly relevant since as emphasised by McCallum (1994) one cannot exclude that in the two countries involved interest rates respond to exchange rate movements. The possibility of such reaction functions has been mostly overlooked in the intervention literature which has modelled intervention policy separately from monetary policy. This could account for the difficulties met in validating the monetary policy-signalling channel. We consider here VARs in levels since we are only interested in examining the effects of shocks and only focus on the effects of intervention on the level of the exchange rate.

Accounting for regime shifts should be a major concern when examining the relationships between central bank intervention, exchange rate and interest rate dynamics. One should allow for the possibility that such relationships depend on the regime that occurs at any given point in time. The major focus of existing work has been to allow for stochastic regime switching within a single equation framework, assuming that in each regime the dynamic behaviour of the exchange rate or the interest rate can be modelled by a linear auto-regressive process.

The strategy we implement starts by extracting the systematic component of central bank intervention with a Probit model in order to disentangle the expected and unexpected components of intervention. The intervention series are used as exogenous variables in a regime-switching VARX estimation in order to identify the regimes for exchange rate dynamics. Finally for each stable regime, we use simulations in order to examine the response of the exchange rate to shocks on both expected and unexpected intervention for the co-ordinated and uncoordinated cases.

The second section will emphasise the difficulties met by existing tests of the now standard monetary policy signalling channel of intervention and introduce the alternative exchange rate target signalling framework. Section 3 will examine the issues left open by available empirical evidence and motivate the research strategy which will be followed in the econometric work, focusing in particular on a unified framework for testing the two signalling channels? Section 4 will present the results of the empirical estimations on the Louvre Accord period with daily data for the German and U.S. intervention on the Dollar. The conclusion will summarise the main findings.

2. Theoretical framework.

As a rule central banks sterilise their interventions in the foreign exchange market by acting in the interbank market in an opposite way. It is now common practice to distinguish the effects of such sterilised intervention[2] on the exchange rate through the portfolio balance channel from the effects on exchange rate expectations through a signalling channel (Isard, 1995). The portfolio-balance channel of intervention (Dominguez and Frankel, 1993) has lost its appeal because the amounts involved seem to small compared to the size of transactions on the foreign exchange market to induce a significant readjustment in agents' portfolios. The signalling channel came too readily to be confused with one of its specific cases where the signal refers to future monetary policy. However many results which seem "perverse" when seen in the light of the latter approach have been rationalised when considered from the point of view of an alternative approach where the signal refers to the exchange rate target of the central bank.

The discussion of signalling effects (Mussa, 1981) suffered initially from the failure to focus explicitly on how much market participants are assumed to know about the incentives of the central bank. Recent work has shown that with rational agents the effectiveness of signalling depends on the degree of information of market participants about the incentives of the central banks. Within the context of a *flexible* exchange rate regime, the signalling view argues that exchange rates would be influenced by interventions since the latter are used by central banks to enlarge the market's information set by providing it with private central bank information.

[2] When interest rates are very close to zero, as currently in Japan, there is no difference between sterilised and unsterilised interventions since in both cases interest rates are unaffected.

The monetary-policy-signalling channel

In one interpretation, interventions should be seen by market participants as a signal of future changes in monetary policy (see Dominguez, 1992). When believed by the market, such signals would alter expectations about future fundamentals, even though current fundamentals would not have changed. The revision of the expectations of the future spot rate associated with the revised expectations on future fundamentals would generate a change in the current exchange rate. Intervention which credibly and unambiguously signals future monetary tightening should affect the domestic currency in the intended direction (Dominguez, 1998). By contrast, when signals are ambiguous or lack credibility, intervention would have undesired effects on the level of the exchange rate. Thus secret interventions, by increasing uncertainty, would lead to a “perverse” response of the exchange rate.

Some empirical work tried to investigate directly to what extent central bank interventions do signal in practice future changes in monetary policy. However even when such evidence was uncovered this generally did not validate the signalling channel. Thus Lewis (1995) found that interventions by the Federal Reserve have some predictive power (over the subsequent two-weeks) for monetary indicators. However this can be explained by technical reasons regarding required reserves and cannot be taken as a validation of the monetary-policy-signalling channel. Kaminsky and Lewis (1996) study univariate processes for the monetary indicators, in particular the Federal funds rate, allowing their evolution to follow two regimes, interpreted as being one of contractionary monetary policy and another of expansionary monetary policy. They examine whether intervention at some lag is useful for predicting the current monetary regime and find that over the period 1985 through 1989 intervention was indeed informative about future monetary policy. However, once again, this does not validate the signalling channel since the results imply that over part of the Louvre Accord period future monetary policy signalled by interventions was in the opposite direction from that implied by the signalling hypothesis. This means for example that dollar sales by the Fed in the foreign exchange market would be followed by contractionary monetary policy. Even with such a wrong sign interventions can be useful in predicting future events. However they also uncovered that the implied movements in the exchange rate were “perverse”.

Recent work (Fatum and Hutchison, 1999) uses new data on the Federal Funds futures markets over the period 1989 through 1993. Their main finding is that purchases of dollars by the Federal Reserve in the foreign exchange market do not raise the Federal Funds futures rate but only generate a rise in the conditional variance of such a futures rate. In the light of these studies, it seems difficult to identify a clear and effective monetary policy-signalling channel.

The exchange rate target signalling channel

The alternative approach to monetary-policy signalling is based on a distinction between monetary policy and intervention policy as two instruments aimed at two different targets. Vitale (1997) who examines the co-ordination between monetary policy and central bank intervention in the foreign exchange market rigorously models this. His study of the effectiveness of intervention aims at determining to what extent the central bank can pursue an independent exchange rate target when at the same time it directs its monetary policy instrument at controlling inflation. In other words, he considers to what extent sterilised intervention represents an additional effective instrument enabling the central bank to pursue some exchange rate objective.

In a game-theoretic setting, Battacharya and Weller (1997) model a central bank, with 'inside information' about its exchange rate target, trading with risk averse speculators who have private information about future spot rates. Since it has a privileged position in the foreign exchange market, the central bank can accurately infer speculators' information related to expectations about the exchange rate. By contrast, speculators only learn part of the actions of the central bank. The central bank is assumed to aim at limiting the deviation of the exchange rate from a target value. To achieve its objective the Bank intervenes in the foreign exchange market. The utility function of the Bank is such that latter faces a trade-off between the expected costs of intervention and the benefit drawn from stabilising the exchange rate around the target.

In this model the spot rate can become very sensitive to interventions. This stems from the fact that the equilibrium spot exchange rate reveals some information about the current exchange rate target of the authorities, which can be used to predict the future spot exchange rate. The authors identify circumstances in which alleged 'perverse' responses to intervention are observed; i.e. the domestic currency depreciates when the central bank purchases it. Such a result is explained by the double effect of an increase in the spot rate on the level of the speculative demand for the currency: the first effect increases the forward rate and thus decreases speculative demand for the forward currency; the second effect leads speculators to revise upwards their expectations of the future spot rate. When the second effect dominates the first, a 'perverse' response to intervention occurs. This can be illustrated when the central bank endeavours to implement a soft-landing of the currency by consistently purchasing it as the currency continues its depreciation. The likelihood of such a ‘perverse’ response is higher when the market holds a relatively precise view of the (central bank’s) exchange rate target and an imprecise one of fundamentals.

The strategic interaction examined by Battacharya and Weller (1997) is essentially static. As such it implies that the time inconsistency of intervention policy is not solved. Time inconsistency gives rise to an "intervention bias"[3] (Almekinders, 1995) analogous to the inflation bias. As we know since Barro and Gordon (1983), reputation is one of the ways to remedy time inconsistency. Thus Eijffinger and Verhagen (1996) model central bank intervention in a repeated game setting. The use of such a framework is motivated first by the repeated interaction involved by frequent interventions and second by the learning process on the part of speculators which induces the central bank to take into account the future consequences of its current intervention policy.

Within such a model (Eiffinger and Verhagen, 1996), the loss function of the central bank involves both intervention costs and losses incurred whenever the exchange rate level (e_t in logarithm) differs from the authorities' target (c_t in logarithm):

$$(1)\quad L_t = (1/2)\,(k\, INV_t)^2 + (\theta/2)\,(e_t - c_t)^2$$

with θ the relative weight on exchange rate stabilisation and k the cost of intervention (INV) per unit of foreign exchange traded. The latter cost includes both transaction cost and the possible losses on the sales (purchases) of foreign exchange by the central bank when the latter does not manage to prevent a depreciation (appreciation) in the domestic currency.

The exchange rate is supposed to be driven by:

$$(2)\quad e_t = E(f_{t+n}\, I\, \Omega_t) + \varphi[E(INV_t\, I\, \Omega_{t-1}) - INV_t] + \phi\, i_t + \varpi\, i^*_t + \varepsilon_t$$

where $E(f_{t+n}\, I\, \Omega_t)$ represents the publicly known distribution of the future fundamentals, i and i* the domestic and foreign interest rates.

When observing the difference between interventions (INV_t) and expected intervention [$E(INV_t\, I\, \Omega_{t-1})$], the market receives information (with noise) about the exchange rate target of the central bank. Thus unexpected intervention leads to a change in exchange rate expectations which will generate a change in the spot rate. Thus φ denotes the size of the response of the market to such new information.

Within such a setting, sterilised interventions may be partly successful in achieving its desired exchange rate target in the short run. Interventions contain an ambiguous sign of such a target. By its very existence, intervention by the central bank transmits to the market some of the hitherto privately held information concerning its own preferences. The market will thus be provided with an anchor on which it will partly base its short-term exchange rate

[3] Eijffinger and Verhagen (1996) shed further light on the size of the "intervention bias", i.e. that part of the total volume of intervention which has no impact on the exchange rate but which cannot be avoided because of the time-inconsistency problem. In a world without private information the optimal solution would be for the central bank to commit not to intervene. However the central bank always has the incentive to renege ex post on its commitment. This leads to a situation where the central bank intervenes without influencing the spot rate. Retaining private information, i.e. not revealing its preferences on the level of the exchange rate, will mitigate the time-inconsistency problem. Indeed it will both reduce activism by the central bank in the foreign exchange market and make effective its interventions. As a result the welfare of the authorities will rise compared to a world without private information.

expectations. This will offer the central bank a means to try and reach its desired exchange rate target.

On average (in the long run) intervention will not influence the exchange rate. However, this does not matter since the short-run link between exchange rates and underlying fundamentals is assumed to be extremely weak. The central bank will not be able to fool the market systematically and it cannot either pursue an exchange rate target which is out of line with the underlying fundamentals.

Such a modelling strategy relies on the presumption that there is no strong and direct relationship between interventions and tactical changes in monetary policy. The central bank uses the short-term exchange rate target to inform speculators about its opinion on the extent to which the current level of the exchange rate represents a serious deviation from the uncertain fundamental value. Of course although the central bank does not know which one among the possible future paths of fundamentals will be relevant, it does have private information about the way in which it will react to all these different paths. The central bank uses the short-term target as a “crude summary indicator” of such private information.

Given that the third channel focuses on the role of the exchange rate target pursued by the central bank, one needs to specify to what extent such models differ from the implicit target zone models developed for instance by Lewis (1995b). The main difference stems from the fact that, in target zone models, traders expect movements in the exchange rate away from targeted levels to be offset with increasing likelihood as rates drift from the target. Accordingly, the latter model implies that the intensity of intervention induces expected reversion to target levels in the determinants of rates and, therefore, the rates themselves (Lewis, 1995b). As a result both the conditional mean and the conditional variance of the exchange rate depend upon the probability of intervention. Such a proposition is contrasted with models of the third transmission channel, which, as we have just seen, emphasise that it is the unexpected part of intervention which will have an impact, and a stabilising one, on the level of exchange rate.

3. The issues left open by available empirical evidence and a suggested empirical strategy.

On the empirical side, a new wave of studies has appeared in the late nineties which have had little relationship (if any) with the policy concerns of either the Japanese or the euro zone central bankers referred to in section 1 above. Indeed, econometric work has devoted its attention to identifying the exchange rate volatility reducing (actually rather enhancing) effects of intervention through the modelling of conditional (in some cases implicit) volatility. Such work has endeavoured to validate the monetary policy signalling view of intervention. As mentioned above, the latter considers that the degree of secrecy of intervention plays a major role in conditioning its effects on exchange rate volatility. However, as mentioned above, to date, the results of such studies have proved unsupportive of such a signalling channel (for a survey, Girardin, 2000). A number of issues left open and the neglect of the teachings of the third intervention channel may account for the difficulties met by the empirical literature on intervention.

Accounting for long-run relationships

Empirical studies of the effectiveness of central bank intervention in the foreign exchange market have assumed that exchange rates are exactly integrated of order one. Accordingly, the focus has been on modelling exchange rate returns, possibly controlling for the effects of contemporaneous monetary policy by including the interest rate differential, and also allowing for some potential impact of actual intervention by the two central banks involved.

One would then estimate an equation such as (3) where the intervention variables are lagged (with a GARCH model fitted on the residuals):

$$(3)\ \Delta \log E_t = a_0 + b_0\, BUY_{t-1} + c_0\, SELL_{t-1} + d_0\, BUY^*_{t-1} + e_0\, SELL^*_{t-1} + f_0\,(i^*_t - i_t) + \varepsilon_t$$

where BUY (SELL) denotes the purchase (sale) of domestic currency by the domestic central bank, an asterisk refers to a foreign variable[4], i the domestic (i foreign) interest rate and E the number of units of domestic currency per unit of foreign currency.

One can alternatively examine the impact of intervention on the deviation from (or the ex post return over) uncovered interest parity[5] (UIP), estimating a constrained version of equation (3) with (f_0=1) At no point would such studies concern themselves with the issue of missing variables or the unbalanced character of the exchange rate returns equation. Indeed, the interest rate differential is not unambiguously a stationary variable. Moreover it may not be the relevant variable, since one should first check that the restriction on the equality of the interest rate coefficients is accepted. If this is not the case, one should keep the levels of the two interest rates. If the interest rate differential (or the interest rates) is (are) integrated of order one, then one would naturally allow for a possible long-run relationship between such a variable(s) and the level of the exchange rate (as in Ramaswamy and Samiei, 2000).

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[4] Using a specification without the interest rate differential, Baillie and Osterberg (1997a) were unable to uncover any effect of Federal Reserve intervention on the next period rate of change of the mark-dollar exchange rate over the August 1985-February 1990 period. Indeed none of the coefficients in (3) are significant. By contrast, Federal Reserve dollar purchases seem to have led to subsequent dollar depreciation against the yen.

[5] When viewed as signalling future monetary policy, U.S. (German) dollar purchases should increase the deviation from uncovered interest parity. In other words such purchases should signal that the authorities have information about policy, which when known by the market would boost the mark-dollar. Over the January 1987 through January 1993 period Baillie and Osterberg (1998) rather find that German dollar purchases decrease the deviation from uncovered interest parity. Over the sub-period October 20, 1987 through 1989, such a result is robust and U.S. dollar purchases also have a positive impact on the deviation from UIP. The latter result is also robust when account is taken of possible differences between co-ordinated and unilateral interventions.

Empirical studies have noticed that sometimes interest rate policy seems to have adopted a stance opposite to the stance of intervention policy. However, none of these has run a fully integrated empirical study of the determinants and effects of the two policies. Indeed, in most studies of the exchange rate effects of intervention, when the interest rate differential is present in the exchange rate equation, it is only to control for the possible contemporaneous monetary policies. Besides, it has been simply postulated that the past level of the exchange rate is never one of the determinants of interest rate decisions. This is all the more surprising that McCallum (1994) has convincingly warned us against the danger of estimating an equation where the exchange rate (returns) is (are) a function of the interest rate differential without explicitly modelling feedback effects. More telling, the interest rate differential was rarely, if at all, included as an argument in the estimated reaction function of the authorities conducting intervention. Accordingly, one should model explicitly the interest rates of the two monetary authorities. Moreover this can allow direct testing of the monetary policy-signalling channel.

Intervention surprises

As seen in section 2 above, models of the third transmission channel imply that only the unexpected part of central bank intervention in the foreign exchange market should matter for the exchange rate, because in the long run intervention is ineffective. This has some similarities with the inflation surprise theory popularised among others by Robert Lucas.

The literature has examined the raw or observed intervention series or tried to disentangle the secret versus publicly reported intervention but it has not been concerned with the respective effects on exchange rates of expected and unexpected intervention. By contrast, the vast literature on the transmission mechanisms of monetary policy has itself put a lot of emphasis on the distinction between the systematic and unsystematic portions of monetary policy (Favero, 2000). In the present case the issue is even more complex since on top of interest rates as a representative instrument of monetary policy in each country, one should model a second instrument, i.e. central bank interventions in the foreign exchange market.

As we know, an alteration in the policy rule(s) will change the coefficients in the equations. In other words a system such as (4) below cannot be used to evaluate systematic intervention policy. However, one can examine the dynamic impact of shocks to intervention policy by keeping all parameters constant. We are indeed mainly concerned with the effect on the exchange rate of both the expected and unexpected part of central bank intervention and rely on the identification of intervention shocks. Such a focus is synonymous with a concern with the systematic as well as the unsystematic part of intervention, the latter being defined as all variations in central bank policy that cannot be accounted for by a rule-based reaction to the state of the economy. Such a study is a means to collect information on the response of financial variables to shocks in interventions.

From the perspective of the strategic interaction model with reputation, one should disentangle the two components of central bank intervention. The difficulty of the current problem is that the system cannot simply be estimated as a VAR model. Indeed, intervention variables are discrete. As such an equation for them can only be estimated separately with qualitative variable methods. The latter have been traditionally used in the literature.

Available studies have indeed examined the determinants of systematic central bank intervention. However, with the exception of Lewis (1995b), researchers have kept the estimation of the intervention reaction function disconnected from the work on the effectiveness of intervention[6]. The aim was then only to check whether interventions are themselves dependent on the exchange rate. The "effectiveness" part of the exercise should rather be considered as the second step in which the results of the first step are included as exogenous variables in a VARX estimation, as in system (4) :

(4) $y_t = \alpha + \Gamma_j \; y_{t-j} + \Phi_k \; x_{t-k} + \gamma_t$

where $y_t = (e_t, i_t, i^*_t)$ and $x_{t-k} = (BUY_{t-k}, SELL_{t-k}, BUY^*_{t-k}, SELL^*_{t-k})$.

VAR in levels.

In order to account for long run relationships between the exchange rate and the two countries' interest rates, given that such variables are usually considered to be integrated of order one, one may be tempted to use a multiple cointegration technique such as the one developed by Johansen (1988). However several reasons should guard against doing so. One of them is that the normality and heteroskedasticity conditions would not be easily met with high frequency data. The second reason is that since there is likely to be fractional integration in our exchange rate or interest rate series, the Johansen procedure would then give biased results.

In the tradition of Sims, Stock and Watson (1990), the specification of a VAR system that we use rather considers variables in levels. In the case of such VARs with polynomial functions of time and one or more unit roots, Sims et al. (1990; see also Hamilton, 1994,

[6] The empirical work by Almekinders and Eijffinger (1996) also departs from other work. First, they combine a GARCH-M model for exchange rates, where interventions influence both the mean and the conditional variance of returns, and a loss function for the central bank. Second, in order to accommodate the fact that the central bank does not intervene on the majority of trading days, they use a "friction" model, to estimate the intervention reaction function. In such a model, the dependent variable is zero as long as independent variables remain close to their desired levels. The central bank's tolerance threshold for deviations of such variables from their desired levels is among the parameters of the model. With daily data over the period February 1987 through October 1989, Almekinders and Eijffinger (1996) find that it is apparent that the Federal Reserve as well as the Bundesbank leaned against the wind selectively and attempted to counteract appreciations of their own currency more strongly than depreciations. Thus the Federal Reserve (Bundesbank) intervened twice as much, in value terms, in response to an appreciation (depreciation) of the dollar vis a vis the mark than in case of a depreciation.

chapter 18) showed that, independently of the order of integration of the variables, one can get a consistent estimation of coefficients. Even when nonstationarities are present there is no requirement to transform the VAR into a VECM form for meaningful inference to be carried out (Canova, 1995). Such a framework is appropriate if one is interested in studying the impact of shocks on intervention (in the context of monetary policy, see Christiano et al, 1999).

The issue of using levels versus growth rates (or first differences) has been mainly debated in the regime-switching literature with reference to forecasting performance. The focus on growth rates seems to have advantages for forecasting since (Hendry and Clements, 1999), it may be more robust than level specifications to structural shifts that are not explicitly modelled. However, since we are not concerned here with forecasting, such considerations are not directly relevant.

Regime switching

A substantive issue relates to the appropriate sample to be considered in the econometric study. We consider it useful here to draw on the teachings of the literature on monetary policy. It is often emphasised that VAR models of the monetary transmission mechanism should be estimated within a single policy regime (Favero, 2000) because regime shifts require different parametrisations (see also Bagliano and Favero, 1998). When estimated over different policy regimes, VAR models of the monetary transmission mechanism show evidence of structural instability. In order to ensure that we study the impact of central bank intervention on exchange rate dynamics within a single regime, we should account for regime shifts. One needs to allow for the possibility that the dynamic behaviour of the exchange rate depends on the regime that occurs at any given point in time.

One possibility would be to consider models which characterise regimes by an observable variable (relative to a threshold value) since these imply that regimes are known with certainty. It has been argued that the modelling of regime switching behaviour for exchange rates with a threshold autoregressive model may be particularly relevant under a system of implicit target zones such as occurred in the second half of the eighties when the G7 attempted to stabilise the mark and yen values of the U.S. dollar (Kräger and Kugler, 1993). G3 monetary authorities would have intervened in the foreign exchange market as a reaction to large depreciations or appreciations of the dollar, which would have led to different behaviour for moderate and large changes of the exchange rate of the dollar.

By contrast, we will consider here models in which the regime is determined by an underlying unobservable stochastic process (s_t), i.e. in which one assigns probabilities to the occurrence of the different regimes. In its most popular version, which we will use here, such a model assumes that the process s_t is a first-order Markov process. As a corollary, the current regime only depends on last period regime. Most existing work in the field of modelling regime switching exchange rate dynamics has focused on a single equation framework where exchange rate returns are assumed to follow a regime-switching process (Engel and Hamilton, 1990). Similar work has dealt with regime switching interest rate dynamics (Hamilton, 1988). We propose here to integrate the two series of models with a regime-switching VAR.

4. Empirical application.

We provide here an empirical application of the strategy proposed in section 3 in order to assess the validity of the second and third channels of central bank intervention. The theoretical framework which motivates the third transmission channel of intervention implies that only unexpected intervention should have an impact on the exchange rate while according to the second channel only intervention validated by future monetary policy should matter. In the first part of our study, in order to get proxies for the expected and unexpected components of intervention, we establish the systematic components of such intervention with a Probit model. The fitted series is taken as a proxy for the probability of intervention (and its complement the probability of non-intervention) on the days when intervention actually occurred.

Because of the possibility of a reaction function we cannot exclude that interest rates respond to exchange rate movements and thus we work with a VAR model. To the extent that a long run relationship may exist between exchange rates and interest rates, one should allow for their occurrence. In the second step, we thus carry out a regime switching study with a vector auto-regressive model. The latter include, as exogenous variables, the various lagged actual central bank intervention variables in order to identify the regimes for exchange rate (and interest rate) dynamics.

When stable regime have been identified, for each of the stable VARXs we examine the response of the exchange rate and interest rates to expected or unexpected intervention. Such a procedure is applied to the German mark-U.S. dollar with daily data over the period following the Louvre accord. We start by presenting the data used.

4.1. Data.

The data used is daily (excluding week ends) and we choose to focus exclusively here on the post-Louvre accord period in order to identify homogeneous regimes. This implies to examine the sample 23 February 1987 through Late December 1989. The intervention data were provided by the Federal reserve and the Bundesbank. In both cases we have a decomposition for the two central banks between dollar sales against Deutsche mark (noted FedSell and BubaSell) and dollar purchases (noted FedBuy and BubaBuy). The day to day interest rates of the two central banks are also from the Fed and Bundesbank databases. The

DM/dollar exchange rate is the opening rate (Eastern time) in America, extracted from Pacific exchange rate service. The only other information we use is about the target exchange rate under the Louvre accord as reported by Funabashi (1988) set at 1.825 on February 22, 1987, then revised to 1.70 in October and brought back to its original value in June 1988. A detailed account of the chronology of, and official rationales for, intervention by the Federal Reserve and the Bundebank after the Louvre accord can be found in Funabashi (1988), and Randall Henning (1994).

4.2. Probit estimation.

When examining central bank intervention behaviour under the Louvre Accord, Lewis (1995) uncovered that most interventions appeared to be directed toward preventing exchange rate movements away from the target. Lewis emphasised the need to specify a probability function for intervention and to estimate it empirically using intervention data. She mostly favoured a reduced form approach but her estimates of the probability function for intervention, "corroborate the view that the probability of intervention was an increasing function of the deviation between exchange rates and their target levels following the Louvre Accord.". (Lewis, 1995, p. 701)[7]. On this basis we will adopt the following framework.

There are two potential events for each type of intervention for the Federal Reserve (resp the Bundesbank denoted with *) which may occur on a given day t :

Dollar purchases are denoted as BUY_t, with :

$BUY_t = 0$ for no purchase;

$BUY_t = 1$ for dollar puchase

Dollar sales are denoted as $SELL_t$, with :

$SELL_t = 0$ for no purchase;

$SELL_t = 1$ for dollar puchase

The Probability distribution is given by :

$$\{Pr(BUY_t = 0)/ Pr(BUY_t = 1)\} = \alpha_3 + \beta_{3j} (e_{t-1}\text{-}c_{t-1}) + \delta_{3j} \Sigma_{j=1 to m} (i_{t-j} - i^*_{t-j}) + \mu_{3j} \Sigma_{j=1 to m} (FedBUY_{t-j}) + \kappa_{3j} \Sigma_{j=1 to m} (BubaBUY_{t-j})$$

[7] Using more closely synchronized exchange rate data, Esaka (2000) confirms these results, establishing that the Bank of Japan intervened to prevent a too large yen appreciation while the Federal Reserve acted to prevent both a too large dollar depreciation and dollar appreciation. Esaka also finds that the exchange rate levels which triggered intervention by the G3 central banks were very close to the targets reported by Funabashi (1988). Baillie and Osterberg (1997b) also uncover that the deviation of the spot rate from the target levels agreed at the Louvre in 1987 Granger-caused intervention: both purchases and sales of dollars in the case of the mark-dollar and only sales of dollars for the yen-dollar (see also for a longer period Beine et al. 1999).

$$\{Pr(SELL_t = 0)/ Pr(SELL_t = 1)\} = \alpha_3 + \beta_{3j} (e_{t-1}\text{-}c_{t-1}) + \delta_{3j} \Sigma_{j=1 to m} (i_{t-j} - i^*_{t-j}) + \mu_{3j} \Sigma_{j=1 to m} (FedSELL_{t-j}) + \kappa_{3j} \Sigma_{j=1 to m} (BubaSELL_{t-j})$$

We expect that the probability of dollar purchases (sales) will be a positive (negative) function of the deviation between the exchange rate and its target. There may be auto-correlation and coordination in interventions, which implies that past dollar purchases (sales) by both the Fed and the Buba should have a positive impact on Fed dollar purchases (sales). Finally, dollar purchases (sales) should be a negative (positive) function of the interest rate differential (i_{t-j} - i^*_{t-j}). Indeed, with the German interest rate lower (higher) than the Fed funds rate, dollar purchases would reinforce the negative (positive) interest rate differential in supporting the dollar.

One of the issues faced when using qualitative variable methods is the risk of disproportionate sampling. The number of observations in one group may be much smaller than the number in the other group, when the data set does not include all the observations because the groups are sampled at different sampling rates. In the case of central bank intervention data, since we have actual intervention volumes by both the Federal Reserve and the Bundesbank the two groups, intervention (Y_t=1) and no intervention (Y_t=0) are sampled at similar rates. Indeed, we do not leave out any observation in either group. There is thus no a priori ground for using the logit model, whose coefficients are not affected by unequal sampling rates. We thus used the probit model but checked that the extracted probabilities are not altered when using the logit model. It thus seems that the assumption of normality is not too artificial.

The Probit model we use is run separately for dollar sales and purchases, in turn for the Federal Reserve and the Bundesbank over the period 23 February 1987 through December 1989. The explanatory variables included are the deviation between the exchange rate on the previous day and the Louvre accord target (both in log : LGAP), the interest rate differential between the Buba and the Fed (DIFINT) lagged one day, and previous dollar sales or purchases both by the Fed and the Buba.

As shown in table 1a, The Fed sells dollars when the dollar was above the target in the preceding days, when the German interest rate was above the Fed funds rate, when the Fed sold dollar on the previous day and when the Bundesbank sold dollars on the two previous days.

As shown in table 1b, the Federal Reserve purchases dollars when the dollar was under the Louvre accord target, when the Fed has purchased dollars on the previous day and when the Buba has done the same two days earlier. The Bundesbank sells dollars with the same determinants as dollar sales by the Fed (table 1.c.) and buys dollars with the same determinants as the Fed (table 1.d.)

The similarity in the determinants of Fed and Buba sales (purchase) of dollars highlights in a clear way the often coordinated character of their intervention in the dollar-mark market (see below table 2). We checked that the number of cases that the models predict correctly (i.e. with a probability greater than 0.5) the occurrence (or lack of) of intervention is of the order of 85 to 95 %.

The probit models give us the probability of intervention based on the variables included in the estimation. We consider that this gives us a proxy for expected intervention by either of the two central bank. Accordingly, the residuals of the four Probit regressions are taken as proxies for the non-systematic part of intervention, i.e. of their unexpected components. We of course only keep those for the days when some intervention occurred. The series thus represents the ex ante probability of either intervention or no intervention when intervention actually occurred.

Table 1 : Determinants of intervention.

a. Dollar sales by the Fed.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-2.33	0.30	-7.72	0.00
LGAP(-1)	0.17	0.02	7.75	0.00
DIFINT(-1)	0.20	0.08	2.40	0.01
FEDSELL(-1)	0.38	0.09	4.12	0.00
BUBASELL(-1)	0.14	0.09	1.53	0.12
BUBASELL(-2)	0.32	0.08	3.87	0.00

b. Dollar purchase by the Fed.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.95	0.10	-18.1	0.00
LGAP(-1)	-0.11	0.03	-3.58	0.00
FEDBUY(-1)	1.05	0.20	5.11	0.00
BUBABUY(-2)	0.34	0.15	2.22	0.02

c. Dollar sales by the Bundesbank.

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-2.24	0.27	-8.16	0.00
LGAP(-1)	0.03	0.01	1.71	0.08
DIFINT(-1)	0.31	0.07	3.92	0.00
FEDSELL(-1)	0.26	0.08	3.11	0.00
BUBASELL(-1)	0.54	0.09	5.71	0.00

d. Dollar purchase by the Bundesbank

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.91	0.09	-19.1	0.00
LGAP(-1)	-0.07	0.02	-2.3	0.01
FEDBUY(-1)	1.02	0.20	5.1	0.00
BUBABUY(-2)	0.46	0.15	3.0	0.00

Sample: 2/24/1987 12/29/1989
BubaSELL= sales of dollars by the Bundesbank (in 100 million US dollars)
FedSELL= sales of dollars by the Federal reserve (in 100 million US dollars)
BubaBUY= purchase of dollars by the Bundesbank (in 100 million US dollars)
FedBUY= purchase of dollars by the Federal reserve (in 100 million US dollars)
Lgap= (e_t-c_t) = deviation of the exchange rate from target(%).
Difint= (German minus US interest rate), (%)

Table 1 (cont.) : Statistics

	FedDELL	FedBUY	BubaSELL	BubaBUY
Mean dependent var	0.14	0.049	0.16	0.04
S.E. of regression	0.30	0.189	0.33	0.19
Sum squared resid	68.0	26.66	81.4	27.5
Log likelihood	-212.6	-103.4	-273.7	-108.0
Restr. Log likelihood	-308.0	-147.0	-335.2	-147.0
LR statistic (5 df)	190.6	87.1	122.9	77.9
Probability(LR stat)	0.00	0.00	0.00	1.11E-16
S.D. dependent var	0.35	0.21	0.37	0.21
Akaike info criterion	0.58	0.28	0.74	0.30
Schwarz criterion	0.62	0.31	0.78	0.32
Hannan-Quinn criter.	0.60	0.29	0.76	0.31
Avg. log likelihood	-0.28	-0.13	-0.36	-0.14
McFadden R-squared	0.30	0.29	0.18	0.26

3.4. VAR in level and MS-VARs

The specification of a VAR system which we use here, considers variables in level since we are interested in studying the effect of intervention on the level of the exchange rate. We estimate a VARX model with regime switching[8] (MS-VARX) such as :

$$(7)\ y_{St} = \alpha_S + \Gamma_{Sj}\ y_{t-j} + \Phi_{Sk}\ x_{t-k} + \mu\ DAY + \beta\, t + \gamma_t$$

where $y_t = (e_t, i_t, i^*_t)$ and s_t denotes an unobservable discrete regime variable which takes on a finite number of positive integer values (1,....,q) and ε_t I S_t - N(0, Ω_{St}). Dummy variables $x_{t-k} = (BUY^{un}_{t-k}, SELL^{un}_{t-k}, BUY^{un*}_{t-k}, SELL^{un*}_{t-k}, BUY^{coord}_{t-k}, SELL^{coord}_{t-k})$ take a value of one when intervention occurs in an uncoordinated (un) or coordinated (coord) way, with the purchase (BUY) or sale (SELL) of dollars by either the Fed (no asterisk) or the Bundesbank (asterisk). We include a time trend and four daily dummies. We assume here that s_t follows and ergodic Markov process[9]. We take a lag length (j) of four days in the VAR (for a similar choice, see Ramaswamy and Samiei, 2000)[10] and a lag length (k) of five days (as recommended by Kaminsky and Lewis, 1996).

We allowed for up to four different regimes but got consistent results with two regimes. The probability of staying in regime one when being in such a regime is 0.989 while the probability of staying in the regime 2 when starting from the latter is 0.991. Each regime has almost an equal number of observations (374 for the first and 364 for the second) while the second regime lasts a little longer than the first (116 days against 91 days).

[8] The methodology is presented in the technical appendix of the working paper version.

[9] The Markov assumption is in some situation questionable and in an univariate context the transition probabilities have been modelled as time varying and dependent on some variables (Gray, 1996).

[10] Kaminsky and Lewis (1996) in their empirical study consider that a lag of one week is the correct lag at which past intervention is useful for predicting current monetary policy.

The Louvre Accord period seems to have corresponded to two successive and quite contrasted regimes (figure 1). The Markov switching VARX implies that the first regime has almost permanently a probability of one from the start of the dollar targeting period in February 23 1987 through June 26 1988. Subsequently and until late 1989, there is almost persistently a probability of one associated to the second regime.

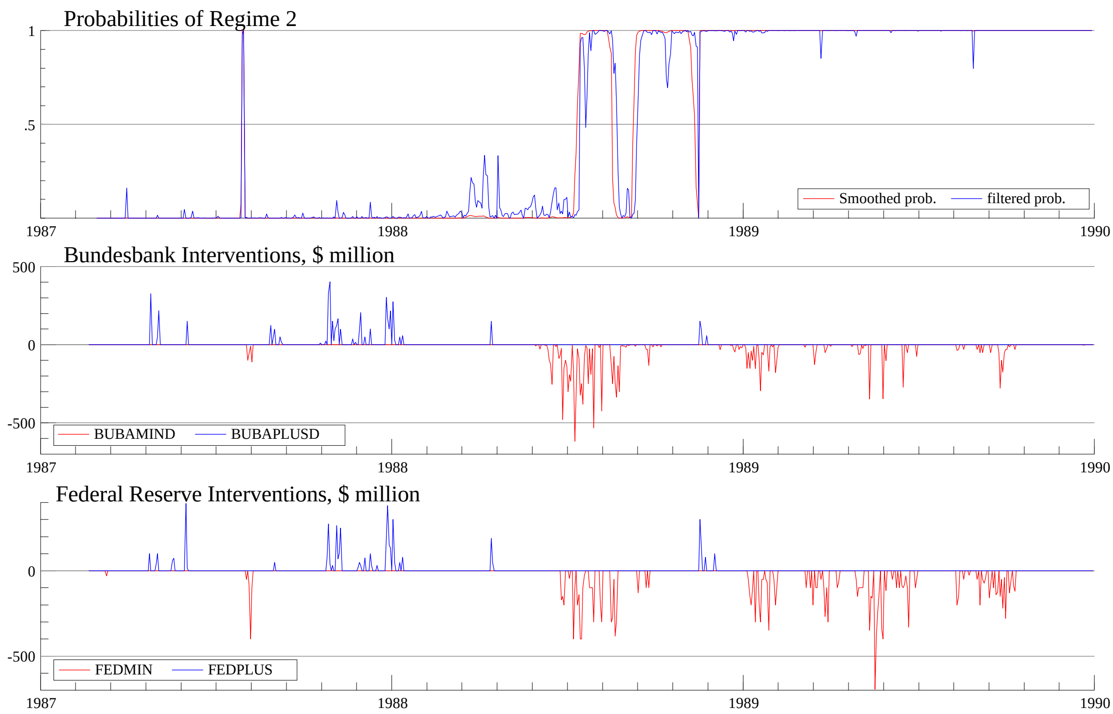
It is possible to match each regime with to the predominance of either dollar sales or purchases by the two central banks (figure 1) The first sub-period correspond mostly to a regime where dollar purchase by both the Bundesbank and the Federal Reserve predominate (on the nature of intervention see table 2) This is also a regime with a weak dollar except for short intervals and for the end of the period.

Table 2. Statistics on the nature of intervention

	Average amount ($ million)	number
Purchase : Period 1		
Buba Coordinated	153.1	22
Fed Coordinated	130.6	22
Buba uncoordinated	83.2	12
Fed uncoordinated	89.1	11
Sales : Period 1		
Buba Coordinated	145.6	62
Fed Coordinated	168.6	62
Buba uncoordinated	55.6	47
Fed uncoordinated	140.0	41

The second regime is characterised by a predominance of dollar strength, except at the beginning and the end of the sub-period. As a result, interventions mostly correspond to dollar sales by both central banks, indeed it is precisely on June, 27 1988 that the U.S. started selling dollars on the foreign exchange market, while the Buba had started a little earlier.

Figure 1 : Probabilities of regime 2 and intervention amounts



4.3. Simulation of shocks on intervention

We now estimate separately a vector autoregressive model for each subperiod[11]. The estimates model is a VARX such as :

(7) $y_t = \alpha + \Gamma_j \; y_{t-j} + \Phi_k \; x_{t-k} + \mu \;\; DAY \; + \beta \, t + \gamma_t$

where $y_t = (e_t, i_t, i^*_t)$ and,

- for the first period $x_{t-k} = (BUYCO^{exp}_{t-k}, BUY^{unexp}_{t-k} \; BUY^{exp}_{t-k}, BUY^{unexp}_{t-k}, BUY^{exp*}_{t-k}, BUY^{unexp*}_{t-k})$ where BUY denotes an uncoordinated purchase of dollars buy the Fed (BUY*=Bundesbank) and BUYCO a coordinated purchase of dollars by both institutions.

- for the second period $x_{t-k} = (SELLCO^{exp}_{t-k}, SELLCO^{unexp}_{t-k}, SELL^{exp}_{t-k}, SELL^{unexp}_{t-k}, SELL^{exp*}_{t-k}, SELL^{unexp*}_{t-k})$ where SELL denotes an uncoordinated sale of dollars by the Fed (SELL*=Bundesbank) and SELLCO a coordinated sale of dollars by both central banks.

[11] Detailed results with usual statistics and the numerous graphs of responses which could not be included here because of space constraints are presented in the working paper version available upon request.

We simulate a shock in turn on both the expected as well as the unexpected components of intervention obtained with the Probit estimation in the VARX in order to isolate the effects on the dollar-mark as well as on the two interest rates. We consider separately the coordinated and uncoordinated cases.

It is useful here to recall the classification introduced by Kaminsky and Lewis (1996) in their study of the correlation between interventions and future monetary policy. They define 'consistent' policies when for instance dollar purchases by the Fed on the foreign exchange market means that the Fed is more concerned about lowering the value of the dollar and might reflect an intention to pursue a more expansionary policy in the future. As a corollary, they dub 'inconsistent' policies those intervention to sell dollars that would aim at depreciating the dollar even though future monetary policy will be restrictive.

They consider three possible results : consistent policies would vindicate the monetary-policy signalling theory. Inconsistent policy would invalidate it even though current intervention and future monetary policy are systematically related. Finally the signalling theory could also be invalidated because there is no information about future monetary policy contained in current intervention.

We examine a shock on expected (unexpected) intervention defined as the average probability of intervention (non-intervention) when intervention is not coordinated between the Fed and the Buba. For coordinated intervention, we consider a shock on the sum[12] of the expected rate of intervention (non-intervention) by the Buba and the expected rate of intervention (non-intervention) by the Fed**.**

Over the first period we only consider shocks to dollar purchase given that dollar sales rarely occurred. As a rule, unexpected dollar purchase leads in the short term to an appreciation in the dollar (light grey areas in the second column of table 3) while expected dollar purchase is conducive in the medium run to a dollar appreciation (dark grey area). This is true with as well as without coordination. As a corollary, unexpected (expected) dollar purchase seems to lead in the medium term (short term) to a perverse response of the dollar, i.e. a depreciation. The signalling of monetary policy element is present whenever intervention is expected since the US central bank subsequently always raises the Federal funds rate in such a way as to generate a positive differential with the German interest rate (medium grey cells). By contrast, unexpected intervention is not systematically validated by subsequent interest policy, except in the case of unexpected Bundesbank intervention validated by Fed monetary policy and coordinated intervention validated by German interest rate decisions .

[12] We consider a weighted sum with weights given by the average share of each central bank in the combined average amount of intervention

Table 3 : effects of shock on intervention over the first subperiod :

dollar purchase

First sub-period	DM/$	i^{GER}	i^{us}	$I^{GER}- i^{us}$
Uncoordinated				
Buba expected	-/+	+/+	+	-
Fed expected	-/+	-/+	+	-
Buba unexpect	+/-	+/-	+	-
Fed unexpect	+/-	+/-	-/-	+/-
Coordinated				
Unexpected	+/-	-	-	-/+
Expected	-/+	-/+	+	-

()/()	Short/medium run
(light grey)	Short term correct effect
(dark grey)	Medium term correct effect
(medium grey)	Validated by interest rate

Such results imply that over the first regime intervention appears to be effective, i.e. able to affect the level of the exchange rate. They also show that the respective relevance of the two signalling channels depends on the time horizon considered. However since unexpected intervention is often validated by subsequent interest rate decisions, there are limits to the vindication of the third channel by such results. Besides the coordinated character of intervention does not seem to make much difference. Our findings that consistent policies were pursued over this period by both the Bundesbank and the Federal Reserve extend and generalise the results obtained by Kaminsky and Lewis (1996) for the Fed in a single equation framework. However we also get the extra result that consistency can be seen in an international perspective. Indeed the Fed raised interest rates after unilateral dollar purchase by the Bundesbank.

Over the second period we only examine shocks to dollar sales given that dollar purchase occurred on very few occasions (table 4). Over this second regime the effectiveness of the various types of intervention does not seem to be closely linked to a specific time horizon. Expected dollar sales lead to a depreciation in the dollar irrespective of the time horizon only if they are coordinated, or in the short run if they are made by the Bundesbank. Unexpected Bundesbank intervention has the right effects whatever the horizon while unexpected Fed intervention only has the correct impact in the medium run. Unexpected coordinated intervention has no effect. Perverse effects of intervention arise irrespective of their expected character. Indeed the dollar appreciates both after fed unilateral expected intervention and after unexpected coordinated dollar sales.

In the second regime, consistency of policy is not a common factor behind the cases of intervention effectiveness. Consistent policies seem to have led to the effectiveness of intervention only in the case of unilateral uncoordinated dollar sales by the Bundesbank. Expected coordinated intervention was effective even though associated with inconsistent policies (except for a short-run in Fed rates). Inconsistency of policy by the Bundesbank was associated with ineffective intervention. The Fed mostly pursued inconsistent policies which as a rule led to the lack of success of intervention. International consistency remains present in only one occasion : i.e. with Fed interest rate reduction after Buba unilateral unexpected intervention.

Table 4 : effects of shock on intervention over the second subperiod : dollar sales

2nd *sub-period*	DM/$	i^{GER}	i^{us}	$i^{GER} - i^{us}$
<u>Uncoordinated</u>				
Buba expected	-/+	-	+	-
Fed expected	+	-/+	+	+/-
Buba unexpect	-	+	-	+
Fed unexpect	+/-	-/-	+/+	-/-
<u>Coordinated</u>				
Unexpected	+	+	+/-	+
Expected	-	-/-	-/0	-

Our findings of inconsistency of policies over the second period can be rationalised for the Fed by the observation that at that time “as monetary policy became more contractionary and remained so well into 1989, this tightening led to a relative strengthening of the U.S.

dollar" (Kaminsky and Lewis, 1996, p.307)[13]. Starting in 1989, there was increasing debates between the Fed and the Treasury on intervention policy, with the former (especially Chairman Greenspan) increasingly sceptical about it. As a result the Fed "was not intentionally signalling future monetary policy changes" through its interventions. Rather "interventions were a reaction by the Treasury to the strengthening of the dollar, as the Fed continued maintaining a contractionary monetary policy. If so, then the signal of intervention in the opposite direction from actual future monetary policy was unintentional" (p. 307).

4. Conclusion

By focusing on features which were mostly overlooked by previous studies, such as the relative impact of expected and unexpected intervention, the reaction of interest rates to exchange rate changes, the necessity to work on (stable-regime) VARs, we provided a unified framework which enables us to find some new evidence in favour of the effectiveness of central bank intervention in the foreign exchange market through two signalling channels. We examined with daily data the dollar-mark targeting period after the Louvre Accord between late February 1987 and late December 1989.

We first proposed to measure expected intervention by the probability of intervention on days when intervention occurred and found that it was a function of the deviation of the exchange rate from target, the interest rate differential (for dollar sales) and past intervention. The similarity in the determinants of Fed and Buba intervention vindicated the often coordinated nature of their actions in the foreign exchange market.

With a Markov-switching VARX in levels, we were able to identify two successive regimes with a change in late June 1988. The first regime is mainly characterised by a weak dollar and dollar purchases by both central banks, while in the second regime mostly a strong dollar and dollar sales predominate.

Examining a VARX for each regime we obtained clear-cut result for the first regime. Indeed, over the period of dollar purchase, intervention appears to be effective, i.e. able to affect the level of the exchange rate. The respective relevance of the two signalling channels depends on the time horizon considered, with unexpected intervention having correct effects in the short run and expected intervention in the long run. However since unexpected intervention is often validated by subsequent interest rate decisions, there are limits to the

[13] "Due to concerns by the Treasury about this strengthening, the U.S. intervened heavily to sell dollars for much of this period. Starting on June 27, 1988 the U.S. sold dollars in the foreign exchange market, totalling 5 billion dollars by September 26. A second round of heavy dollar selling began on January 6, 1989. Since monetary policy remained relatively tight for this period, interventions were systematically in the opposite direction of the signalling story. This pattern shows up as 'inconsistent policies'". (p.305)..." intervention provides significant information about future monetary policy. However, most of the information comes from interventions to sell dollars, followed by tight monetary policy".

vindication of the third channel by such results. Besides the coordinated character of intervention does not seem to make much difference. Moreover, the international dimension of policy consistency may be worth considering. Indeed, unilateral dollar purchase by the Bundesbank was subsequently validated by Fed interest rate increases.

Such well articulated results do not apply for the period of dollar sales even though some interventions, mostly unexpected and uncoordinated or expected and coordinated, still seem able to affect correctly the exchange rate. Perverse effects of expected intervention do occur. The partial failure of monetary-policy signalling is due to the well documented stylised fact that policy was inconsistent in as much as for example tightening in the U.S. generated a dollar appreciation which intervention countered through dollar sales. Moreover, the international consistency of policy seems to have remained only partly at work.

The methodology presented here is currently being applied to other experiences of intervention by the Federal Reserve and the Bundesbank as well as by other central banks in order to test the generality of the results. Besides, we neglected the possible issue of heteroskedasticity. However we checked that within a stable regime the exchange rate equation did not suffer from such problems. A full modelling of conditional volatility in the present context is implemented in a multivariate framework in work in progress.

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