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The impact of FX central bank intervention in a noise trading framework

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ABSTRACT

In this paper, we analyse the effectiveness of the direct central bank interventions using a new effectiveness criterion. To this aim, we investigate the effects of central bank interventions (CBI) in a noise trading model with chartists and fundamentalists. We first estimate a model in which chartists extrapolate past returns and fundamentalists forecast a mean reverting dynamics of the exchange rate towards a fundamental value. Then, we investigate the role of central bank interventions for explaining the switching properties between the two types of agents. We find evidence that in the medium run, interventions increase the proportion of fundamentalists and therefore exert some stabilizing influence on the exchange rate.

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1. Introduction

Direct interventions in the foreign exchange (FX) market have often been used as a policy instrument by the major central banks. By sterilizing their operations, monetary authorities have used these interventions as a stabilisation tool independent of monetary policy. While some authorities like the US Federal Reserve have been increasingly reluctant to use central bank interventions (CBIs hereafter), other major central banks like the European Central Bank (ECB) or the Bank of Japan (BoJ) have conducted several rounds of interventions over the last 5 years.

Despite the wide use of direct interventions by the central banks, researchers (as well as policy makers) have questioned the effectiveness of such an instrument. Within the literature devoted to the conduct of foreign exchange rate policies, the issue of effectiveness is the one which has received the greatest attention. Recent surveys (see [Humpage, 2003](#)) offer a useful review of this strand of the literature. One problem in assessing whether interventions have delivered the intended goal is that the objectives followed by the central banks are rarely known by external researchers. Several possible objectives have been mentioned including influencing trend movements, reversing past trends,

smoothing exchange rate volatility or creating monetary base through unsterilized operations. While a couple of international agreements like the Plaza agreement in 1985 and the Louvre agreement in 1987 provide some insight about the ultimate goal of these interventions, the objectives are likely to change over time and to differ across central banks.¹

In this paper, we develop an analysis directly consistent with a new criterion of effectiveness. A direct criterion of effectiveness used in the empirical literature is whether the exchange rate level reacts to the central bank purchases or sales of foreign currency in the intended direction the day of the intervention ([Beine et al., 2002](#)). The adoption of this criterion stems from the fact that the most frequent objective followed by central banks concerns the dynamics of the first moment of exchange rate returns. In general, the bulk of the empirical studies found that central bank interventions did not induce the intended changes in the exchange rate level. Some studies found even some moderate evidence of perverse results, which is difficult to rationalize (see nevertheless [Bhattacharya and Weller, 1997](#)). Quite recently however, new empirical approaches have provided more support for efficiency in the sense that the exchange rate was found to react significantly (and in the intended direction) to the central bank operation. Using

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E-mail addresses: michel.beine@uni.lu (M. Beine), Paul.DeGrauwe@econ.kuleuven.be (P.D. Grauwe), marianna.grimaldi@riksbank.se (M. Grimaldi).¹ Lack of transparency in the FX policy is clearly one major source for identifying the explicit goals. The use of imprecise terms in central bank's statements also leads to some difficulty of interpretation.

intradaily data, Dominguez (2003) as well as Payne and Vitale (2003) indeed show that such an effect might show up in the very short run, i.e. within a few minutes after the occurrence of the operations.

While simple and straightforward, the use of this criterion of effectiveness raises two questions. First, the objective followed by the central bank might be less simple than influencing the level within the day or the hour of the intervention. For instance, the central bank might be willing to break a past depreciating or appreciating trend of its currency. In this case, insignificant results in terms of returns might lead to overemphasizing the poor performance of the operations. To tackle this point, some authors Fatum and Hutchison (2003) have conducted event studies that allow to introduce more flexibility in terms of the possible objectives followed by the central bank(s).² The second issue is the optimal horizon followed by central banks. While this horizon might differ across central banks and over time, central bank surveys (Neely, 2001) tend to show that central banks also care about the developments of the exchange rate beyond the day of the intervention. Promising outcomes generated by the intervention in the very short run might thus be meaningless for central bankers if they are reversed later on. Conversely, the use of successive interventions that might signal commitment of the central bank to defend the currency might lead to more favourable results that can be difficult to identify in the (very) short run.

In this paper, we adopt another criterion for efficiency of the FX central bank interventions. We consider a given central bank intervention as efficient if it moves the exchange rate in a direction consistent with the fundamental equilibrium exchange rate. Central banks often claim that their interventions aim at restoring the value of exchange rates to a level consistent with the fundamentals. While central banks pursue other goals, the specific objective of minimizing the degree of misalignment has been extensively included in loss functions used in theoretical analyses (see Vitale, 1999 as well as De Grauwe and Grimaldi, 2006 among others). The adoption of such a policy has been advocated by several authors including for instance Neely (2004) claiming that the central bank should act as a long-term speculator in the FX market. Theoretical analyses such as De Grauwe and Grimaldi (2006) also suggest that central bank interventions might drive the exchange rate in a direction consistent with fundamentals. In contrast to the analysis of simple regression coefficients capturing some contemporaneous impact, the adoption of this criterion allows for some role for central bank interventions in the medium run. To this aim, we assess the impact of interventions conducted by the Bundesbank (ECB after the inception of the Euro) and the Federal Reserve within a noise trading framework, i.e. a model allowing for the presence of two types of agents, namely chartists and fundamentalists. The noise trading framework has successfully been applied by authors to explain the discrepancy between the short and long-run exchange rate dynamics (De Grauwe and Dewachter, 1995). It reflects the complex dynamics produced by the interaction of two types of agents whose existence has been empirically supported by the results of surveys of practitioners (Cheung and Chinn, 2001 for instance). As originally done by Vigfusson

(1996), the use of a two-regime Markov-switching regime allows to conduct an econometric analysis consistent with the theoretical assumption of two types of agents. Our analysis of central bank intervention in the context of a chartist-fundamentalist framework is related to the recent analysis of Reitz and Taylor (2008) but exhibits noticeable and important differences.³

The paper is organized as follows. In Section 2 we present a model of the foreign exchange market in which two types of agents, chartists and fundamentalists, interact. In Section 3 we test the prediction of this model and identify the effects of interventions. Section 4 briefly concludes.

2. The underlying theory

2.1. The theoretical framework

In this section we present a simple exchange rate model. The model is based on De Grauwe and Grimaldi (2006a) and is explained there in greater detail. It starts from utility maximising agents selecting their optimal portfolio using a mean-variance utility framework. This allows to derive the standard optimal holding of foreign assets by agent i , $d_{i,t}$ ⁴

$$d_{i,t} = \frac{(1+r^*)E_t^i(s_{t+1}) - (1+r)s_t}{\mu\sigma_{i,t}^2}, \quad (1)$$

where s_t is the exchange rate (the price of the foreign currency in units of domestic currency) in period t , E_t^i is the forecast made about next period's exchange rate by agent i in period t , μ is the coefficient of risk aversion, r and r^* are the domestic and foreign interest rates respectively (assumed to be constant) and $\sigma_{i,t}^2 = (1+r^*)^2 V_t^i(s_{t+1})$. Aggregating the individual demands and setting market demand equal to the market supply of net foreign assets, Z_t , allows us to derive the market clearing exchange rate:

$$s_t = \left(\frac{1+r^*}{1+r} \right) \frac{1}{\sum_{i=1}^N \frac{w_{i,t}}{\sigma_{i,t}^2}} \left[\sum_{i=1}^N w_{i,t} \frac{E_t^i(s_{t+1})}{\sigma_{i,t}^2} - \Omega_t Z_t \right], \quad (2)$$

where $w_{i,t} = \frac{n_{i,t}}{\sum_{i=1}^N n_{i,t}}$ is the weight (share) of agent i , and $\Omega_t = \frac{\mu}{(1+r^*) \sum_{i=1}^N n_{i,t}}$.

Thus the market clearing exchange rate is determined by the forecasts of the agents, E_t^i , about the future exchange rate, their respective weights $w_{i,t}$ and by the net supply of foreign assets Z_t . The latter is determined by the current account and the official interventions in the foreign exchange market. Note also that the forecasts are weighted by their respective variances $\sigma_{i,t}^2$. When agent's i forecasts have a high variance the weight of this agent in the determination of the market exchange rate is reduced.

³ Using a smooth transition model, Reitz and Taylor (2008) find evidence in favour of a coordination channel, i.e. the fact that interventions can move the exchange rate towards its equilibrium value. While we also conclude in favour of such a channel, our two-regime Markov Switching econometric analysis is, unlike their model, based on a structural model of chartist and fundamentalist agents. The proportion of those agents depend on the profitability of their respective forecasting rules. In our model, intervention will alter the dynamics of the exchange rate by changing the relative profitability of the rules, while in the Reitz and Taylor approach, intervention affects the confidence attached by the informed traders to the misalignment value of the exchange rate for processing their orders.

⁴ If the model is interpreted as an asset pricing model of one risky asset (shares) and a risk free asset, the corresponding optimal holding of the risky asset becomes

$$d_{i,t} = \frac{E_t^i(s_{t+1} + y_{t+1}) - (1+r)s_t}{\mu\sigma_{i,t}^2},$$

where s_{t+1} and y_{t+1} are the price and the dividend at $t+1$, respectively, and $\sigma_{i,t}^2 \equiv V_t^i(s_{t+1} + y_{t+1})$ where s_{t+1} and y_{t+1} are the price and the dividend at $t+1$, respectively, and $\sigma_{i,t}^2 \equiv V_t^i(s_{t+1} + y_{t+1})$.

² While interesting, we do not follow here this kind of approaches that in turn raise some questions about their implementation. There are in particular two critical issues associated to the use of event studies for assessing the impact of FX interventions. The first one is the definition of an event and in particular the definition of clustered operations that should be considered as one single event. The second point concerns the endogenous definition of the event. For instance, if a particular central bank keeps intervening until the objective is reached, the use of event studies might lead to a bias in favour of efficiency. Interestingly, this general conclusion turns out to be more supported by this strand of the literature.

Two types of forecasting rules are assumed. One is called a “fundamentalist” rule, the other a “technical trading” (chartist) rule.⁵ The agents using a fundamentalist rule, the “fundamentalists”, base their forecast on a comparison between the market and the fundamental exchange rate, i.e. they forecast the market rate to return to the fundamental rate in the future. In this sense they use a negative feedback rule that introduces a mean reverting dynamics in the exchange rate.

The chartists are assumed to follow a positive feedback rule, i.e. they extrapolate past movements of the exchange rate into the future. Finally agents evaluate the fitness of these two forecasting rules, by comparing their (risk adjusted) profitability *ex post* and then deciding whether to keep the rule or switch to the other one. Thus, the model is in the logic of evolutionary dynamics, in which simple decision rules are selected. These rules will continue to be followed if they pass some “fitness” test (profitability test). This switching mechanism then determines the weights of chartists and fundamentalists w_{ct} and w_{ft} . For more detail see De Grauwe and Grimaldi (2006a). These authors show that the model is capable of generating all the empirical “puzzles” observed in the foreign exchange market. These empirical puzzles are first and foremost the disconnect phenomenon (see Obstfeld and Rogoff (2000) who coined the term “disconnect puzzle”). De Grauwe and Grimaldi (2006a,b) show that the model is capable of mimicking this disconnect puzzle. The mechanism producing this disconnect originates from the dynamic interaction of chartists and fundamentalists. A series of stochastic shocks can make chartist extrapolation profitable thereby attracting an increasing number of agents using extrapolative forecasting rules. This goes on producing misalignments of the exchange rate until it is reversed by shocks in the fundamentals that tend to make fundamentalist forecasting rules more profitable thereby increasing the importance of these rules in forecasting.

2.2. Modelling official interventions in the foreign exchange market

The model presented in the previous section allows for an easy way to introduce the interventions of the central bank. The supply of foreign assets Z_t in Eq. (2) is determined by the current account position, i.e. a surplus (deficit) in the current account increases (decreases) the supply of foreign assets. The supply of foreign assets, however, can also be influenced by the intervention activities of the central bank. More specifically, when the central bank sells foreign exchange it increases the supply of foreign assets Z_t . This will generally put downward pressure on the exchange rate. This can also be seen from Eq. (2): the sign of Z_t is negative. Conversely when the central bank buys foreign exchange it reduces the supply of foreign assets putting upward pressure on the exchange rate.

It can be useful to analyse the impact effect of a surprise change in foreign assets on the exchange rate. We obtain this by isolating the effect of a change in Z_t in Eq. (3). Setting the expectational terms equal to zero, and using the definition of Ω_t we obtain

$$\Delta s_t = - \left(\frac{\mu}{1+r} \right) \frac{1}{\frac{w_{ct}}{\sigma_{ct}^2} + \frac{w_{ft}}{\sigma_{ft}^2}} X_t, \quad (3)$$

where $X_t = \Delta Z_t / N$, i.e. the supply of foreign assets per capita. We have also assumed that there are only two types of agents, i.e. chartists and fundamentalists (subscripted by c and f , respectively).

Eq. (3) makes clear that the effect of a foreign exchange market intervention on the exchange rate will be difficult to predict *ex ante* because it depends on the weights the chartists and fundamentalists have in the market, together with the forecast errors

they have been making in the past. In other words the effect of interventions will depend on the market structure and the risk perceptions at the time of the intervention. Since these factors change continuously, the effect of interventions will also change.

It should also be stressed that we analyse the effects of sterilized interventions here, i.e. interventions that are not allowed to affect domestic money market conditions, including the domestic interest rate. Thus we analyse interventions that do not affect the fundamentals.⁶

We investigate the question of the effectiveness of interventions assuming a simple intervention rule. The intervention rule we consider is one in which the central bank is continuously in the market smoothing the movements of the exchange rate by using a “leaning against the wind” intervention rule.⁷ We specify this rule as follows:

$$\Delta Z_t = \zeta (\Delta s_{t-1}), \quad (4)$$

where $\zeta \geq 0$. Thus when the exchange rate increases (decreases), the central bank sells (buys) foreign exchange in the market so that the supply of foreign assets increases (decreases). The parameter ζ measures the intensity with which the central bank performs these operations. Note that as in the case of the private agents the current exchange rate is not in the information set of the central bank. The current exchange rate is the market clearing exchange rate that will be the outcome of the decisions of both the private agents and the central bank, but is not yet known when agents make their decision. This is in the logic of the behavioural finance model used here. Individual agents (both private and public) lack the cognitive skills to understand “the whole picture”, i.e. they do not know the underlying model which they need to know to compute the market clearing exchange rate in period t (see De Grauwe and Grimaldi, 2006a).

This simple intervention rule can be implemented by substituting Eq. (4) into Eq. (2) and solving the model numerically taking into account the forecasting rules and the switching mechanism as presented in De Grauwe and Grimaldi (2006b). We show some results of simulating the model in the time domain in Fig. 1 using a particular configuration of parameters (in De Grauwe and Grimaldi (2006b) extensive sensitivity analyses are performed). Panel (a) shows the exchange rate in the absence of any intervention ($\zeta = 0$). This is the free float solution. It exhibits large movements of the exchange rate around its fundamental. The next two panels (b) and (c) show the exchange rate for increasing intensity of intervention. In panel (b) we assume that $\zeta = 0.01$ and in panel (c) we assume that $\zeta = 0.1$. We find that as ζ is increased the exchange rate is forced to move more tightly around its fundamental. Thus it appears that this simple rule is capable of reducing the large disconnection of the exchange rate from its fundamental in a free float environment. As a result the application of this rule ensures that the exchange rate better reflects the underlying fundamental.

The intuition behind this result is that the “leaning against the wind” strategy of the central bank reinforces the mean reverting dynamics in the market thereby strengthening the hand of the fundamentalists at the expense of the ‘trend chasers’ (chartists). This stabilizes the market and reduces the probability of the emergence of bubbles. Thus the effect of this intervention is that the exchange rate follows the movements of the underlying fundamentals more closely.⁸

⁶ The interventions carried out by the ECB (Bundesbank) and the Fed over the investigated period in the empirical analysis are reported by the central banks to have been sterilized.

⁷ This leaning-against-the wind type of behaviour has been supported by the estimation of empirical reaction functions for various central banks. See Almekinders and Eijffinger (1996) for the Bundesbank.

⁸ In De Grauwe and Grimaldi (2006a) we analysed the target intervention rule as proposed by Miller and Williamson (1987). The results are very similar to the simple leaning against the wind rule analysed here.

⁵ The idea of distinguishing between fundamentalist and technical traders rules was first introduced by Frankel and Froot (1987).

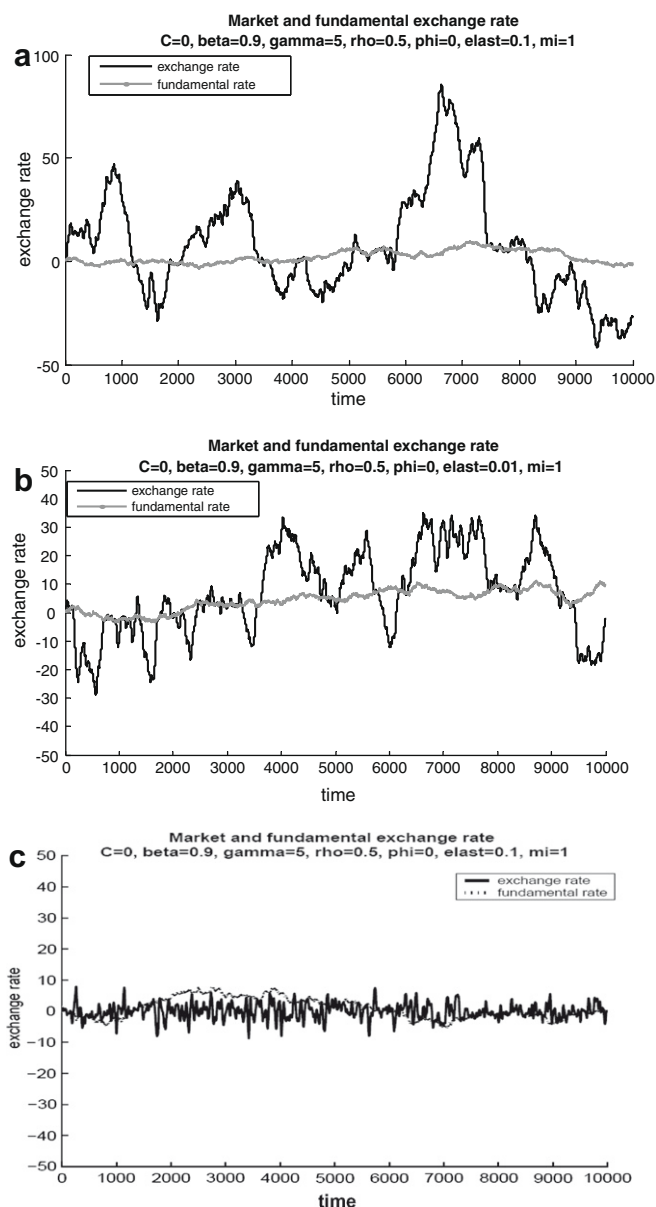


Fig. 1. Simulated exchange rate under intervention rule.

In order to shed additional light on the question of why a simple intervention rule can be effective, we show the average weight of the chartists and fundamentalists corresponding to the three scenarios in Table 1. We see that in the free float simulation the chartists have on average a weight of 90% in the market (the fundamentalists' weight is then 10%), while in the scenario of intense intervention ($\zeta = 0.1$) the average weight of the chartists declines to 76% (the average weight of fundamentalists increases to 24%). Thus when the central bank successfully stabilizes the exchange rate so that it closely reflects the fundamentals, the fundamentalists on average have a higher share in the market than when the central bank does not intervene. Put differently, systematic interventions by the central bank change the structure of the foreign exchange market, i.e. they reduce the importance of chartists and increase the importance of fundamentalists. Thus, the "leaning against the wind" intervention rule of the central bank creates an environment in which the fundamentalists are more active thereby keeping the exchange rate close to its fundamental. The reason why this is made possible is that the intervention rule increases

Table 1

Mean profits and weights of fundamentalists and chartists along with intervention intensity (ζ).

	Mean profits and weights of fundamentalists and chartists		
	$\zeta = 0$	$\zeta = 0.01$	$\zeta = 0.1$
Mean profit fundamentalists	0.0010	0.0045	0.0081
Mean weight fundamentalists	0.1	0.13	0.24
Mean profit chartists	0.1099	0.0971	0.0888
Mean weight chartists	0.9	0.87	0.76

the mean reversion forces in the market thereby making fundamentalists forecasting rules more profitable. We show this in Table 1 where we present the average profits of chartists and fundamentalists in three scenarios. We find that in the intervention scenarios ($\zeta = 0.01$ and $\zeta = 0.1$) the fundamentalists make significantly more profits than in the free float scenario ($\zeta = 0$). The reverse is true for the chartists' profits. This confirms that the intervention rule of the central bank increases the relative profitability of fundamentalist forecasting rules, thereby enhancing the position of fundamentalists in the market and increasing their weight⁹. By the same token it reduces the weight of chartists in the market. Thus the stabilizing effect of the intervention rule comes about indirectly, i.e. it makes fundamentalist forecasting more attractive thereby allowing the market to discover the fundamental value of the exchange rate more effectively.

These results are consistent with the signalling channel of foreign exchange market interventions. In our model the interventions signal the central bank's commitment to avoid too large departures from the fundamental exchange rate. This signal has the effect of enhancing the influence of fundamental variables on the exchange rate.

The previous results assume a rule based intervention policy. The question that arises is how a stochastic intervention by the central bank affects these results. Using the same model as the one presented here, De Grauwe and Grimaldi (2006b) show that when the central bank intervenes in a random way, the effects of these interventions on the exchange rate are highly unpredictable. The reason why they obtain this result can readily be seen from Eq. (3). A random change in X has an unpredictable effect on the exchange rate because, as we argued earlier, it depends on market conditions prevailing at the time of the change in X . As a result, a given sale or purchase of foreign exchange can have very different effects on the exchange rate depending on the volatility in the market and the share of chartists at the time of the intervention.

3. The empirical investigation

3.1. The basic chartists-fundamentalists model

In this section, we propose an empirical estimation of the impact of interventions, building on the theoretical framework developed in the previous section. The empirical counterpart of the theoretical model involves the modelling of chartist and fundamentalist traders whose proportions are ultimately affected by the occurrence of the central bank interventions. A natural way to do this is to specify a model with switching properties between a chartist and a fundamentalist regimes.

We focus on the dynamics of the USD against the Euro (DEM before 1999) over a long period ranging from 1985 to 2003. We work at the bi-weekly frequency. On the one hand, the respective

⁹ Note that even in the intervention scenarios, chartism remains more profitable than fundamentalism.

behaviours of the chartists and fundamentalists are clearly identifiable in the medium run. More precisely, typical chartists rule involve computations of moving average ranging from 14 to 200 days (see Neely, 2002 for instance). Fundamentalists basically react to deviations to equilibrium exchange rates which are computed at a macroeconomic frequency. On the other hand, central bank interventions are carried out at an intradaily frequency (the central bank typically reacts to short run exchange rate evolutions – see Neely, 2001) and the official data are available on a daily basis. The choice of the bi-weekly frequency for the data should therefore be seen as a compromise. It more or less matches the frequency that are typically used in previous estimations of this type of models (Vigfusson (1996), Manzan and Westerhoff, 2007).¹⁰

The estimated model is a two-regime Markov switching model. Each regime captures the behaviour of a particular type of agents trading in the FX market. At this stage, the switching properties of the model are not investigated further in the sense that the regime transition probabilities are supposed to be constant over time.¹¹ We denote e_t as the log of the Euro/USD exchange rate and we define the (bi-weekly) return as $r_t = 100 * \ln(e_t) - \ln(e_{t-1})$.

In the first regime, the chartist regime, in line with the theoretical model, agents are supposed to use only past exchange rate developments to forecast future fluctuations of the currencies. The general specification of the chartist regime is given by:

$$r_{c,t} = C(r_{t-1}) + \varepsilon_{c,t}, \quad (5)$$

where $r_{c,t}$ is the forecasted value of r_t by chartists, $\varepsilon_{c,t}$ is the error term peculiar to chartists and C is the general function used by chartists for the purpose of forecasting.

In contrast to chartists, fundamentalists consider the exchange rate as reacting to misalignments of the current exchange rate level with the fundamental equilibrium value:

$$r_{f,t} = -\psi(e_{t-1} - f_{t-1}) + \varepsilon_{f,t}, \quad (6)$$

where $r_{f,t}$ is the forecasted value of r_t by fundamentalists, $\varepsilon_{f,t}$ is the error term peculiar to fundamentalists, ψ is the parameter used by fundamentalists to forecast the exchange rate using the known value of the exchange rate misalignment and f_{t-1} is the empirical counterpart of the log of the fundamental equilibrium exchange rate. Typically, parameter ψ should be negative in this regime to capture a mean reverting behaviour of the exchange rate towards the fundamental value (depreciation required to correct overvaluation).¹² In the Markov-switching model, the dynamics of the exchange rate is driven by the value of a latent variable l_t that captures whether the prevailing regime is the chartist one ($l_t = c$) or the fundamentalist one ($l_t = f$). The special insight of the first-order Markov-switching model is that the dynamics of l_t is driven by first-order transition probabilities. In the basic Markov Switching model, these transition probabilities are assumed to be constant over time. In the case of two regimes, these transition probabilities are defined as:

$$p = \text{Prob}(l_t = c | l_{t-1} = c), \quad (7)$$

$$q = \text{Prob}(l_t = f | l_{t-1} = f). \quad (8)$$

In this model, p captures the probability of remaining in the chartist regime from one period to the other. It is therefore a measure of the persistence of the regime from which it is possible to compute theoretically the expected number of periods during which the economy will be in this regime.¹³ For the sake of the future extension to the case of time-varying transition probabilities (TVTP), it may be useful to express p and q through a logistic specification of the type:

$$p = 1 - (1 + \exp(\pi_0))^{-1}, \quad (9)$$

$$q = 1 - (1 + \exp(\kappa_0))^{-1}. \quad (10)$$

Notice that if the parameters π_0 and κ_0 expressed on the logistic scale take both zero values, then p and q equal 0.5. In this case, the probability of remaining in the regime is equal to the probability of leaving the regime, suggesting that a Markov-switching approach is rather inappropriate to capture the dynamics of the exchange rate return. Although these specification tests may appear rather simple, Hamilton (1996) shows that t -tests applied to the transition probabilities of the type $[\hat{p} - p_0] / \hat{\sigma}_{\hat{p}}$ (where p_0 denotes the value of p under the null and $\hat{\sigma}_{\hat{p}}$ the estimate of the standard error of \hat{p}) can be trusted, both asymptotically and in finite samples.¹⁴

3.2. Preliminary investigation

In order to estimate model (5)–(7), we first need to tackle two points. The first one is the choice of an empirical measure of the fundamental equilibrium exchange rate f_t that plays an important role in the definition of the fundamentalist regime. Previous work (Vigfusson, 1996; Manzan and Westerhoff, 2007) has typically used the PPP value as a measure of the equilibrium exchange rate. However, while interesting, PPP levels capture only one type of equilibrium and rely on the relevance of the law of one price. As an alternative, we use here recent estimates of Bénassy-Quéré et al. (2004) of these equilibrium exchange rates. The specific insight of these estimates is that they provide levels consistent with a joint equilibrium of all countries included in their sample (broadly speaking, the OECD countries). Furthermore, the equilibrium value is defined as the one consistent with external and internal balance of these economies.

We first compute for a given year the value of the nominal equilibrium exchange rate for the Eurozone in terms of USD from the misalignment values estimated by Bénassy-Quéré et al. (2004) using the average value of the nominal exchange rate over the year. Since we compute misalignment values at much higher frequencies, we smooth this equilibrium value by interpolation in order to get rid of the artificial jumps due to changes of the calendar year. We then compute misalignment levels at the bi-weekly frequency by computing the distance of the (log of) the exchange rate from (the log of) this smoothed value of the equilibrium.¹⁵ Fig. 2 plots the evolution of the smoothed misalignment degree of the Euro against the dollar over the sample period (positive values refer to Euro undervaluation). From the figure, one can identify two distinct periods of dollar overvaluation: the first one ranges from the beginning of the sample (January 1985) to the end of 1986; the second one

¹⁰ The choice of a trading rule based on a moving average pattern involving two months is consistent with the literature devoted to technical trading in the FX market. For instance, Schulmeister (2007) studies the profitability of such trading rules based on moving averages of various lengths. He finds that most of the selected models display a duration of profitable positions between 30 and 60 days. In contrast, trading rules based on short-term trends (say for duration less than 15 days) turn out to be less profitable.

¹¹ We will relax this assumption later on in Section 3.4 when we will consider time-varying transition probabilities (TVTP).

¹² Of course, given the fact that the empirical specification slightly deviates from the theoretical model, we relax the assumption that Ψ is comprised between 0 and 1.

¹³ Indeed, the respective expected numbers of periods are equal to $1/(1-p)$ and $1/(1-q)$.

¹⁴ Hamilton provides some Monte Carlo analysis for $T = 50$ and $T = 100$, i.e. for much smaller samples sizes than the ones considered here ($T = 498$). The distributions of these t -statistics in small samples are found however to be skewed rightward.

¹⁵ As for the exchange rate quotation, we use values observed on Fridays at 21.00 GMT + 1 physical time. This choice ensures that interventions conducted by both central banks during the two last weeks occur before the quotation of the rate, assuming implicitly that these interventions take place on their own local markets. This assumption is supported by the evidence provided by Dominguez (2003) concerning the timings of the reported FX operation.



Fig. 2. Misalignment of the Euro against the USD (in percent).

begins in mid 1998 and persists until the end of the sample (May 2003).

The second issue is the exact nature of the C function in the chartist regime (Eq. (5)). Chartists are usually reported to use a complex set of moving average rules leading to heterogeneous strategies across agents. This heterogeneity makes the identification of the aggregate chartist forecasting rule quite cumbersome. Since chartist behaviour is not directly observable, there is a large number of admissible specifications for Eq. (5), which need to be evaluated. The retained specification should be therefore selected on the basis of data adjustment. As a preliminary check, we have estimated simple AR-GARCH models of the following type:

$$r_t = r_0 + \sum_{i=1}^g \rho_i r_{t-i} - \lambda(e_{t-1} - f_{t-1}) + \varepsilon_t, \quad (11)$$

$$\sigma_t^2 = \omega + \varphi \varepsilon_{t-1}^2 + \eta \sigma_{t-1}^2,$$

where r_t is the return of the DEM/USD exchange rate, σ_t^2 is the conditional variance and $r_0, \rho_i, \lambda, \omega, \varphi$ and η are parameters to be estimated.¹⁶ We find reasonable evidence of a mean reverting behaviour of r_t towards the equilibrium level with λ equal to a value close to 1.35 and a significance level slightly above 5%. We do not find any evidence of significant autoregressive coefficients for g up to 10. This is hardly surprising given that the model is a single regime model capturing some mixture of the dynamics between the chartist and the fundamentalist regimes. Nevertheless, almost all coefficients turn out to be positive, suggesting that agents make use of extrapolative moving average rules capturing the medium-run evolution of exchange rates. Replacing the autoregressive part $\sum_{i=1}^g \rho_i r_{t-i}$ by the past cumulated returns $[e_{t-1} - e_{t-(p+1)}]$, we find limited evidence of a positive relationship. In particular, we find that for $g = 4$, this term exhibits a positive relationship with a p -value slightly above 10%. This might suggest that on average chartists extrapolate returns using a 2-months window. We build on this preliminary evidence to find a suitable specification to Eq. (5) in the chartist regime.

3.3. The constant transition probabilities case

Based on the preliminary evidence and after testing competing models, the retained specification for the chartist equation is:

$$r_{c,t} = \alpha_1(e_{t-1} - e_{t-5})\mathbf{1}_{\{|r_{t-1}| < \bar{b}\}} + \alpha_2(e_{t-1} - e_{t-5})\mathbf{1}_{\{|r_{t-1}| > \bar{b}\}} + \varepsilon_{c,t}, \quad (12)$$

where $\mathbf{1}$ is the indicator function taking 1 if the condition within brackets is satisfied, 0 otherwise and \bar{b} is some constant threshold. In this specification, chartists use past exchange rate trends defined over the last four periods (last 2 months) in a non linear way. The extrapolation rate is different whether short run volatility (captured by $|r_{t-1}|$) is below or above some threshold. To measure this threshold \bar{b} , we choose the average value of $|r_{t-1}|$ over the entire sample.¹⁷ This specification therefore captures the fact that chartists will behave differently whether the level of exchange rate volatility has been relatively high or not.

The Markov-switching regimes are estimated by the Expected Maximum Likelihood (EML) procedure and rests on the Gaussian assumption for the underlying density.

Table 2 reports the estimates of the basic chartist-fundamentalist model for two alternative specifications. Several comments are in order. First, the model estimations clearly identify the fundamentalist regime. The ψ parameter is significantly positive, suggesting a mean-reverting behaviour of e_t towards its fundamental value f_t . This finding is highly robust to alternative specifications and to the extension of the model to time-varying transition probabilities (see Section 3.4). Second, the model estimates suggest that in the chartist regime, agents tend to extrapolate past trends only when the short-run volatility is relatively high ($\alpha_2 > 0$). The p -value of this parameter is slightly above the 5% significance level (p -values of 5.3% and 5.7% for respectively specification (1) and specification (2)). In contrast, when the level of short-run volatility is historically low, chartists see the exchange rate as following a random walk: α_1 is insignificantly different from zero and is therefore excluded in the second specification (last column in Table 1). These results suggest that the chartist regime is at best

¹⁶ In order to save place, we do not report the estimated values for $r_0, \rho_i, \omega, \varphi$ and η but these can be obtained upon request.

¹⁷ Note that given the fact that exchange rate volatility is often clustered over time, $|r_{t-1}|$ will also proxy the contemporaneous level of volatility.

Table 2
The chartist-fundamentalist model: Euro-USD January 1985–May 2003.

	(1)	(2)
α_1	0.018 [0.039]	–
α_2	0.987* [0.510]	1.007* [0.529]
ψ	1.574** [0.785]	1.592* [0.778]
σ_c^2	2.583*** [0.235]	2.605*** [0.246]
σ_f^2	1.658*** [0.161]	1.665*** [0.160]
π_0	2.620*** [1.238]	2.516*** [1.214]
κ_0	2.687*** [0.916]	2.658*** [0.869]
p	0.932*** [0.078]	0.925*** [0.084]
q	0.935*** [0.055]	0.935 [0.053]
$N\ obs$	981	981
$Log\ Lik$	–1042.9	–1043.03

Standard errors of EML estimates in brackets. S.E. of p and q computed with the delta method.

- * Refers to significance at 10%.
- ** Refers to significance at 5%.
- *** Refers to significance at 1%.

non stabilising for the exchange rate and can be even destabilizing in relatively turbulent markets. Importantly, the results are consistent with the theoretical framework in which chartists are supposed to follow a positive feedback rule.

3.4. The role of interventions

3.4.1. The TVTP model

In specification (9) and (10), the transition probabilities of remaining in a particular regime depend only on the previous state of the economy (l_{t-1}), i.e. the nature of the regime prevailing during the previous period. One possibility to capture the impact of exogenous variables is to make these transition probabilities dependent on these variables. In our analysis, we introduce central bank interventions that take place during the two preceding weeks. While specific, this extension is consistent with the theoretical model exposed in Section 2. Indeed, in the chartists-fundamentalists framework, the dynamics of the exchange rate is intrinsically related to the proportion of each type of agents. These proportions depend primarily on the profitability of the respective forecasting rules. In turn, the relative profitabilities are affected by the occurrence of the central bank interventions in the FX markets. As a result, as suggested by the simulation outcomes, the proportions of chartists and fundamentalists are affected by the central bank purchases and sales of foreign currency.

To implement the TVTP estimation, we follow Filardo (1994) and use a logistic specification. In this case, denoting by $I_{i,t-1}$ intervention of type i which has taken place between $t - 1$ and t and building on Eqs. (9) and (10), we extend the chartist-fundamentalist model as:

$$p = Prob(l_t = c | l_{t-1} = c, I_{i,t-1}) = 1 - (1 + \exp(\pi_0 + \sum_{i=1}^m \pi_i I_{i,t-1}))^{-1}, \quad (13)$$

$$q = Prob(l_t = f | l_{t-1} = f, I_{i,t-1}) = 1 - (1 + \exp(\kappa_0 + \sum_{i=1}^m \kappa_i I_{i,t-1}))^{-1}. \quad (14)$$

The full model is made of Eqs. (6)–(14).

3.4.2. CBI data

The central bank intervention data used in this paper are direct purchases and sales of foreign currencies carried out by the Fed and the Bundesbank (ECB after the inception of the Euro) over the period ranging from 1 January 1985 to 31 May 2003.¹⁸ We use daily official interventions, i.e. interventions released by the central banks themselves. These exclude false rumours of interventions. Given the available statistical information, there are several ways through which one can capture the activity of central banks in the FX markets.

First, one can measure central bank's activity through the total amounts sold or purchased on the markets. As an alternative, one can capture the presence of these central banks by either dummy variables or by the total number of intervention days over the period under investigation. Here, we disregard the amounts and use the latter approach. Second, we use official data. However, using the mere number of official daily intervention days might be misleading in the sense that the exact number of interventions over the two previous weeks might also be unknown. As a result, we use two alternative measures. The first one computes the number of official intervention days over the two previous weeks by a given central bank. The second one uses a dummy variable capturing whether a particular central banks was active or not in the market during the previous period.

A final point concerns the distinction between concerted and unilateral operations. This distinction stems from two reasons. First, there is some evidence that coordinated operations might exert different impacts from unilateral interventions. The signalling theory that emphasizes the information content embedded by these operations also implies such an asymmetric effect. Nevertheless, this distinction has been especially relevant for studies using high frequency data and it is less clear that such a decomposition is needed when using bi-weekly data. From a statistical point of view, the distinction between concerted and unilateral operations also allows to reduce the observed degree of correlation between the intervention variables and to reduce the problems of multicollinearity (see Beine et al. (2003) for some extensive evidence on weekly data). This high degree of correlation is due to the important proportion of concerted operations observed especially during the first part of the sample. This is particularly important when measuring central bank activity by the total number of intervention days over the previous period. As a result, we use two alternative measures of central bank activity. As a first measure, we use the number of intervention days of both central banks (ECB and the Fed), whether they are coordinated or not. As a second measure, we disentangle these operations into unilateral operations of each central bank and concerted operations.

3.5. The results

Table 3 reports the estimation results of the full chartists-fundamentalists model with transition probabilities depending on the central bank interventions $I_{i,t-1}$. Each column reports the results obtained with a different measure for $I_{i,t-1}$. Column (1) reports the results obtained with central bank activity measured by the total number of intervention days of the Fed (268 intervention days) and the Bundesbank (318 intervention days). As expected,

¹⁸ We do not consider the BoJ interventions on the YEN/USD market for two important reasons. First, unlike the ECB or the Fed, it is very unlikely that the BoJ interventions aim at reducing the degree of exchange rate misalignment. For instance, over the second part of the investigation period, a lot of BoJ interventions have been conducted in a unsterilized way to raise inflation expectations, in line with the suggestions of Svensson (2001) among others. Second, unlike for the Fed and the BB, most recent interventions of the BoJ were secret, i.e. unreported to the FX traders. See Beine and Lecourt (2004) on this. This means that the signalling and the coordination channels that are central to our analysis cannot be operative for those interventions.

Table 3
FX interventions in the chartist-fundamentalist model: Euro-USD, January 1985–May 2003.

	(1)	(2)	(3)	(4)
α_1	-0.009 [0.039]	0.003 [0.030]	0.009 [0.032]	-0.006 [0.040]
α_2	0.800 [0.535]	0.890** [0.438]	0.834* [0.430]	0.925* [0.504]
ψ	1.759*** [0.645]	1.996*** [0.653]	1.972*** [0.652]	1.592*** [0.635]
σ_c^2	2.699*** [0.221]	2.555*** [0.166]	2.538*** [0.154]	2.723*** [0.192]
σ_f^2	1.812*** [0.103]	1.709** [0.121]	1.700** [0.122]	1.775*** [0.089]
π_0	4.331*** [0.767]	3.921*** [0.780]	3.966** [0.819]	4.928*** [1.087]
π_1 [Fed, c]	0.363 [0.599]	-0.071 [0.414]	-	5.093 [4.934]
π_2 [ECB, c]	-0.924** [0.439]	-0.830** [0.383]	-0.891** [0.372]	-3.989*** [1.453]
π_3 [Coord, c]	-	-0.644 [0.551]	-1.157 [1.064]	-3.809** [1.760]
κ	6.066* [3.212]	4.723*** [1.815]	4.784*** [1.673]	16.576 [40.207]
κ_1 [Fed, f]	-2.423 [2.005]	-0.395 [0.433]	-	-16.375 [40.163]
κ_2 [ECB, f]	-0.086 [0.923]	-1.051 [0.990]	-0.200 [0.682]	-15.247 [40.207]
κ_3 [Coord, f]	-	-1.060 [0.681]	-1.807 [1.220]	-15.078 [40.211]
Nobs	981	981	981	981
Log Lik	-1041.35	-1040.13	-1040.68	-1040.13
p-Value LRT	0.27	0.47	0.34	0.09

given the share of coordinated interventions (161 intervention days) this results in a high degree of correlation (0.724), which may lead to imprecise estimates of the impact. This degree of correlation is very much reduced when measuring central bank activity by the number of unilateral and concerted operations.¹⁹ The results specific to this specification are reported in column (2) of Table 3. Results of column (3) are obtained with the same specification, with the unilateral Fed interventions excluded to increase efficiency. Finally, results of column (4) are obtained with central bank activity captured by dummies rather than by the number of intervention days over the previous two-week period.²⁰

On the whole, we find that the occurrence of interventions has induced some increase in the proportion of fundamentalists, especially when these operations took place when the chartist regime prevailed. Indeed we find that the transition probability of remaining in the chartist regime significantly decreases as a result of the occurrence of the FX interventions. This is the case for the Bundesbank interventions ($\pi_2 < 0$). We observe the same effect for coordinated interventions when central bank activity is captured through a single dummy variable (see $\pi_3 < 0$ in column 4). This may suggest that traders pay attention to the fact that the central banks were active during the past two weeks rather than to the pure number of occurrences of this type of operation.²¹ Importantly, we do not find any evidence of some effect of interventions

driving the exchange rate towards a value consistent with the chartist dynamics.²²

We find evidence in favor of efficiency for the unilateral operations of the Bundesbank and to a lesser extent the concerted interventions. In contrast, the unilateral operations of the Fed display weak effects in terms of the dynamics of chartists and fundamentalists. In the theoretical model, the adoption of an intervention rule that aims at reducing the degree of misalignment results in higher efficiency compared to interventions conducted in a random way. Almekinders and Eijffinger (1996) find that the Bundesbank intervened in reaction to deviations of the exchange rate from the CB target. To the extent that this target is similar to the equilibrium exchange rate, this suggests that the Bundesbank did not behave very differently compared with the representative central bank in the theoretical model. As for the recent period, the three unilateral interventions of the ECB in November 2000 took place when the Euro was obviously undervalued with respect to the dollar. While Almekinders and Eijffinger (1996) also found that the Fed adopted a leaning-against-the-wind policy before 1990, they also document a stronger reaction of the US authorities to exchange rate volatility. This suggests that the Fed is less keen to adopt a specific intervention rule aiming at reducing the degree of misalignment. This behaviour was confirmed in the nineties during which the official motivation to intervene was more to react to market disorders.²³

To sum up, we find that if there is some effect of these operations at a 2-weeks horizon, the purchases or sales carried out by the central bank tend to push the exchange rate in a direction consistent with the fundamentals. This can be interpreted to mean that interventions were on average effective in the medium run. This contrasts with the usual claim that interventions are not effective (and even counterproductive) since they hardly manage to move the exchange rate in the intended direction.

4. Conclusion

This paper aims at revisiting the issue of effectiveness of central bank interventions in the FX market. As an alternative to what has been used in the literature, we define an effective operation as the one driving the exchange rate closer to its fundamental value. To this aim, we analyse the effects of a central bank intervention rule within a theoretical framework capturing the interaction of the behaviour of chartist and fundamentalist traders in the FX market. The intervention is found to affect the relative profitability of the strategies developed by both type of agents, leading to an increase in the proportion of fundamentalist traders and hence a market exchange rate closer to the fundamental level.

We empirically assess the effectiveness of the interventions and focus on the effects of the operations carried out by the ECB (Bundesbank before the inception of the Euro) and the Federal Reserve in the Euro/USD market. We test to what extent the occurrence of the central bank interventions tended to affect the transition probabilities relative to the chartist and the fundamentalist regime. We find some evidence that in the medium run, the occurrence of some unilateral and to a lesser extent coordinated interventions led to a decrease in the proportion of chartists. To the extent that the chartist traders are found to extrapolate past exchange rate

¹⁹ The correlation between concerted operations and unilateral Fed interventions (resp. BB interventions) amounts to 0.286 (resp. 0.391). The correlation between unilateral operations of the Fed and those of the Bundesbank is equal to 0.131.

²⁰ Using this measure, we observe 54, 45 and 62 occurrences for respectively the concerted, the Fed and the Bundesbank interventions.

²¹ Once more, it should be stressed that traders are not necessarily able to observe the total number of operations in the short run. This is especially the case during the first part of the sample in which the quality of news wire services was relatively lower.

²² For the central bank interventions taking place when the fundamentalist regime prevails, while negative, the impact is never significant due to the very high value of uncertainty obtained in the parameter estimation. This is for instance striking in column 4 of Table 2 (see κ_1 , κ_2 and κ_3 parameters). Such a blowing up of the standard deviation might reflect that very few interventions occur when such a regime prevails, leading to very poor estimations of these parameters.

²³ Interestingly, the quarterly report on the Treasury and Federal Reserve foreign exchange operations issued after the last intervention in 2000 states that the reason to intervene in support of the Euro was the prevailing excess exchange rate volatility.

movements to forecast future values, we find that the interventions have the effect of bringing the exchange rate more in line with a value consistent with the fundamentals in the economy.

We take the view that our criterion of effectiveness of interventions is consistent with the general objectives pursued by central banks. It abstracts from simple criteria used before like the contemporaneous impact that can be inconsistent with the medium run goals followed by monetary authorities. Interestingly, while the bulk of previous studies often concluded against the effectiveness of the central bank interventions in the short run, our findings tend to give more support in favour of a reasonable degree of effectiveness in the medium run.

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