Target Zone Interventions and Coordination of Expectations[1]

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Abstract. Foreign exchange markets display regularly severe bubbles. This paper explores whether or not the so-called target zone interventions are an effective tool for central banks to stabilize the exchange rate. We define such intervention operations as buying/selling an undervalued/overvalued currency when the distance between the exchange rate and its fundamental value exceeds a critical threshold value. On the basis of a nonlinear empirical exchange rate model with chartists and fundamentalists, we find that not only target zone interventions have the power to reduce misalignments but also to earn profits.

Key Words. Foreign exchange markets, technical and fundamental analysis, heterogeneous agents, central bank interventions.

1. Introduction

Since exchange rates affect directly international competitiveness and the performance of national economies, they are arguably the world economy's most important prices. Unfortunately, foreign exchange markets do not seem to be very efficient. For example, Ref. 1 detects significant bubbles and crashes in the DEM/USD and JPY/USD market. Therefore, it is not surprising that central banks try to stabilize foreign exchange markets. However, the empirical evidence is ambivalent about the usefulness of intervention operations (see e.g. Ref. 2). The aim of this paper is to examine this issue from a theoretical perspective.

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In a number of studies (see e.g. Refs. 3-11), it is argued that financial market dynamics is driven mainly by the interaction between heterogeneous agents, so-called chartists and fundamentalists. As vividly expressed by Ref. 12, financial markets may be viewed as evolutionary systems between different competing trading strategies. Strategies that have performed well in the past have a higher market impact than their worse performing competitors. As it turns out, technical and fundamental trading rules may coexist in speculative markets, implying that technical analysis may survive natural selection pressure. Intricate price dynamics arise due to the fact that the impact of the trading strategies changes endogenously over time. For instance, if the popularity of fundamentalism decreases, bubbles are likely to occur.

Reference 13 explores whether chaos control methods may help the central banks to stabilize the exchange rate dynamics. Using the prototype nonlinear chartist–fundamentalist model of Ref. 3, they find that certain control algorithms, such as the OGY method [named after Ott, Grebogi, and Yorke (Ref. 14)], indeed have the power to reduce the exchange rate variability and misalignments, even if the dynamics is considerably polluted by noise. Interestingly, some of these algorithms are related to the actual central bank intervention rules: The OGY method may be interpreted as a more sophisticated version of the targeting long-run fundamentals rule, which is often carried out by the central banks (see e.g. Ref. 2).

The study by Ref. 13 should be regarded as preliminary, since several interesting aspects remain open. First, to conduct chaos control methods, one needs typically a priori knowledge on the system equations. Such information may in general be retrieved from time series information; yet, in the case of foreign exchange markets, this requirement appears to be rather hard. Second, the derived intervention rules basically suggest intervening every period (i.e. every day). But policy makers may not want to manipulate the exchange rate so regularly. As reported by Refs. 15–16, the Federal Reserve Bank and the Bundesbank intervened together in the DEM/USD market in the period between 1979 and 1996 once every four trading days. At other times, they were not active so often. Third, the parameters of the exchange rate's law of motion have been set such that it can mimic characteristic bull and bear markets. Although this is a common procedure, the results would be more reliable if the parameters were estimated directly from empirical data.

In this paper, we seek to address these three issues by investigating the effectiveness of a robust low-frequency intervention heuristics within an empirical exchange rate model recently developed by Ref. 17. The main engine of the dynamics of their setup is that fundamentalists become less active the more the exchange rate disconnects from its fundamental value. The underlying intuition is that fundamentalists lose confidence in their strategy when they have mispredicted the direction of the exchange rate change. The structure of the model is backed up by the data: Via a STAR GARCH procedure, significant parameter estimates with correct signs are derived for major currencies vis-á-vis the US dollar.

This paper focuses on target zone interventions which imply buying/selling an undervalued/overvalued currency when the distance between the exchange rate and its fundamental value exceeds a critical threshold value. To make the rule as simple and robust as possible, we fix the central bank's actual per period intervention volume. Note that this mechanism is different from the historical European currency system. There the authorities have stopped the exchange rate from leaving a certain exchange rate band. In our model, interventions start when the exchange rate leaves a specified target zone. Within the band, the central bank is indifferent to the path of the exchange rate.

We find that intermittent target zone interventions apparently suffice to reduce misalignments in foreign exchange markets. Suppose that the central bank sets a target zone of ± 8 percent around the fundamental value. Taking our estimates literally, the model predicts the following: To reduce the distortion by about 50 percent, the central bank has to intervene on average only once every 40 trading days. In addition, the intervention strategy seems to be profitable. By buying low and selling high, the relation of profits to the total intervention volume is close to 10 percent. The intervention works as follows: It shifts directly the exchange rate toward its fundamental value, chartists amplify this new exchange rate trend, and more fundamentalists are encouraged to become active. By coordinating the behavior of chartists and fundamentalists, the temporary intervention effect is likely to become a permanent one.

The paper is organized as follows. In Section 2, we recall briefly the empirical exchange rate model of Ref 17; in Section 3, we explore the effectiveness of target zone interventions. Section 4 concludes the paper.

2. Simple Empirical Chartist-Fundamentalist Model

2.1. Motivation. The chartist-fundamentalist approach is based on the observation that financial market participants use simple technical and fundamental trading strategies to take their investment decisions (see e.g. Ref. 18). While technical analysis identifies trading signals out of past price movements, fundamental analysis predicts prices to return to fundamentals. The nature of technical analysis tends to be destabilizing whereas the nature of fundamental analysis is stabilizing. The interplay between positive and negative feedback rules may cause a complex price dynamics. Some studies exploit the nonlinearity of the agents' trading rules (see e.g. Ref. 3). Within other contributions, the market impact of the rules changes over time (see e.g. Ref. 6). The fact that these models are able to replicate the stylized facts of financial markets quite well is seen as a kind of empirical validation.

Let us briefly review the model of Ref. 17. The exchange rate adjusts via a loglinear price impact function: Excess buying drives the exchange rate up and

excess selling drives it down. The orders of chartists positively depend on the most recent exchange rate trend and the demand of fundamentalists is proportional to the mispricing. A constant number of chartists is always active in the market, but the market impact of fundamentalists is time-dependent. Most importantly, if the exchange rate disconnects from its fundamental value, fundamentalists lose their confidence in the usefulness of their trading rule and consequently abstain from trading. If misalignments decrease, as predicted by fundamental analysis, they reenter the market. Furthermore, misalignments are conditioned on volatility. Without fluctuations, convergence is not possible. Hence, if exchange rate volatility declines, fundamentalists expect mean reversion to be less likely.

Estimations based on daily data for major currencies reveal indeed that, the more the exchange rate deviates from its fundamental value, the more fundamentalists leave the market. The model indicates that foreign exchange markets become increasingly unstable during bubbles. Therefore, the diminishing force of fundamentalists alone may not suffice to bring exchange rates back in line. A natural question which arises is whether the central bank interventions may help to deflate bubbles.

2.2. Setup. The model is estimated via a STAR GARCH procedure developed in Ref. 19. In technical terms, the model consists of a mean equation, a smooth transition variable, and a standard GARCH (1,1) volatility equation

$$S_t - S_{t-1} = a^C(S_{t-1} - S_{t-2}) + a^F(F_{t-1} - S_{t-1})W_{t-1} + \varepsilon_t, \tag{1}$$

$$W_t = \frac{2\exp[-b\,|\,F_t - S_t\,|\,/\sqrt{H_t}]}{1 + \exp[-b\,|\,F_t - S_t\,|\,/\sqrt{H_t}]}, \tag{2}$$

$$H_t = c^1 + c^2\varepsilon_{t-1}^2 + c^3 H_{t-1}, \tag{3}$$

with

$$\varepsilon_t = \nu_t\sqrt{H_t}, \; \nu_t^{iid} \sim (0,1).$$

According to (1), the change in the log exchange rate S depends on the orders of chartists (first term), the orders of fundamentalists (second term), and a random element (third term). a^C and a^F stand for positive reaction coefficients of chartists and fundamentalists, respectively. The fundamental value is denoted by F. The transition variable W takes into account that the impact of fundamentalists diminishes with increasing misalignments and decreasing volatility. A GARCH (1,1) model is used to update volatility.

2.3. Estimation Results. The fundamental value is approximated by the purchasing power parity (henceforth, ppp).[5] For daily spot DEM/USD exchange rates over the period from 1980 to 1996 the model's parameters are estimated as follows:

$$a^C = 0.03, \quad a^F = 0.004, \quad b = 0.035,$$

$$c^1 = 0.0000011,$$

$$c^2 = 0.069, \quad c^3 = 0.909.$$

All coefficients are of the correct sign and statistically significant, at least at the 5 percent level. Similar results are obtained for GBP/USD and JPY/USD exchange rates (see Ref. 17 for more details).

Figure 1 illustrates the working of the model. The first panel displays daily log DEM/USD exchange rates (solid line) and ppp data (dashed line). Both time series are normalized to zero at 1990, assuming that ppp holds at the beginning of the 1990s. The second panel shows the estimated impact of fundamentalists. The lasting US dollar bubble in the mid 1980s is accompanied by a deep fall in confidence in fundamental analysis. In particular, the impact of fundamentalists dropped below 10 percent when the dollar peaked in mid 1985. The third panel depicts the evolution of changes in log exchange rates (i.e. the returns). Periods of low volatility clearly alternate with periods of high volatility, which is typical for financial markets (see e.g. Ref. 21).

Using (1)–(3) and the above parameters, we can, of course, produce artificial time series. Figure 2 contains a simulation run over 5000 observations. The first, second, and third panels again present log exchange rates, weights of fundamentalists, and returns, respectively. For simplicity, we have set the fundamental value constant ($F = 0$). The dynamics in Figure 2 resembles the dynamics in Figure 1. For instance, the exchange rate circles in a complex way around its fundamental value and bubble periods coincide with periods in which fundamental analysis is unpopular. Exactly when the stabilizing impact of fundamentalists is most needed, mean reversion pressure is low so that the mispricing may gain additional momentum. The bottom panel reveals that the model has the potential to produce volatility clustering. Further diagnostic tests confirm also that the returns are serially uncorrelated and that the distribution of the returns is nonnormal, i.e. it possesses fat tails.

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[5] We recall that the purchasing power parity states that the exchange rate between two currencies adjusts such that the purchasing power of a given amount of money tends to be the same in the two countries. Since many empirical studies in fact find strong support for mean reversion toward long-run purchasing power parity, ratios between national price levels are frequently used to compute fundamental values (see e.g. Ref. 20).
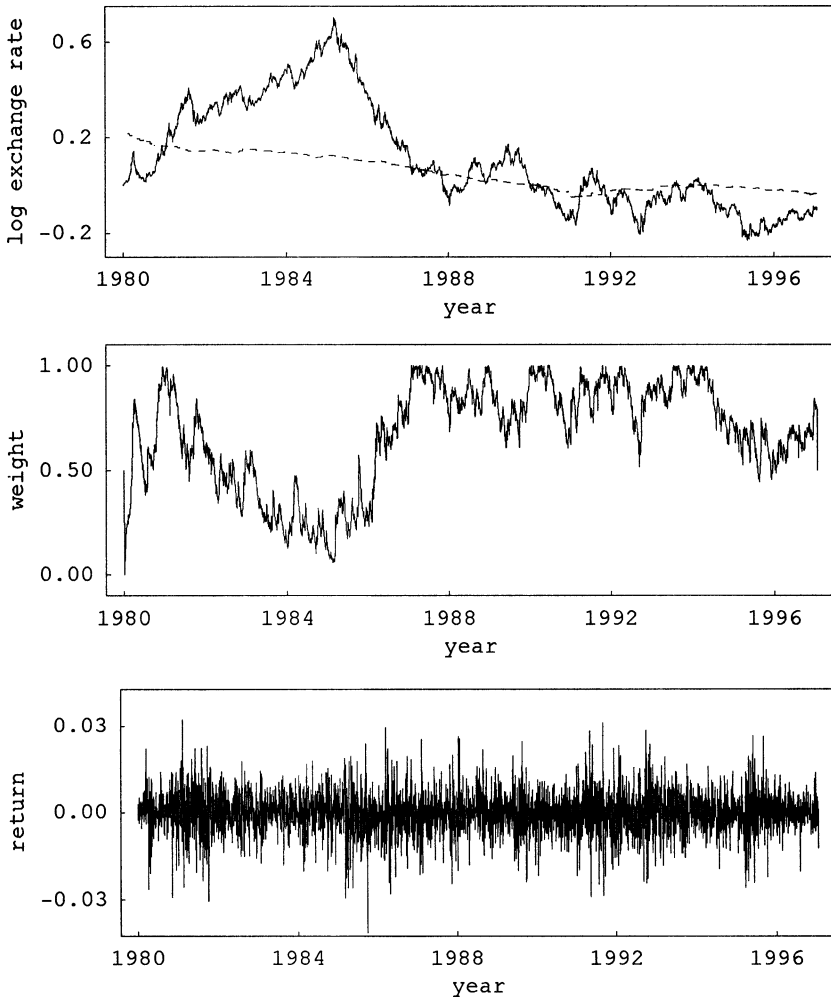
Fig. 1.   The top panel displays daily log DEM/USD exchange rates (solid line) and ppp data (dashed line) for the period 1980–1996. Both time series are normalized to zero at 1990, assuming that ppp holds at the beginning of the 1990s. The middle panel shows the estimated weights of the fundamentalists, whereas the bottom panel depicts the evolution of the returns.

3. Target Zone Interventions

3.1. Specification. The previous section suggests that foreign exchange markets are inherently unstable. Bubbles may not end endogenously, but may need some external force such as random trade or new information. Such external stimulus may also be injected by the central banks. Next, we try to present a
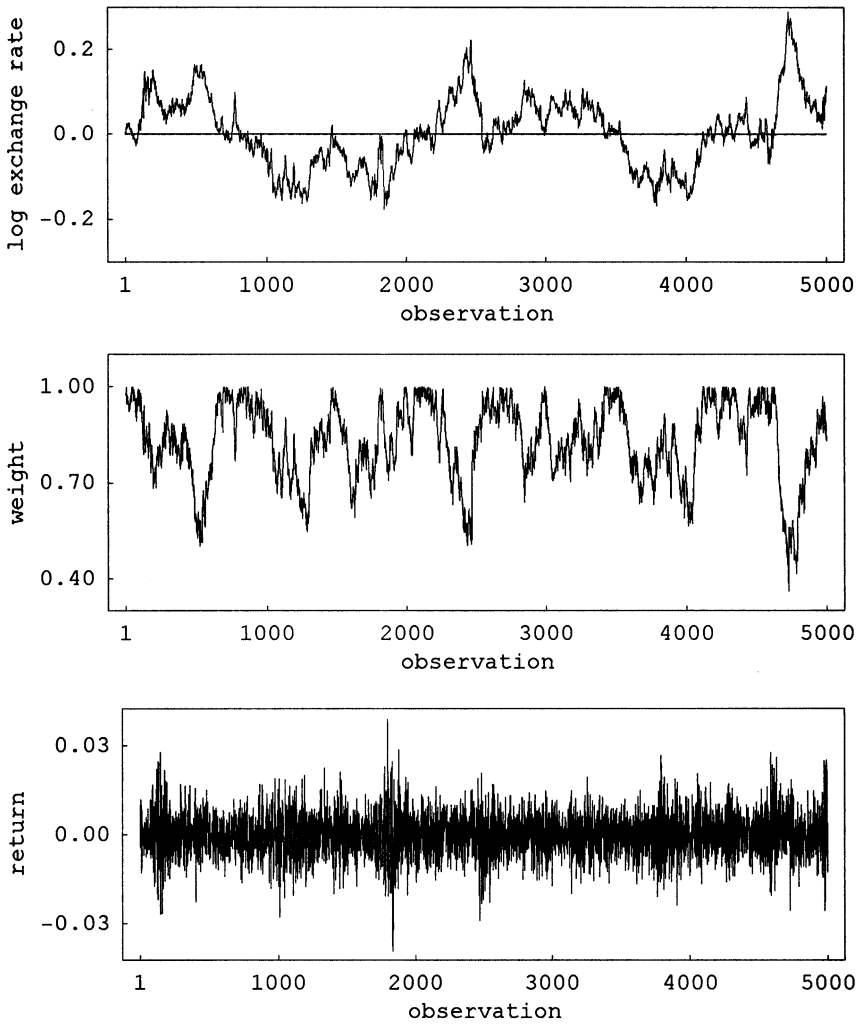
Fig. 2. The three panels present a simulation run of log exchange rates, weights of fundamentalists, and returns, respectively. The parameter setting is as in Section 3.2, 5000 observations.

simple robust low-frequency intervention method suitable for this task. The so-called target zone interventions may be written as

$$
D_t^{\text{CB}} = \begin{cases} +d, & \text{for} \quad F_t - S_t > e, \\ -d, & \text{for} \quad S_t - F_t > e, \\ 0, & \text{otherwise,} \end{cases} \tag{4}
$$

where d is a fixed intervention size and e defines the range of the target zone. Suppose, for instance, that $e = 0.2$. Then policy makers do not intervene as long as the distance between the exchange rate and its fundamental value is lower than 20 percent. If the exchange rate is misaligned more than 20 percent, then they either sell $(S > F)$ or buy foreign currency $(S < F)$. The intervention variable D_{t-1}^{CB} is added to the right-hand side of (1), else the system remains as before.

We measure the success of this method with the help of four statistics. The distortion in the market is computed as the average absolute distance between the log exchange rate and its log fundamental value

$$\text{distortion} = (1/T) \sum_{t=1}^{T} |S_t - F_t|, \tag{5}$$

where T is the sample length. The profitability of intervention operations is calculated as

$$\text{profit} = S_{T+1} \sum_{t=1}^{T} D_t^{CB} - \sum_{t=1}^{T} S_t D_t^{CB}. \tag{6}$$

The first term of (6) captures what the accumulated position of the central bank is worth after period T, while the second term keeps track of the gains and losses due to individual interventions. The frequency of intervention is just given as the number of intervention days divided by the number of trading days

$$\text{frequency} = (1/T) \sum_{t=1}^{T} I_t, \tag{7}$$

fundamental value, although the central bank trades only once in a while. In numerical terms, the distortion decreases from about 0.084 to 0.037. The central bank becomes active 125 times in 5000 periods (i.e. in 2.5 percent of the trading days). Moreover, the interventions are profitable and the net position of the central bank appears rather balanced.

The method works as follows. The intervention has a direct effect on the course of the exchange rate, i.e. it pushes the exchange rate toward its fundamental value. By inducing such a trend, additional orders of chartists are triggered which further guide the exchange rate back toward its fundamental value. In addition, the confidence of fundamentalists in their trading strategy increases, i.e. more stabilizing fundamentalists are active on average (see the central panel of Figure 3). Note that, whenever the exchange rate converges toward its fundamental value, both chartists and fundamentalists trade in the same direction. One may thus say that target zone interventions help coordinate the expectations of heterogeneous agents.
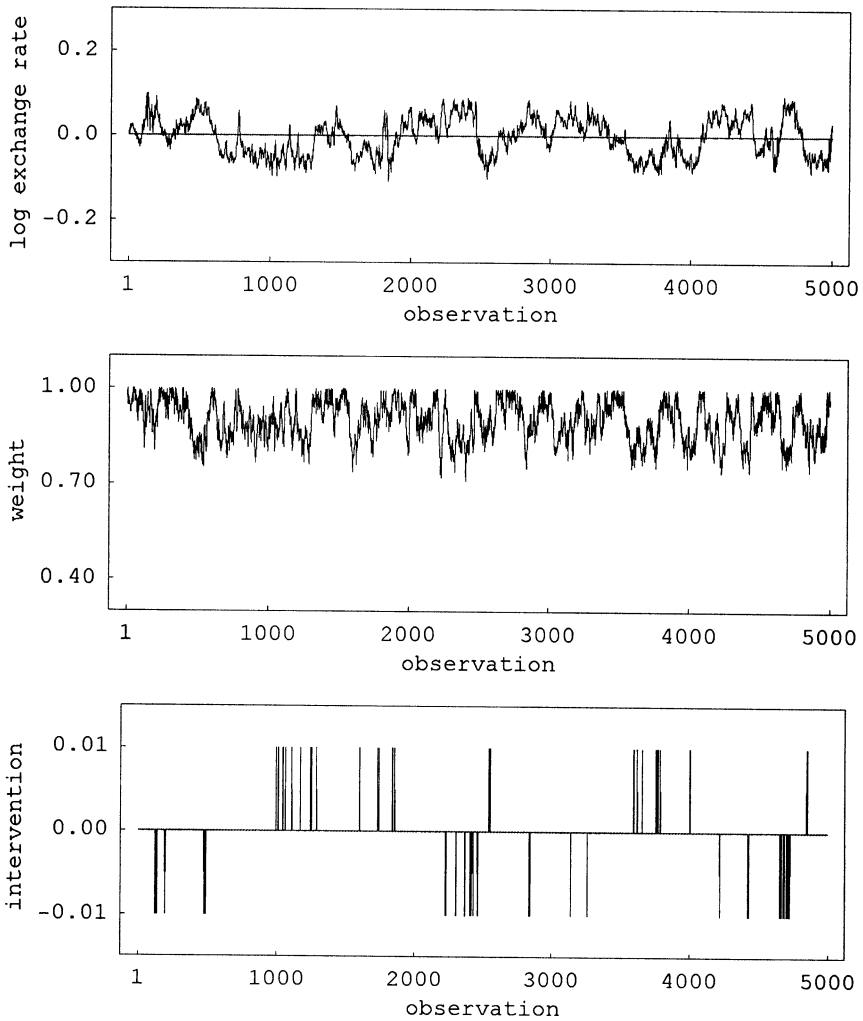
Fig. 3.   The three panels show a simulation run of log exchange rates, weights of fundamentalists, and target zone interventions, respectively. The same simulation design is used as in Figure 2, but $d = 0.01$ and $e = 0.08$.

Note that coordinated behavior may lead to stronger exchange rate changes: If chartists and fundamentalists trade in opposite direction, their orders partially cancel out each other and the price adjustment is comparatively low. However, if chartists and fundamentalists trade in the same direction, the excess demand and thus the consecutive price adjustment increases. As long as the exchange rate moves toward its fundamental value, such a volatility-enhancing strategy may be
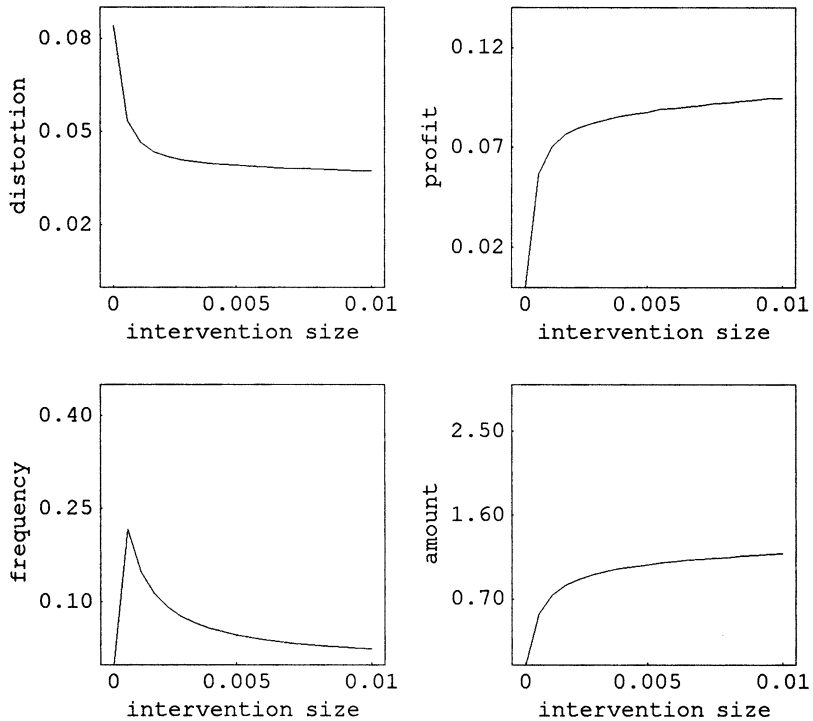
Fig. 4. The four panels reveal the impact of increasing intervention sizes d on the distortion, profitability of interventions, frequency of interventions, and total amount of interventions, respectively. All estimates are averages over 10 simulation runs with 5000 observations each. The intervention size d is increased in 20 discrete steps from 0 to 0.01. The target zone is $e = 0.08$. The remaining parameters are as in Section 3.2.

intended by the central banks, since it drives the exchange rate faster toward its long-run equilibrium value (for an empirical account, see Ref. 22). But it makes sense to halt this mechanism for two reasons. First, the central bank may not want to manipulate the exchange rate in every period. Second, coordination of chartists and fundamentalists close to the fundamental value is prevented. This is important, since then the risk that the exchange rate overshoots its long-run equilibrium value decreases. Clearly, if the exchange rate is close to its fundamental value, uncoordinated behavior is beneficial in the sense that it hinders the emergence of a new (destabilizing) exchange rate trend. The central banks may take care of these issues by selecting an appropriate target zone.

3.2. Monte Carlo Analysis. To evaluate the success of target zone interventions, a more general kind of analysis is needed. Figure 4 shows how the statistics react to an increase in the intervention size. All estimates are computed as averages
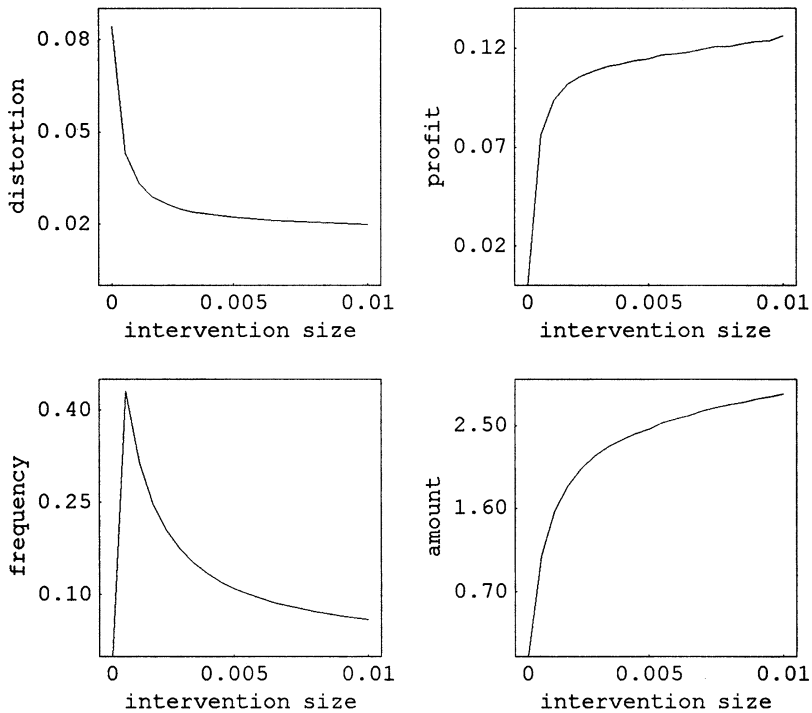
Fig. 5. The four panels reveal the impact of increasing intervention sizes d on the distortion profitability of interventions, frequency of interventions, and total amount of interventions, respectively. The same simulation design is used as in Figure 2, but now $e = 0.04$.

over 10 simulation runs with 5000 observations each. The intervention size d is increased in 20 discrete steps from 0 to 0.01. The target zone is $e = 0.08$ and the remaining parameters are as in Section 3.2.

Target zone interventions are in fact a powerful instrument to stabilize foreign exchange markets. For an intervention size of $d = 0.01$, the distortion is reduced by around 50 percent, although the policy makers only trade in about 2.5 percent of the cases. Moreover, interventions earn profits. Compared to the total amount of intervention, they may be as large as 10 percent. Our study suggests also that, when the central authorities decide to intervene, they should do it rather forcefully. If the intervention size is low, they have to intervene much more frequently, yet the outcome is still not as good.[6]

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[6] Additional simulations reveal that central bank interventions decrease the profitability of both technical and fundamental trading rules. Moreover, as was pointed out by Blake LeBaron, a credible target zone may become self-fulfilling. If the exchange rate nears its intervention threshold, chartists may stop speculating on a trend continuation. Both aspects are quite interesting and deserve more research.
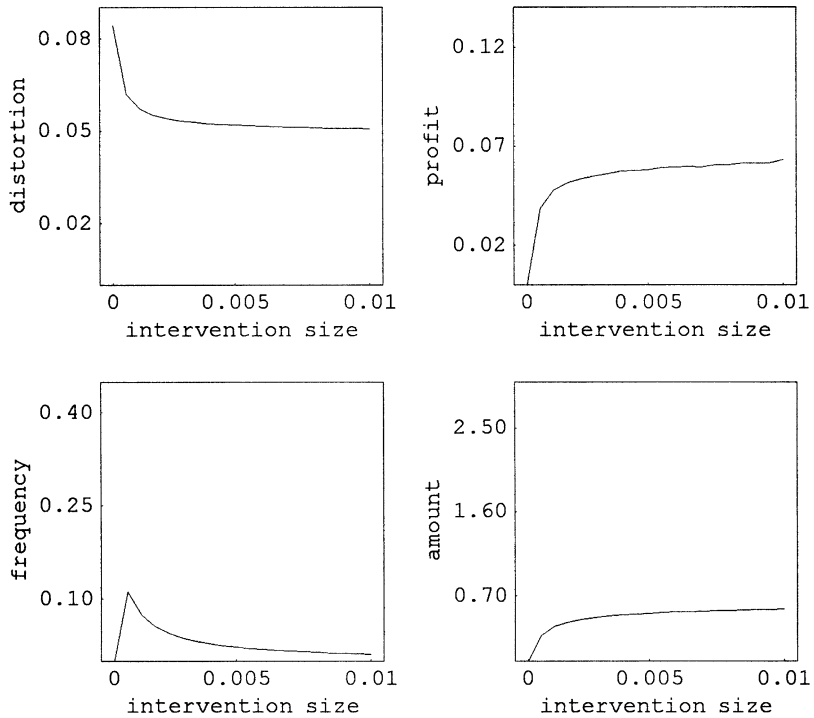
Fig. 6.   The four panels reveal the impact of increasing intervention sizes d on the distortion, prof-
itability of interventions, frequency of interventions, and total amount of interventions, respectively.
The same simulation design is used as in Figure 2, but now $e = 0.12$.

Are these results robust with respect to different target zones? Figures 5
and 6 display the findings for bands with $e = 0.04$ and $e = 0.12$, respectively.
Overall, the results are qualitatively the same as in Figure 4. We see again a
reduction in the distortion and positive profits. However, the smaller the target
zone, the lower the distortion and the higher the profits, but also the more fre-
quent the interventions. For instance, for $e = 0.04$ and $d = 0.01$, the central bank
intervenes on average every 17 periods and thereby drives the distortion down
to 2 percent.

For the deutsche mark/dollar spot market, Ref. 23 estimate that $1 billion
of net dollar purchases increases the deutsche mark price of a dollar by about
0.5 percent. The largest intervention that we consider in our paper is $d = 0.01$.
Within our setup, such an intervention shifts the exchange rate by 1 percent
and thus corresponds to an actual intervention of around $2 billion. Note that
such an intervention size is not unrealistic. Both the Federal Reserve Bank and
the Deutsche Bundesbank intervened quite forcefully in the 1980s. For instance,

the Deutsche Bundesbank bought or sold a couple of times more than 1 billion deutsche mark in that decade. The largest single intervention of the Deutsche Bundesbank was 3.2 billion deutsche mark (see Ref. 24 for more details). Similar activities have been observed for the Federal Reserve Bank. Hence, if both central banks coordinate their intervention activity, they can easily manage interventions of $d = 0.01$. However, since the central banks have unlimited resources (and since the interventions seem to be profitable), there is no reason for a central bank not to operate alone. And, of course, also smaller interventions sizes, say $d = 0.005$, already fulfill their goal.

Summarizing, by buying/selling and undervalued/overvalued currency when the deviation of the exchange rate from its fundamental value exceeds a critical threshold, a central bank decreases the average exchange rate distortion and generates significant trading profits. Moreover, such a target zone intervention heuristics has two additional advantages. First, the central bank has not to be active in every trading period. Second, the heuristics is easy to conduct and the informational requirements for the central bank may be regarded as rather low.[7] Overall, our results seems to be robust with respect to different target zones and intervention sizes.

A final comment seems to be in order. Our results are apparently not far away from what some central banks have done in the past. Inspecting actual intervention data from the Federal Reserve Bank and the Bundesbank, Refs. 15–16 conclude that the interventions produced profits. Reference 2, who conducted a survey study among monetary authorities regarding their intervention practice in the 1990s, concludes that interventions are quite common in foreign exchange markets. The percentage of business days on which they report having intervened, ranged from 0.5 percent to 40 percent, with 4.5 percent being the median. In addition, policy makers indicated that they seek to return the exchange rate to fundamental values.[8]

4. Conclusions

Can central banks control the cyclical behavior of exchange rates? Using an empirical chartist-fundamentalist model in which the market impact of fundamentalists depends on the strength of their belief in fundamental analysis, we find that low-frequency target zone interventions are not only profitable but manage also to reduce distortions considerably. Such an intervention is executed when the exchange rate leaves a prespecified band around the fundamental value and works as follows. It drives directly the exchange rate toward its fundamental value, the

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[7] At least in contrast to rules derived from chaos control methods such as the ones discussed in Ref. 13.

[8] Given the evidence presented here, it is surprising that the European Central Bank has remained quite inactive since the launch of the Euro, especially with respect to the Euro's extreme cyclical course.

new exchange rate trend is amplified by chartists, and fundamentalists are encouraged to take larger positions. In other words, the stabilizing direct effect of the intervention is amplified and prolonged, since it stimulates additional uniform trades of chartists and fundamentalists.

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