

Technical analysis and the effectiveness of central bank intervention

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Abstract

Using daily data on foreign exchange interventions of both the Bundesbank and the Fed we provide further evidence that central banks earn profits with interventions and that technical trading rules are unusually profitable on days on which interventions take place. We argue that what lies at the root of these seemingly contradictory results is that (a) intervention profits and trading rule profitability are measured over different horizons and (b) after interventions, exchange rates tend to move contrary to central banks' intentions in the short run, but in agreement with their intentions in the long run. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Technical analysis is a generic term covering a great variety of rules for taking investment decisions. What is common to all rules is that they condition on past prices. While there is a lot of evidence of technical analysis being used by financial market practitioners (e.g. Taylor and Allen, 1992), the question whether technical trading rules have any predictive power in financial markets is controversial (Malkiel, 1990). In recent years, however, evidence supporting the profitability of technical trading rules has been mounting (for review, see Neely, 1997). It has frequently been suggested that a source of the profitability of using technical trading rules on foreign

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exchange markets is government interference with free market forces through central bank interventions (Sweeney, 1986; Levich and Thomas, 1993). In a recent study, LeBaron (1999) examines the relationship between interventions and trading rule profits and finds firstly, that Moving Average trading rules are remarkably efficient at predicting exchange rate changes on days when central banks intervene and secondly, that technical trading rule profitability is dramatically reduced if intervention days are removed from the sample. This is very suggestive of the fact that there exists a connection between central bank interventions and technical trading rule profitability. LeBaron examines whether there exists a common factor causing both interventions and trading rule profitability, but finds no indications of such a factor. LeBaron's results support the suggestion that technical traders can gain at the expense of central banks. This, however, seems to stand in contrast to the results of Leahy (1995), who, also using daily intervention data, finds that the Fed made substantial profits with its interventions.

In this paper we confirm LeBaron's results and extend them by looking at a wider range of trading rules and by considering not only Fed but also Bundesbank intervention data. We also extend Leahy's results by giving evidence that the Bundesbank made very large profits with its interventions, too. We argue that what lies at the root of these seemingly contradictory results is that trading rule returns and intervention profits are measured over different horizons. We examine the relationship between interventions and subsequent deviations from uncovered interest parity for varying horizons and find that while exchange rates (net of interest differentials) move in a manner that is inconsistent with the aim of the interventions in the short run, the opposite is true in the long run. Moreover, we show that trading rule profits in the first days after intervention episodes end are highly negative.

The paper is organized as follows: after describing the data in Section 2, we confirm and extend LeBaron's (1999) results in Section 3. Section 4 provides evidence that both Fed and Bundesbank made substantial profits with their interventions. In Section 5 we address the effectiveness of interventions and examine the behavior of exchange rates after interventions over time. Section 6 concludes.

2. Data summary

The analysis uses daily USD/DEM exchange rates and daily USD and DEM overnight eurorates¹. The sample runs from January 2, 1979, to July 25, 1994. Table 1 gives summary statistics of the log first differences of daily exchange rates and of daily interest differentials². Exchange rate changes appear to have little drift, but

¹ Exchange rates are the New York market close (bid and offer side) from the Federal Reserve Bank of New York. Euromarket rates are bid rates around 10:00h Swiss time provided by the Bank for International Settlements.

² Exchange rates are arithmetic means of the bid and offer quotes. Moreover, daily interest differentials are determined by dividing annual rates of interest by 260. Dividing the interest differential by 360 would lead to an understatement of the influence of interest differentials because of weekends. We divide by 260 (=52×5 working days per year) instead so that interest differentials are correctly accounted for *on average*.

Table 1
Exchange rate and interest differential summary statistics

	$(s_t - s_{t-1})^a$	$\frac{1}{260}(i_t - i_t^*)^b$
Mean	3.38E -05	7.20E -05
Median	0	1.13E -04
Maximum	0.055	0.0013
Minimum	-0.0345	-2.88E -04
SD	0.0073	1.5E -04
Skewness	0.211 ^c	-0.209 ^c
Kurtosis	5.417 ^c	4.783 ^c
Jarque-Bera	1018.0 ^c	—
Arch-LM (<i>F</i> -stat)	30.83 ^c	3842.2 ^c

^a s_t is the logarithm of the USD value of one DEM

^b $i_t(i_t^*)$ are USD (DEM) eurorates

^c Indicates significance at the 1% level

there is evidence of skewness and excess kurtosis (fat tails). The interest differential between the US and Germany was positive on average, yet the negative tail of the distribution is relatively thick, as reflected in negative skewness. Moreover, there is evidence of fat tails for interest differentials, too. We also carried out the Jarque–Bera test of normality and Engle’s (1982) ARCH-LM test of conditional heteroskedasticity. The Null-hypothesis of homoskedasticity is strongly rejected for both time series and that of normality is rejected for exchange rates.

The intervention series consists of daily amounts of USD (DEM) purchased by the Fed (Bundesbank) from January 2, 1979 to July 25, 1994³. Fig. 1 shows the DEM/USD exchange rate as well as the cumulative USD position of each central bank. Whereas the Bundesbank intervened more or less continuously during the sample period, the Fed hardly intervened at all for substantial parts of the sample (most noticeably during the first Reagan administration in the early 1980s)⁴. Between 1979 and 1994 the Bundesbank was a net seller of USD on a scale exceeding 40bn, most of which occurred, it seems, to counteract the strong USD appreciation between 1981 and 1984.

Table 2 contains some statistics of the intervention series. On days on which interventions took place, Fed interventions had an average absolute size of \$116m, which is more than 50% larger than the corresponding figure for the Bundesbank⁵. The Fed intervened on average on 1 day in eight, the Bundesbank almost on 1 day in four and either central bank slightly less than on 3 days out of ten. It thus appears

³ Source: Federal Reserve Bank, Bundesbank. Ideally, one would have liked to use also more recent data. Note, however, that only 12 interventions by either Fed or Bundesbank took place between July 1994 and end 1996. This compares with 487 days on which the Fed intervened and 936 on which the Bundesbank intervened during the sample period considered here.

⁴ See Dominguez and Frankel (1993) for a history of intervention activity during this time.

⁵ This compares to an estimated average daily turnover of about USD 1200bn in 1995 (BIS, 1996: 5).

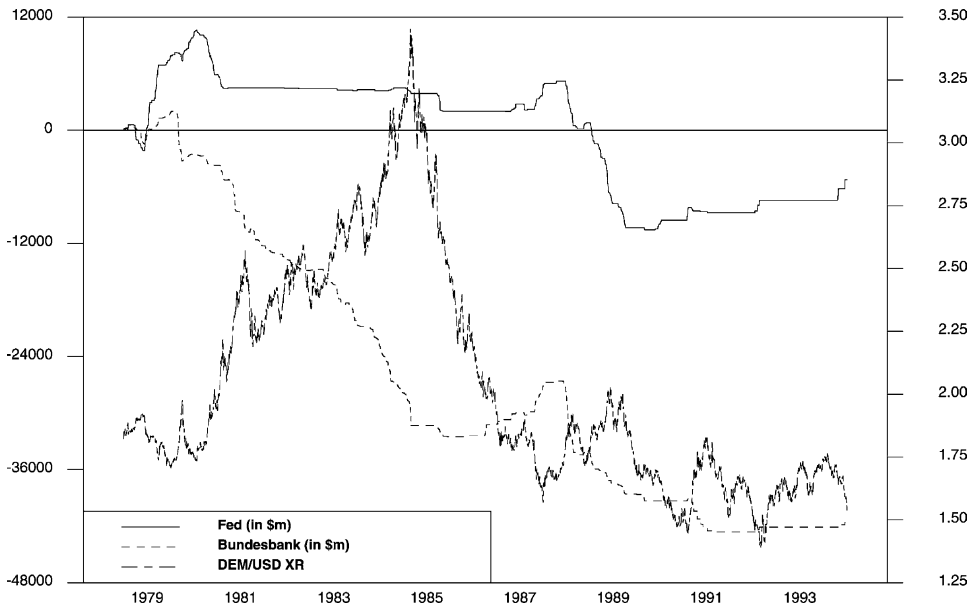


Fig. 1. DEM/USD Exchange rate and cumulative central bank interventions (1/79–7/94).

Table 2

Intervention summary statistics

	Fed	Buba	Either
Mean (x_t) ^a	-1.3	-10.2	-11.5
Mean ($ x_t , x_t \neq 0$)	115.7	73.7	107.0
Fraction in Market	0.12	0.23	0.28
$P(x_t = 0 x_{t-1} = 0)$	0.94*	0.88*	0.87*
$P(x_t \neq 0 x_{t-1} \neq 0)$	0.57*	0.60*	0.67*

^a x_t is the amount of USD purchased at t

^b * indicates significance at the 1% level

that the Fed intervened less frequently than the Bundesbank, but when it did, it intervened more heavily. Last but not least, intervention- and non-intervention-periods tend to cluster, as reflected by Markov switching probabilities significantly greater than one half.

3. Technical trading rule profitability for flexible exchange rates

3.1. Significance of Moving Average trading rule returns

When addressing the issue of the profitability of technical trading rules, the first question that needs to be answered is which trading rules in particular should be

looked at. The approach taken in this paper is to look at the most basic variant of a trading rule class that is known to have been in wide use at the time our sample starts and to examine its profitability for all reasonable parameter values⁶. We look at Moving Average trading rules, which, in their simplest form, state that one should go long in a currency if (as long as) the spot exchange rate is greater than the average of the exchange rates over the last N days⁷. If we denote the trading rule signals by ϕ_t in such a way that ϕ_t takes on the value of +1 if the trading rule signals a long position and -1 if it signals a short position, Moving Average trading rule signals can be defined formally as follows:

$$\phi_t = \begin{cases} +1 & s_t > \frac{\sum_{i=0}^{N-1} s_{t-i}}{N} \\ -1 & s_t < \frac{\sum_{i=0}^{N-1} s_{t-i}}{N} \\ \phi_{t-1} & s_t = \frac{\sum_{i=0}^{N-1} s_{t-i}}{N} \end{cases} \quad (1)$$

s_t is the natural logarithm of the arithmetic mean of the bid and the offer USD/DEM exchange rate⁸. More ‘sophisticated’ versions of Moving Average trading rules use short moving averages in place of the spot exchange rate or include a filter to avoid so-called whiplash signals. Examining the simplest version has the advantage that it is possible to analyze its profitability exhaustively as there is only one discrete parameter.

Letting $s_t^{(+1)}(s_t^{(-1)})$ denote the natural logarithm of the bid (offer) USD/DEM exchange rate, daily rates of return, r_t , are evaluated as follows:⁹

$$r_t = \phi_{t-1}(s_t^{(\phi_t)} - s_{t-1}^{(\phi_{t-1})}) - \frac{1}{260}(i_{t-1} - i_{t-1}^*) \quad (2)$$

⁶ Other authors examine trading rules that are either said to be popular in practice or assumed to be representative in some other sense (e.g. Brock et al., 1992). This approach is not unproblematic since on the one hand the number of rules used in practice is very large and on the other since returns are only measured ex post and “... there remains some doubt as to whether the reported excess returns could have been earned by a trader who had to make a choice about what rule or combination of rules to use at the beginning of the sample period” (Neely et al., 1996). Another approach is to examine the profitability of rules that are chosen on the basis of their past performance—either during a selection period (Neely et al., 1996) or recursively each period anew (Skouras, 1998).

⁷ See Cornell and Dietrich (1978: 115) for an assertion of the widespread use of Moving Average trading rules.

⁸ Using the logarithm of exchange rates as the input of the trading rule ensures that signals are identical independent of whether one expresses the exchange rate as USD/DEM or as DEM/USD.

⁹ Throughout the paper, whenever $S_t(s_t)$ is written without superscript it refers to the (natural logarithm) of the arithmetic mean of the bid and offer USD/DEM exchange rate at the New York close.

$i_t(i_t^*)$ are the USD (DEM) overnight eurorates. Note that in our definition of trading rule returns transaction costs are taken into consideration through the bid-offer spread prevailing on the day on which a trading rule signals a change in position. The average bid-offer spread equalled about 0.05%, which is somewhat larger than the level of transaction costs usually assumed in the literature on technical trading rule profitability. For instance, both Neely et al. (1996) and Osler and Chang (1995) assert that large institutional traders face transaction costs as low as 0.05% for a *round trip*. For this reason technical trading rule returns evaluated as in Eq. (2) can be seen as conservative measures of trading rule profitability. Moreover, using actual bid and offer quotes is more accurate since one need not make the unrealistic assumption that transaction costs are constant throughout the sample period.

Fig. 2 displays the average annual rate of return from following Moving Average trading rules with the parameter for the length of the moving average ranging from 2 to 500¹⁰. It also contains the lower bounds of one-sided 95% confidence intervals, which are derived assuming that returns are independently and identically distributed (i.i.d.) with finite variance, invoking the central limit theorem.

In particular for lengths of the moving average below 170 there seems to be strong

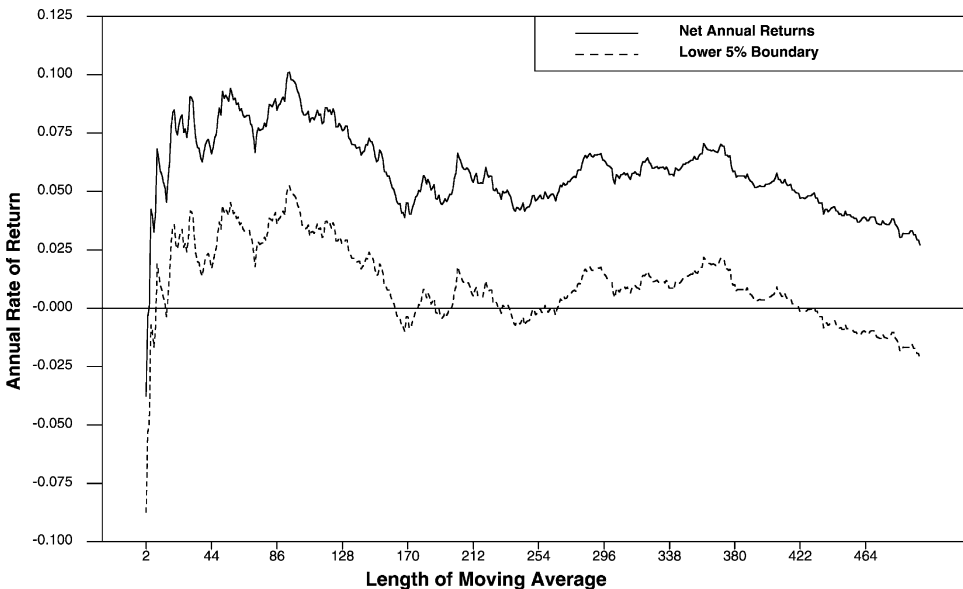


Fig. 2. One-sided 95% confidence intervals for MA trading rule returns.

¹⁰ The largest parameter value considered in either the academic or the professional literature is 250. For this reason it seems fair to assume that this range covers all reasonable parameter values.

evidence that trading rule returns are greater than zero¹¹. It might be objected, however, that high trading rule returns indicate that exchange rate changes are not i.i.d. and that thus trading rule returns cannot be i.i.d. either. This makes the use of standard confidence intervals problematic.

One way to deal with this is to make explicit assumptions concerning the process generating exchange rate changes, estimate its parameters and to use bootstrapping simulations to assess the significance of trading rule returns¹². We consider both a Random Walk with drift and a GARCH model as data generating processes¹³. The following GARCH model was estimated¹⁴:

$$\begin{aligned}\Delta s_t &= \alpha_0 + \sum_{i=1}^n \alpha_i \Delta s_{t-i} + u_t \\ h_t &= \beta_0 + \beta_1 h_{t-1} + \beta_2 u_{t-1}^2 \\ u_t &= \sqrt{h_t} v_t \\ v_t &\sim N(0,1).\end{aligned}\tag{3}$$

Table 3 contains the estimation results¹⁵. Using the estimated parameters along with the corresponding residuals, 2000 pseudo time series were generated for each model¹⁶. MA(25), MA(50), MA(100), MA(150) and MA(200) trading rules were applied to each of these and the proportions of pseudo time series for which the trading rules yielded as large or larger returns than for the original series were determined¹⁷. Table 4 contains the average annual rates of return of the trading rules

¹¹ For reasons of brevity we only note that the observed returns remain substantial even when they are adjusted for risk. For instance, the annual Sharpe ratio for lengths of the moving average between 10 and 170 averaged 0.65, which compares to a benchmark value of between 0.3 and 0.4 for well-diversified stock portfolios. More detailed results concerning risk-adjusted trading rule returns are contained in LeBaron (1991) and in Saacke (1999), Chap. 3.

¹² For an excellent introduction to bootstrapping see Efron and Tibshirani (1993). See Brock et al. (1992) for a good exposition of bootstrapping methodology as applied to trading rule profitability.

¹³ A Random Walk with drift has been considered by Levich and Thomas (1993) for daily exchange rate changes. Brock et al. (1992) consider GARCH-in-Mean and Exponential-GARCH models for daily DJIA-returns. LeBaron (1991) uses a GARCH model for weekly exchange rate changes.

¹⁴ We used the GARCH model as proposed by Bollerslev (1986). The number of ARCH and GARCH terms was determined using the Schwarz (1978) criterion. The lagged endogenous variables to be considered in the regression equation were determined as follows: The model was first estimated with only a constant term. Examining the Ljung-Box Q -statistic for lags up to 40, the standardized residuals (v_t) were then checked for autocorrelation. When evidence of autocorrelation was found, more lagged endogenous variables were added successively until signs of autocorrelation disappeared. After this, lagged endogenous variables whose parameter estimates were not even marginally significant were removed, at each step checking again for autocorrelation in the residuals.

¹⁵ It might seem peculiar that α_5 was included although its t -statistic is clearly insignificant. The reason for this is that its inclusion substantially affected the Ljung-Box Q -statistics.

¹⁶ Interest differentials were scrambled alongside residuals and were used in the calculations of trading rule profitability.

¹⁷ Transaction costs were assumed to be equal to the average bid-offer spread of the exchange rate series used before (0.05%). They were assumed to be incurred at each change from short to long position or vice versa.

Table 3
Parameter estimates for the GARCH(1,1) models of daily DEM/USD exchange rate changes

	Coefficient	Std. Error	<i>p</i> -value
α_1	-0.034	0.017	0.054
α_2	0.023	0.017	0.167
α_3	0.022	0.016	0.172
α_5	0.015	0.016	0.336
β_0	0.000	0.000	0.000
β_1	0.882	0.007	0.000
β_2	0.083	0.007	0.000
$Q(10)$	10.22	0.421	
$Q(20)$	25.58	0.180	
$Q(40)$	39.87	0.476	

Table 4
Significance of selected MA trading rules

	MA(25)	MA(50)	MA(100)	MA(150)	MA(200)
Random Walk					
Mean Orig.	0.082	0.086	0.093	0.065	0.051
Mean Boot.	-0.043	-0.034	-0.021	-0.011	-0.005
Stdev. Boot.	0.031	0.031	0.031	0.031	0.031
Boot. <i>p</i> -value	0.000	0.000	0.000	0.011	0.041
GARCH(1,1)					
Mean Orig.	0.082	0.086	0.093	0.065	0.051
Mean Boot.	-0.039	-0.029	-0.016	-0.006	-0.001
SD Boot.	0.032	0.032	0.032	0.032	0.032
Boot. <i>p</i> -value	0.000	0.000	0.000	0.014	0.111

for the original time series, the annual mean and standard deviation of trading rule returns for the simulated time series, as well as the proportions of simulations in which returns were higher (*p*-values) for each of the two Null-models.

Clearly, neither model can account for the size of trading rule returns observed in this period, which confirms the results found by Levich and Thomas (1993) and LeBaron (1991). It thus seems as if there were some time dependencies in exchange rate changes that Moving Average trading rule can exploit. This immediately raises the question of who or what is responsible for these time dependencies. One explanation is considered in the next section.

3.2. Technical trading rule profitability during central bank interventions

It has frequently been suggested that central bank interventions may introduce exploitable patterns into the movement of exchange rates. The most explicit formulation of this hypothesis is to be found in Szakmary and Mathur (1997).

If central banks smooth out changes in exchange rates and delay adjustment to underlying fundamental forces by leaning against the wind, it may be expected that trend-following forecasters profit from interventions (p. 514).

The story seems to run as follows: After an exogenous shock to fundamentals, the exchange rate would, without central bank interventions, jump to a new equilibrium level (e.g. Dornbusch overshooting). Wishing to reduce volatility, central banks try to prevent the exchange rate from jumping by leaning against the wind. Thereby they delay the adjustment of the exchange rate. If adjustment is delayed, exchange rates will display a trend during the phase of adjustment. This trend may then be picked up and exploited by trend-following forecasters, who utilize trading rules of the type considered in the previous section.

LeBaron (1999) is the first study that examines the relationship between interventions and technical trading profits empirically. LeBaron finds that the MA(150) trading rule is extremely efficient at predicting the sign of the change of the exchange rate from period $t-1$ to t conditional on the Fed intervening in t . Moreover, he finds that trading rule signals at $t-1$ tend to have the opposite sign of interventions at t and that trading rule returns on days on which no interventions took place are insignificant. Neely and Weller (1999) show that these results not only hold for the MA(150) rule but also for technical trading rules generated by genetic programming.

It suggests itself to examine the relationship between interventions and trading profits when Bundesbank interventions are taken into consideration too. Fig. 3 contrasts annual rates of return of Moving Average trading rules on days when either Fed or Bundesbank intervened with returns on days when neither intervened. Clearly,

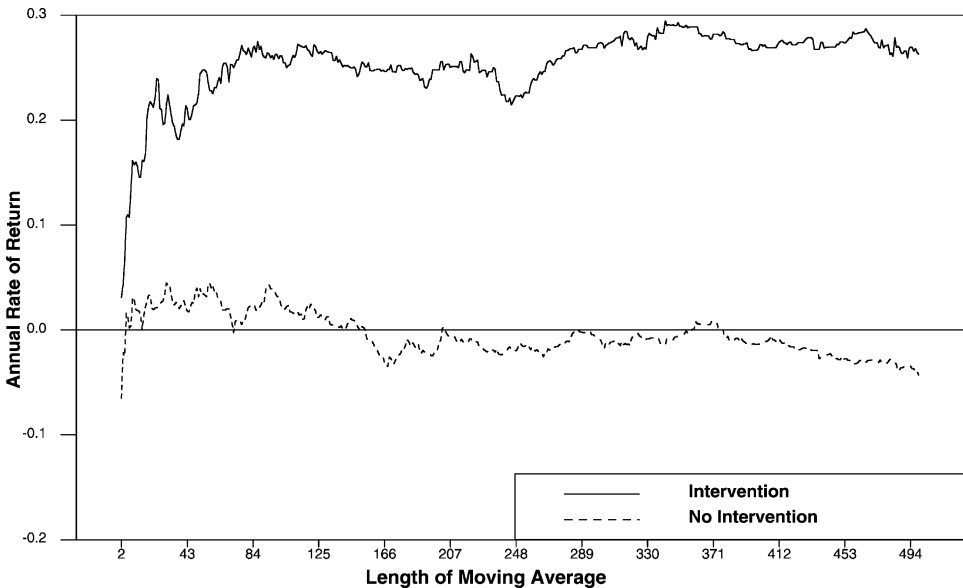


Fig. 3. MA trading rule returns on intervention versus non-intervention days.

there is a substantial difference¹⁸. In contrast to LeBaron (1999), however, we find that returns of some Moving Average rules are at least marginally significant on days when there were no interventions. We also examined the proportion of the trading rule signals which had the opposite sign of interventions by either Fed or Bundesbank. Fig. 4 shows the proportions as well as 95% confidence intervals for each trading rule with moving averages between 2 and 500. Clearly, for all lengths of the moving average the proportion of trades against the central banks are significantly greater than 0.5¹⁹.

Thus LeBaron's (1999) conclusion that, "something different is going on when the Federal Reserve is active in terms of foreign exchange predictability", extends to Bundesbank intervention activity. It is tempting to interpret these results as indicating that central banks introduce exploitable patterns into exchange rate movements and thereby transfer money to extrapolative technical traders. This warrants a closer look at the relationship between trading rule profitability and the profitability of central bank interventions. This issue is addressed next.

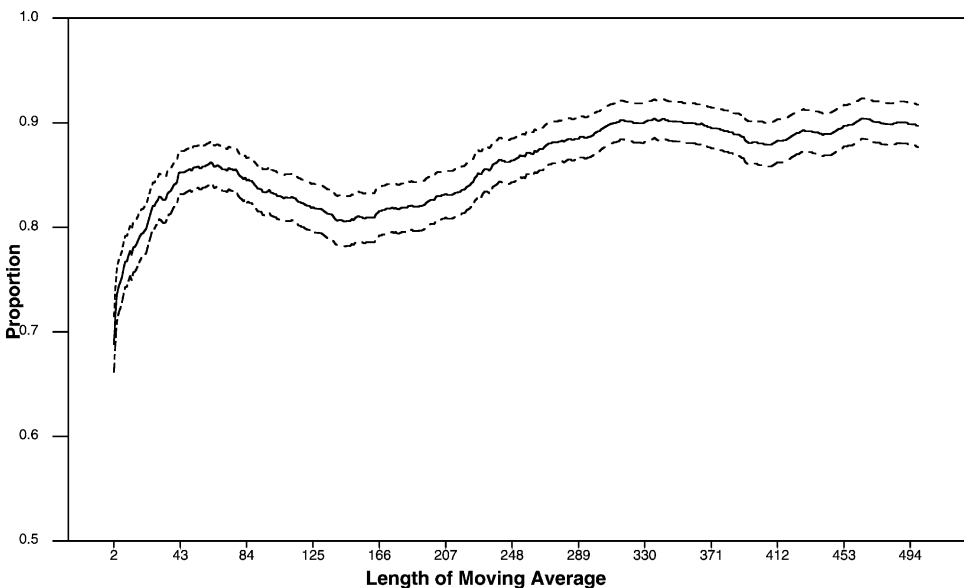


Fig. 4. Proportion of Positions contrary to central banks with 95% confidence intervals.

¹⁸ We find that this is also true if either only Bundesbank or only Fed interventions are considered. Moreover, it turns out that trading rule returns on days when only the Fed intervened are considerably higher than returns when only the Bundesbank intervened. We also note that the contrast between intervention and non-intervention periods remains when returns are adjusted for risk. See Saacke (1999) for details.

¹⁹ Again, the same is true if Fed and Bundesbank interventions are examined individually.

4. The profitability of central bank interventions

The issue of whether foreign exchange intervention is profitable is controversial (for review, see Sweeney (1997)). One criterion according to which one can differentiate studies of this question is the frequency of the data used. Some studies use quarterly (or monthly) changes in foreign exchange reserves as a proxy for central bank interventions. This has a number of drawbacks. An obvious problem is that intra-monthly changes in reserves are missed. Moreover, reserve changes do not correspond one to one with interventions because of transactions between central banks, forward market interventions and official borrowing of foreign currency (Leahy, 1995: 824).

There are only few studies using daily intervention data, which is due to the reluctance of central banks to part with the data. The best known paper in this literature is Leahy (1995), which uses intervention data for the Fed from 1973 to 1992. Leahy finds that, as of 31.12.1992, the Fed had earned \$12.3bn (\$4.2bn) intervening in the DEM/USD (JPY/USD) market (Leahy, Table 1). He employs a number of tests to examine whether interventions have any predictive power for subsequent deviations from uncovered interest parity. However, he does not perform an outright test of the significance of the profits.

As a starting point, we adopt Leahy's approach to measuring intervention profits with the only major deviation that we use overnight eurorates rather than 3-month Treasury bill rates²⁰. Let x_t be the amount of DEM bought on day t ; as before S_t is the USD/DEM exchange rate and $i_t(i_t^*)$ are the USD (DEM) overnight eurorates. Let T be the last date in the sample. The profitability of interventions is analyzed by creating a zero-cost portfolio which mirrors intervention activity. It is assumed that whenever the Fed/Bundesbank buys DEM, it borrows the necessary funds in the Eurodollar market and invests the purchased DEM in the Eurodeutschmark market. When DEM are sold the reverse transactions are carried out. A further, crucial assumption is that each such intervention position is maintained until the last day of the sample. Under these assumptions, the contribution of the intervention at time t to profits from intervention measured as of date T can be approximated as follows:

$$X_{t,T} = x_t \left[e^{\frac{1}{260} \sum_{j=t}^{T-1} i_j^*} - e^{S_t - S_T + \frac{1}{260} \sum_{j=t}^{T-1} i_j} \right]. \quad (4)$$

The first part of the square bracket is the return on the x_t DEM purchased and invested every day anew in the Eurodeutschmark market (assuming for the purpose of illustration that x_t is positive). The second part of the square bracket is the cost of borrowing the necessary funds for the intervention²¹. We borrow $x_t S_t$ USD at t and have to pay it back with interest at the exchange rate prevailing at time T . Total

²⁰ As it turns out, it makes practically no difference which of these two interest rates one uses. Compare Fig. 5 below with Leahy (1995) Fig. 1.

²¹ Another way of looking at it is as the opportunity cost of the investment (Leahy, 1995: 826).

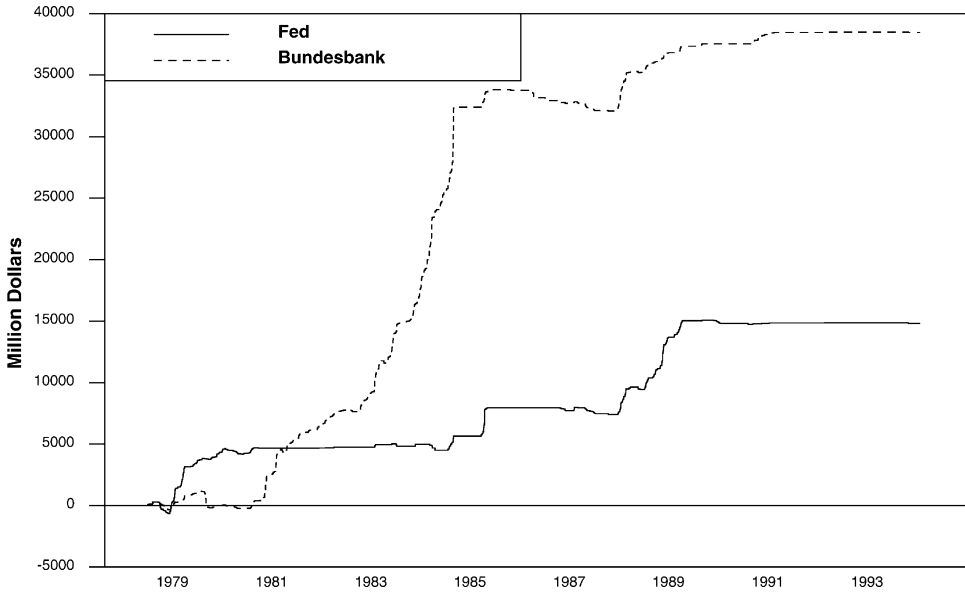


Fig. 5. Cumulative contributions to intervention profits.

profits from interventions measured as of date T are thus the sum of the contributions of interventions before T ²².

$$\Pi_T = \sum_{t=1}^{T-1} X_{t,T} = \sum_{t=1}^{T-1} x_t \left[e^{\frac{1}{260} \sum_{j=t}^{T-1} i_j^*} - e^{s_t - s_{T+\frac{1}{260} \sum_{j=t}^{T-1} i_j}} \right]. \tag{5}$$

Table 5 contains intervention profits evaluated as of the last day in the sample (i.e. $T=25.7.1994$). According to this measure of intervention profits, the Fed earned around \$14.8bn while the Bundesbank even earned \$38.5bn. Since our method of calculating intervention profits assumes that each intervention position is held until the last day in the sample, the estimates of intervention profits are very sensitive to

Table 5
Profitability of central bank interventions (\$m)

	Total Profits 25/07/94	Profits for: USD +20%	Profits for: USD -20%	Bootstrap p -value Random Walk
Fed	14808.8	12640.6	17457.1	0.008
Bundesbank	38479.8	15753.2	66238.0	0.114

²² Note that the term in square brackets can be interpreted as the ex-post deviation from uncovered interest parity between time t and T .

changes in the value of the exchange rate in T . In order to check whether our results are robust against changes in S_t we also calculated intervention profits for a 20% higher and 20% lower value of S_t . While profits remain positive, in particular Bundesbank profits react very strongly to changes in the exchange rate. This is not surprising given that the Bundesbank was a very large net seller of USD during the sample period (see Fig. 1). Another way of looking at the sensitivity of the intervention profits is to ask how much the exchange rate on the last day of the sample would have to differ from S_t in order for intervention profits to disappear. For the Bundesbank we find that if the DEM/USD exchange rate had been 2.18 rather than the actual 1.59, profits would have been zero. For the Fed no exchange rate assumption annihilated the profits completely²³.

In order to assess whether these figures may have come about by chance, we again carry out bootstrapping simulations²⁴. Assuming that the intervention series is independent of the exchange rate series, we generate pseudo exchange rate time series and look at the empirical distribution of intervention profits for the simulated exchange rate series given the original intervention series. It might be objected that the assumption of independence does not hold since there is strong evidence that central banks react to movements in exchange rates (Dominguez and Frankel, 1993: 77). However, the fact that interventions depend on past exchange rates is only a problem if we allow for some time dependence in exchange rate changes in our Null-model²⁵. For this reason we will only consider the Random Walk model in the simulations.

Table 5 also contains the results of carrying out 2000 bootstrapping simulations. We find that for less than 1% of the simulated exchange rate series did the original Fed interventions yield as high or higher profits, while the corresponding figure for the Bundesbank is as large as 11.4%. Note that this is although the estimated intervention profits of the Bundesbank were substantially larger than those of the Fed. This is again due to the fact that the Bundesbank was a very large net seller of Dollars over the sample period, since this entails that whenever a simulated USD exchange rate series depreciates greatly, large intervention profits will show up. Nevertheless, the results for Fed and Bundesbank taken together represent strong evidence that central bank interventions have been profitable²⁶.

In Fig. 5, intervention profits measured as of the last day in the sample (i.e. $\Pi_{25.7.1994}$) are broken up according to when they originated. The most noteworthy aspect of the figure is that it shows that almost all interventions have contributed

²³ This is because the Fed was net long DEM only to a limited extent so that even if the DEM had become worthless, interest gains would still have overcompensated the losses incurred.

²⁴ Another way of testing the significance of intervention profits has recently been suggested by Sjöö and Sweeney (1999).

²⁵ To illustrate the point suppose that both exchange rate changes and interventions are positively auto-correlated. Thus, if at t the Dollar appreciates and the Fed sells Dollars one can expect that not only this intervention but also those on the subsequent days will be unprofitable.

²⁶ Since it thus appears that neither technical traders nor central banks lose money and since trading on the foreign exchange market is a zero-sum game, the intriguing question arises, at whose cost they make their profits. Answering this question is, however, beyond the scope of this paper.

positively to intervention profits. At first sight this might seem to stand in contradiction to our previous result that technical trading rules make most of their profits from taking positions contrary to those of central banks. However, this seeming contradiction disappears if it is recognized that trading profits and intervention profits are measured over different horizons: In our definition of intervention profits (and thus also in Fig. 5) the contribution of each intervention to intervention profits is dependent on the development of the exchange rate and of interest rates from the date of the intervention until the last day in the sample. This means that for all but the last, say 260 observations we looked at the long term profitability of these interventions. In contrast, MA trading rules signal changes in investment postures every few weeks/months (depending on the length of the moving average)²⁷.

The root of the seeming contradiction in the profitability of both interventions and technical trading rules is that profitability is measured over different horizons. Whereas trading rule returns are averages of daily returns on a position that changes frequently, intervention profits are the result of much more stable positions taken by the central banks (recall the stability of cumulative interventions shown in Fig. 1).

In this context it is also worth pointing out that the fact that technical trading rules are highly profitable when they indicate positions contrary to those of central banks does not necessarily mean that central banks lose money on the days on which they intervene. This is because it is not clear a priori that if the exchange rate has moved contrary to central banks' intentions from the New York close at $t-1$ to that at t , then it also did so between the time of the intervention at t and the close at t . In contrast, it is even conceivable that interventions moved the exchange rate in the desired direction, but that it had moved so much in the opposite direction before the intervention that this effect is concealed²⁸.

5. Effectiveness of central bank interventions

In order to analyze the reaction of the exchange rate to interventions over time more precisely, we examine the relationship between interventions and subsequent deviations from uncovered interest parity (UIP). For this purpose we estimate the following equation for varying horizons K ²⁹:

$$\left[e^{\frac{1}{260} \sum_{j=t}^{t+K-1} i_j^*} - e^{s_t s_{t+K} + \frac{1}{260} \sum_{j=t}^{t+K-1} i_j} \right] = \alpha + \beta x_{t-1} + u_t. \quad (6)$$

As before, s_t is the natural logarithm of the USD/DEM exchange rate, $i_t(i_t^*)$ are the USD (DEM) overnight eurorates and x_t is the amount of USD bought on day t . $K > 1$

²⁷ See also Neely (1998) for a very thorough discussion of the relationship between the profitability of MA trading rules and the profitability of central bank interventions.

²⁸ Casual empiricism suggests that in the first minutes/hours after an interventions, exchange rates move in accordance with central banks' intentions. Indeed, it appears to be part of foreign exchange folklore that being on the other side of the market when a central bank intervenes is something to be avoided.

²⁹ Interventions need to be lagged to avoid a simultaneity bias.

induces u_t to have an ‘overlapping observation’ structure. In order to take account of this and because of heteroskedasticity in deviations from UIP, we use Newey and West (1987) autocorrelation and heteroskedasticity consistent covariance estimators. Figs. 6 and 7 show parameter estimates of α and β , as well as Newey–West standard errors when interventions of Fed and Bundesbank are pooled. We let the horizon, K , range from 1 to 520 days (approximately 2 years).

Parameter estimates for α (which might also be interpreted as estimates of a time invariant risk premium) are never significantly different from zero. For $K=1$, the estimate of β is marginally significantly smaller than zero (t -value of 1.71). For horizons shorter than 26 days the estimates remain negative, before turning positive and ending up being significantly greater than zero for horizons greater than 330 days³⁰. It thus appears that after central bank interventions exchange rates (net of interest differentials) tend to move in a manner inconsistent with central banks’ intentions in the short run, but that this effect reverses in the long run.

As regards the question whether central bank interventions are effective, our results are inconclusive. Even though there appears to be an empirical regularity that exchange rates tend to move in accordance with interventions eventually, this does not imply that interventions in anyway caused the exchange rate to reverse its trend

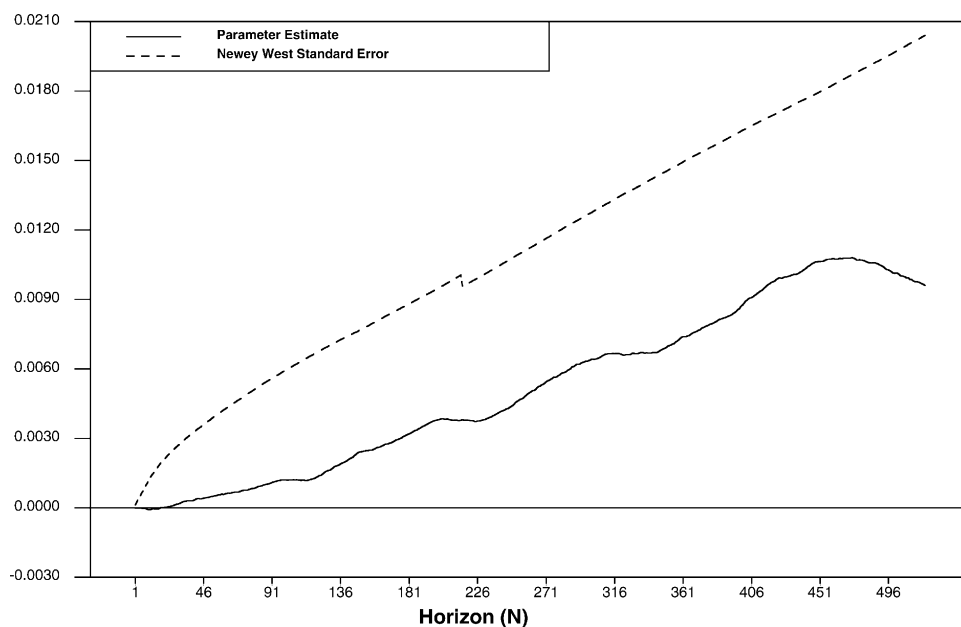


Fig. 6. Regressing interventions on future deviations from UIP: estimates of alpha.

³⁰ The corresponding results when Fed and Bundesbank interventions are not pooled are similar. It is worth noting, however, that the ultimate sign change occurs after substantially fewer days for the Fed than for the Bundesbank (after 12 versus 141 days).

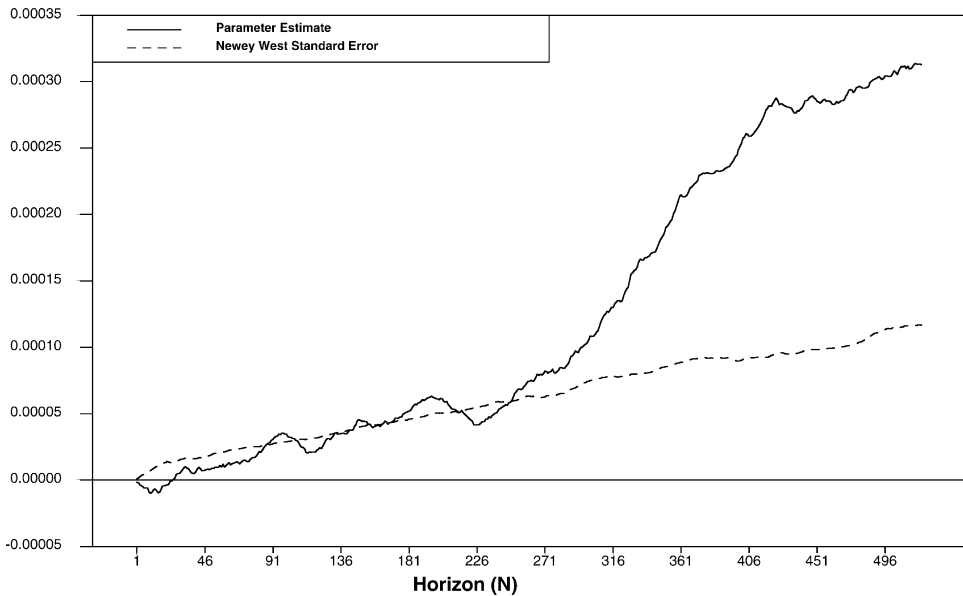


Fig. 7. Regressing interventions on future deviations from UIP: estimates of beta.

or to move towards the central bank's target level. The fact that interventions are profitable in the long run suggests that central banks on average buy low and sell high. However, to what extent this is evidence that interventions are effective because they are 'stabilizing' in Friedman's (1953) sense is questionable, in particular given the evidence on the short term behavior of exchange rates after interventions³¹.

Our results concerning the behavior of exchange rates immediately after interventions are largely consistent with the existing literature on the effectiveness of central bank interventions. Econometric estimates of the influence of interventions on the level of the exchange rate are usually insignificant and even if they are significant, they have the wrong sign³². Casual observations, on the other hand, have been more favorable towards the effectiveness of interventions. For instance, Dominguez and Frankel (1993) observe that:

... in 10 out of 11 episodes, during the period of intervention, the mark-dollar rate moved in the opposite direction to intervention operations. But ... in 10 of the 11 episodes, in the month following the end of the intervention operations, the mark-dollar rate moved in the same direction as the operations (p. 95).

³¹ On the issue of stabilizing versus destabilizing speculation see LeBaron (1999), footnote 6 and the references contained therein.

³² Baillie and Osterberg (1997), Table 1; Weber (1994: 16ff); Dominguez and Frankel (1993: 113ff). Slightly more successful is Dominguez (1990: 143ff). See Almekinders (1995: 77ff), for a very thorough survey of the literature.

while Catte et al. (1994) find that:

All of the episodes were successful in the sense that interventions inverted the trend of the dollar and (...); in nine cases they were definitively successful in the sense that in the next episode intervention was in the opposite direction. ... Three were short lived lasting no more than three weeks (...), while the remaining episodes (...) should probably be considered as successful *tout court* because their effects either lasted for several months or were interrupted by minor rebounds that induced central banks to intervene again in the same direction (...) (p. 206).

Of course, claims such as these are often attacked on the grounds that they are not based on an unambiguous methodology³³. It is nonetheless interesting to note that our finding that exchange rates (adjusted for interest differentials) move in a direction contrary to central banks' intentions in the short run and in the desired direction in the long run describes the same phenomenon³⁴.

Finally, let us turn to the question of the motivation behind central bank interventions. According to an IMF directive, central banks should only intervene to counter disorderly market conditions. An alternative view is that central banks try to reverse exchange rate trends away from what they consider as the exchange rate's fundamental value. If this interpretation was correct, one would expect that central banks stop intervening as soon as an exchange rate trend reverses. However, moving average trading rules by construction incur losses precisely in the first few days after an exchange rate trend reverses. Thus if the latter interpretation of the motivation of central banks was correct, one would expect that in the first days after intervention episodes moving average trading rules are unprofitable.

In order to test this prediction, we split up the sample into three subsamples: Firstly intervention periods, secondly post-intervention periods, which are defined as the first 10 days after the end of an intervention period and thirdly periods which neither coincide with nor are preceded by interventions³⁵. Fig. 8 shows annual rates of return for each of the three subsamples. Clearly, the hypothesis that trading rule returns should be negative during the first days after interventions is borne out in the data, lending support to the view that interventions are intended to reverse exchange rate movements that are considered out of line with fundamentals³⁶.

In line with the earlier results of high trading rules returns on intervention days, it also appears that technical trading rule profitability during interventions periods

³³ Almekinders' (1995: 86), critique of Dominguez and Frankel (1993) and Truman's (1992) comment on the paper by Catte et al. (1994).

³⁴ Note also the connection between our results and those of Goodhart and Hesse (1993); see in particular Fig. 7a–h.

³⁵ Instead of defining some ultimately arbitrary criterion according to which the starting and ending dates of intervention periods are to be identified, our approach is to make use of the set of intervention periods which were identified by Catte et al. (1994) using confidential intervention data for 16 central banks. See Catte et al. (1994: 203), for the description of the criteria used to identify intervention periods.

³⁶ Defining post-intervention periods as the first 5 or 15 days after an intervention episodes gave very similar results.

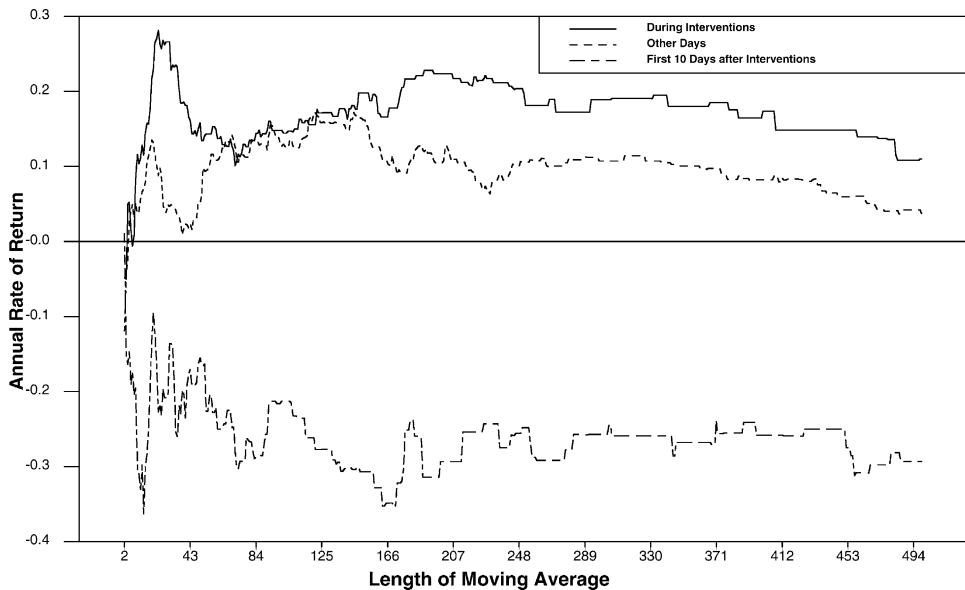


Fig. 8. MA Trading rule returns during and after intervention periods.

identified by Catte et al. (1994) was very high. Moreover, trading rule returns in periods that neither coincide with nor are preceded by intervention periods are often as large or even larger than returns for the whole sample period. On the one hand, this strongly suggests that technical trading rules are not only profitable during intervention periods and provides further evidence against the hypothesis that central bank interventions are solely responsible for the profitability of technical trading rules. On the other hand, this shows that the exceptionally high trading rule returns during intervention periods are reduced to average technical trading rule returns during the first few days after interventions.

6. Conclusions

In this paper we gave further evidence for central banks earning profits with their foreign exchange interventions. We also confirmed that Moving Average trading rules are highly profitable on days when central banks intervene, and showed that the trading rules tend to bet against central banks. This seeming contradiction turned out to be due to (a) intervention profits and trading rule profitability being measured over different horizons and (b) after interventions, exchange rates moving contrary to central banks' intentions in the short run, but in agreement with their intentions in the long run. Moreover, we found that trading rule returns on days that neither coincide with nor are preceded by interventions are positive and are about as large as trading rule returns for the entire sample, which implies that even if interventions were a cause of trading rule profitability, they would not be the only one.

It is worth noting that our results fit in well with Taylor and Allen's (1992) study of the use of technical analysis in foreign exchange markets. About 90% of the respondents to their questionnaire survey use at least some chartist input at short horizons (intraday to one week), while at long horizons (one year or longer) 85% of respondents view fundamental analysis as more important than chart analysis. Our results suggest that at short horizons the respondents do well to take chartism into account. On the other hand, the fact that central banks make profits in the long run, suggests (if we assume that interventions are aimed at bringing exchange rates in line with fundamentals) that it is rational to base one's decisions on fundamental analysis in the long run.

There is also an interesting connection between our results and those of studies of expectations' formation on foreign exchange markets. Analyzing survey data on exchange rate expectations Frankel and Froot (1990) find that while short term (1-week–3-month) expectations exhibit bandwagon tendencies, in the long term market participants tend to forecast a return to a long-run equilibrium such as Purchasing Power Parity³⁷. If, as suggested, we view interventions as being aimed at stopping trends away from fundamentals, our results concerning the short and long term relationship between interventions and subsequent deviations from uncovered interest parity suggest that this so-called expectational twist may simply be a sign of profit maximizing behavior.

As regards the question of the effectiveness of interventions, the only conclusion one can draw is that they are not immediately successful. To what extent they contribute to the exchange rate trends turning earlier than they would otherwise have done is unclear. It is important to note, however, that our results are also compatible with central bank interventions having no influence at all on exchange rates (but simply exploit long term exchange rate misalignments). In the worst case it may even be that interventions are seen by technically inclined market participants as a confirmation of the existence of a strong trend³⁸. In this case interventions might be counterproductive by attracting additional technical traders and thereby prolonging deviations of the exchange rate from its fundamental value.

The question remains what connects central bank interventions and technical trading rule profitability. An alternative to the view that interventions are responsible for trading profits would be that both interventions and technical trading rules are addressing the same phenomenon: large swings in flexible exchange rates, which cannot be explained (let alone predicted) on the basis of economic fundamentals. Technical trading rules might try to exploit (or even partially cause/prolong) them while central banks might try to reduce their amplitude. Given their different aims, they end up on opposite sides of trades. While this is just one interpretation that squares with the empirical regularities presented in this paper, a closer analysis of the effects technically motivated trading has on exchange rate dynamics seems war-

³⁷ Frankel and Froot (1990: 96ff). See also the evidence in Froot and Ito (1989) and Ito (1990) on the consistency of short- and long term exchange rate expectations.

³⁸ Note that this might be an explanation for the fact that central banks sometimes intervene secretly.

ranted. A better understanding of what makes technical trading rules profitable may be essential to answering the question of the scope and limitations of central bank interventions.

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