Technical Trading Rule Profitability and Foreign Exchange Intervention *

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Abstract

There is reliable evidence that simple rules used by traders have some predictive value over the future movement of foreign exchange prices. This paper will review some of this evidence and discuss the economic magnitude of this predictability. The profitability of these trading rules will then be analyzed in connection with central bank activity using intervention data from the Federal Reserve. The objective is to find to what extent foreign exchange predictability can be confined to periods of either high or low central bank activity. The results indicate that after removing periods in which the Federal Reserve is active, exchange rate predictability is dramatically reduced.

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1 Introduction

One of the biggest controversies between academic and applied finance is the usefulness of technical trading strategies. These rules, which intend to find patterns in past prices capable of giving some prediction of future price movements are sold by many as easy ways to make money, and scoffed at by many as charlatanism. Since the publication of Fama & Blume (1966) most academics have agreed that the usefulness of these ad hoc forecasting techniques was probably close to zero. Two facts suggest that this conclusion may be a little premature. Recently, Brock *et al.* (1992) showed using a bootstrap methodology that the rules did at least generate statistically significant forecastability. More important to this study, for foreign exchange markets the evidence has been much more suggestive of technical trading rules actually providing useful trading information.[1] This is strengthened by other foreign exchange puzzles related to biases in forward markets, and deviations from uncovered interest parity, summarized in Hodrick (1987).

This paper looks at a possible explanation for some of the predictability found in foreign exchange markets. That is, predictions coming from very simple moving average type trading rules generate returns which are not eliminated by transactions costs and are economically large. From a trader's standpoint the rules used here are extremely primitive, and this paper does not have much to say to traders operating at higher frequencies and using more complicated rules. It is trying to address why such obvious and simple rules "leave so much money on the table."

The explanation that will be explored is whether any of this predictability is related to central bank behavior. Using intervention series available from the Federal Reserve, predictability will be compared during periods with and without intervention. Recent work by Dominguez & Frankel (1993) suggests a stronger impact from sterilized foreign exchange intervention than previously thought which reopens the question about what kind of impact central banks have in modern floating foreign exchange markets.

This paper is less of a direct analysis of intervention on foreign exchange rates, and more of an indirect picture of how it affects one type of agent. In spirit it might be closest to the the studies of Leahy (1989) and Taylor (1982) which try to analyze the profitability of one player, the Federal Reserve. This study takes a different approach by analyzing the profitability of the potential trading of one player, a slightly naive agent, using a pretty common off the shelf trading rule. All of these are related to Friedman's (Friedman (1953)) hypothesis that a currency stabilizing central bank should be making money on foreign exchange intervention. Here, we turn the table and look at the question from the trader's side. Is this trader loosing money when the central bank is in buying low and selling high?

The paper follows in 4 short sections. First, the times series are summarized. The second section reviews the results of previous work, and clearly demonstrates the magnitude of predictability in these series. The next section looks at predictability when the Federal Reserve is not active, and the next section performs some empirical explorations on the dynamics of intervention and foreign exchange movements. The final section concludes.

[1]The earliest tests were in Dooley & Shafer (1983). Also, Sweeney (1986) presents results consistent with some usefulness to technical rules. More recent studies have included Taylor (1992), LeBaron (1991), and Levich & Thomas (1993). The latter two employed bootstrap techniques to further emphasize the magnitude of the forecastability. Other related evidence includes that of Taylor & Allen (1992) which shows the extent to which traders continue to use technical analysis. Also, LeBaron (1992) uses the technical trading rules to build moment conditions for estimation of persistent trend processes.

2 Data Summary

This study uses both weekly and daily foreign exchange series from NatWest Bank provided by DRI. The series represent the London close for the West German Mark (DM) and Japanese Yen (JY) extending from January 2nd, 1979 through, December 31st, 1992. The weekly series use the Wednesday close from this daily series. The interest rate series are 1 week eurorates (London close) for each currency from the London Financial Times and NatWest Bank covering the same period. Summary statistics for the log first differences of the two daily foreign exchange series are given in table 1. This table displays features that are fairly well known for relatively high frequency foreign exchange series. They are close to uncorrelated, not very skewed, and the kurtosis is large.

	DM	JY
Mean*100	0.003	0.012
Std.*100	0.723	0.654
Skew	0.132	0.453
Kurtosis	5.161	5.715
ACF(1)	0.012	0.015
ACF(2)	0.000	0.015
ACF(3)	0.028	0.034
ACF(4)	-0.009	0.005
ACF(5)	0.029	0.037
Bartlett	0.017	0.017

Table 1: *Exchange Rate Summary Statistics*
Summary statistics for the daily foreign exchange series from January 2nd, 1979 through, December 31st, 1992, representing 3544 daily observations.

The most important series used in this study are the Federal Reserve intervention values provided by the Federal Reserve Bank. These series represent the amount of intervention from the Federal Reserve in purchases (or sales) of dollars in relation to the DM or JY.[2] Figure 1 shows the DM/$ exchange rate plotted along with the amount of Federal Reserve purchases(+) or sales(-) of dollars. A few important features are clear from the picture. First, intervention is a very sporadic policy with long periods in which the Federal Reserve remained calm. Second, there appears to be a lot of persistence to the direction of intervention in terms of purchases and sales, but overall intervention has been relatively balanced between the buying and selling sides. Finally, it is difficult to tell whether certain episodes of intervention moved the exchange rate in the desired direction simply by looking at the picture.

Table 2 gives a further summary of these intervention series. It shows that unconditionally the mean intervention levels are close to zero which is consistent with figure 1. However, the table shows that conditional on the intervention occurring the mean absolute value of daily purchases or sales is near 100 million dollars. The most important numbers in table 2 (for this study) are the fraction of days that intervention is going on. For the DM this is 0.118, and for the JY this is 0.056, indicating that Federal Reserve intervention activity only occurs on a small fraction of days. The table also estimates markov transition probabilities from no intervention to intervention $P(I|O)$, and intervention to no intervention $P(O|I)$. These estimates show that the no intervention periods

[2]This study uses the "In Market" series only.

are persistent, however, when intervention is going on it is about equally likely to continue or end on the next day.[3]

	DM	JY
Mean	-2.1	-1.79
Mean Absolute Value	15.1	6.70
Mean(In Market)	-15.6	-30.9
Absolute Mean(In Market)	112	115
Fraction In Market	0.118	0.056
$P(I\|O)$	0.065	0.029
$P(O\|I)$	0.416	0.468

Table 2: *Intervention Summary Statistics*
Units are either in millions of U.S. dollars, or fractions and probabilities.

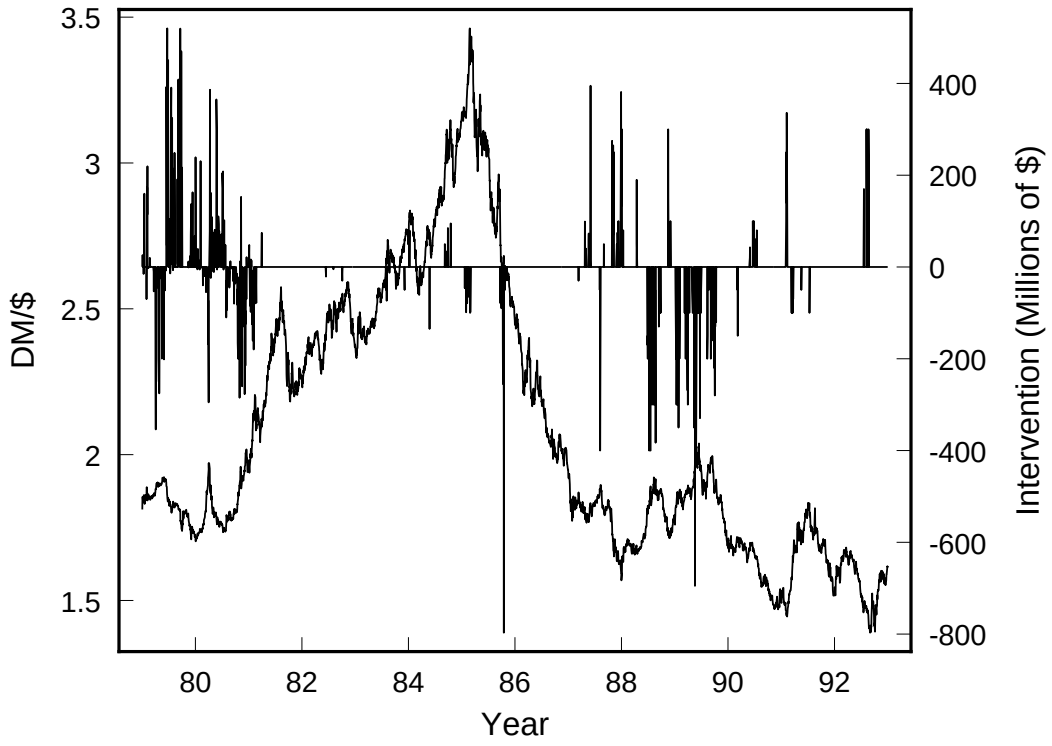

Figure 1: *DM/$ Exchange Rate with Federal Reserve Intervention*

[3]This crude markov analysis does not take into account that intervention might be generally active during a several week period, but there may be some days during this time that intervention is not active.

3 Trading Rule Evidence

This section repeats earlier statistical evidence on the forecasting properties of a simple technical trading rule. Many of these results are given in more detail in LeBaron (1991). Forecasts will be examined over 1 day and 1 week horizons. The rule used compares the current price to a moving average of past prices. Let P_t be the \$/DM exchange rate at time t. Define ma_t as

$$ma_t = \frac{1}{M} \sum_{i=0}^{M-1} P_{t-i},$$

where M is the length of the moving average. For the daily data $M = 150$ and for weekly $M = 30$.[4] Define a buy or sell signal s_t as

$$s_t = \begin{cases} 1 & \text{if } P_t \geq ma_t \\ -1 & \text{if } P_t < ma_t \end{cases} .$$

This is an extremely trivial type of trading rule, but the strategy here is to look at the simplest versions of trading rules following common practices in use.

The application of this rule will be simplified to make some of the analysis clearer. Let $p_t = \log(P_t)$, and r_t, r_t^* be the domestic and foreign rates of interest respectively. Dynamic returns from the strategy will be defined as,

$$x_t = s_t(p_{t+1} - p_t - (\log(1 + r_t) - \log(1 + r_t^*))).$$

The value on the right side is simply the log difference on the exchange rate corrected for the interest differential. This return is then multiplied by $+1$ or -1 depending on the buy or sell signal. This corresponds roughly to a zero cost strategy of borrowing in one currency to go long in the other.[5] For completeness the strategy will also be implemented without the interest rate differential,

$$x_t = s_t(p_{t+1} - p_t).$$

Table 3 examines the these dynamic trading returns for both daily and weekly exchange rates. The t-statistics in the table test whether the mean returns are zero. It is clear from the table that the means from the dynamic strategies are statistically different from zero at any reasonable significance level. It also appears that adjusting for the interest differentials and changing from daily to weekly returns does not affect the results greatly. These t-tests may not be the proper way to test for significance because of the deviations from normality, so a second experiment is performed. A sample of bootstrapped random walk price series is generated using the log price differences of the original series. These differences are scrambled with replacement and a new series is built. Then the returns from the dynamic strategies, implemented on these simulated random walk series, are compared to the original. The column labeled P-Value presents the fraction of simulations generating a dynamic return larger than the original. The column agrees with the

[4] Trading rule profitability is not overly sensitive to the the actual length of the moving average. See LeBaron (1991) for some evidence on this. Also, these moving average lengths are very commonly used by traders.

[5] The interest rates used are 1 week Eurorates. This covers the correct return span for the weekly returns. For the daily returns it is only an approximation.

Series	N	Mean	Std.	t-ratio	Sharpe	Trade Fraction	P-Value
DM Daily: No Interest	3394	0.031	0.73	2.44	0.666	0.027	0.014
DM Daily: Interest	3394	0.033	0.73	2.62	0.718	0.027	0.004
DM Weekly: No Interest	694	0.149	1.61	2.44	0.667	0.065	0.004
DM Weekly: Interest	694	0.161	1.61	2.62	0.717	0.065	0.002
JY Daily: No Interest	3394	0.036	0.66	3.19	0.872	0.017	0.002
JY Daily: Interest	3394	0.034	0.66	3.50	0.958	0.017	0.000
JY Weekly: No Interest	694	0.167	1.46	3.02	0.826	0.049	0.004
JY Weekly: Interest	694	0.185	1.47	3.32	0.909	0.049	0.000

Table 3: *Trading Rule Tests*

Tests for significance of 1 period trading rule returns. N is the number of returns tests, and mean is their mean value. T-Ratio is a t-test for the mean 1 period return. Sharpe is the estimated 1 year Sharpe ratio. Trade Fraction is the fraction of days on which a trade takes place. P-value is the fraction of 500 simulated random walks generating a return as large as that in the actual data.

t-tests in indicating the significance of these means. The column labeled Sharpe estimates the Sharpe ratio over a one year horizon. This is approximated as,

$$\sqrt{N}\frac{E(r)}{\sigma_r}$$

where σ_r is the standard deviation over the short horizon. N is the number of small periods in a one year period. This approximation is correct if the dynamic returns were independent over time. [6] The values in the table show that when ignoring transactions costs Sharpe ratios in the range of $0.6 - 0.9$ are attained. This compares with Sharpe ratios of around 0.3 or 0.4 for buy and hold strategies on aggregate U.S. stock portfolios.[7] Finally, the column labeled "Trade Fraction" shows the fraction of days on which an actual trade took place, or in other words the fraction of times the strategy had to switch currencies. The low numbers here foreshadow the relatively small impact from transactions costs that will be shown later.

	Zero Cost Returns				Sharpe Ratios for Varying Costs			
Series	Mean	Std.	Max	Min	0 %	0.1 %	0.2 %	0.5 %
DM Daily	7.00	10.16	33.05	-22.46	0.689	0.626	0.443	0.155
DM Weekly	7.91	12.34	36.89	-27.15	0.641	0.599	0.532	0.327
JY Daily	9.73	9.41	42.97	-6.35	1.033	0.981	0.864	0.670
JY Weekly	10.02	10.61	44.03	-9.22	0.945	0.903	0.819	0.694

Table 4: *1 Year Return Experiments*

Max, min and simulated Sharpe ratios for varying transactions costs. All values are for 1 year horizon interest rate adjusted returns.

[6] The Sharpe ratios used here are for continuously compounded expected returns. Sharpe ratios for actual returns will be larger due to Jensen's inequality.

[7] See Hodrick (1987) or LeBaron (1991) for some further references and examples of Sharpe ratios on aggregate portfolios. For connections between Sharpe ratios to variance bound tests and more information on conditional Sharpe ratios for other portfolios see Bekaert & Hodrick (1992).

To better asses the economic significance of this predictability table 4 presents some simulation estimates of risk/return tradeoffs. One year periods are chosen at random from the entire sample and the returns over that period are summed. After 500 of these 1 year subperiods have been chosen the mean and standard deviation are estimated and used to estimate Sharpe ratios. Different levels of transactions costs are simulated by subtracting the costs every time a trade is made (change in sign in s_t). The table is in general agreement with the previous one for the zero cost Sharpe ratios. It also tells us that implementing the rules with a 0.1% transaction cost does not greatly reduce the Sharpe ratios which are still in the range of $0.6 - 0.9$.[8] The table does show an eventual drop off in the Sharpe ratio as the costs are increased. It is also clear that for the DM there are some 1 year periods in which the rule performs badly with returns less than -20 percent.

In summary, this section has demonstrated significant forecastability from a simple moving average trading rule for two foreign exchange series. The results are unquestionably large statistically. Since they generate large Sharpe ratios, and their infrequent trading causes the returns to persist even when transactions costs are considered these returns appear to be economically significant as well.[9] Another curious feature that comes out of the first two tables is that it appears that considering interest rates does not make much of a difference for these results. It is a little disturbing that interest rates have such a small impact on the results, but it is consistent with deviations from uncovered parity which suggest that in the short run exchange rates movements do not correspond closely to interest rate differentials. Another interesting fact that appears is that changing from daily to weekly frequency also does not make much of a difference. This is somewhat curious since one would expect that giving the rule the chance to trade at the daily frequency would allow it greater opportunities. It is suggestive that what the rule picks up is a relatively long term phenomenon.

4 Removing Intervention Periods

This section looks at one possible explanation for the previously demonstrated puzzle in foreign exchange series. Is it possible that Federal Reserve intervention might be the cause for some of the predictability seen in some of these series. Some of the previous tests are repeated with the foreign exchange intervention periods removed. Figure 2 presents a time series of both the Federal Reserve intervention series along with a rolling estimate of 1-year Sharpe ratios for the interest adjusted daily DM returns. It is clear that the rule returns change over time, but the connection between the rules and intervention is not obvious from the figure.

This type of experiment is made more precise in table 5 where the experiments from table 3 are repeated with intervention days removed. We examine only the dynamic returns from t to $t+1$ conditioned on the intervention series being zero on $t+1$. For weekly series an intervention period is defined as a week in which intervention occurred on at least 1 day. The results suggest a dramatic change when intervention periods are removed. For the DM series all of the t-statistics are not significantly different from zero, and the Sharpe ratios are close to 0.1. For the JY the results are not as dramatic, but mean returns have gone into the range of only being marginally significant

[8] This transaction cost is considered a reasonable upper bound for what large traders face in foreign exchange markets.

[9] The judgement of economic significance would require more detailed testing of a specific model. For the moment all that can really be concluded is that the numbers appear "troublingly large".

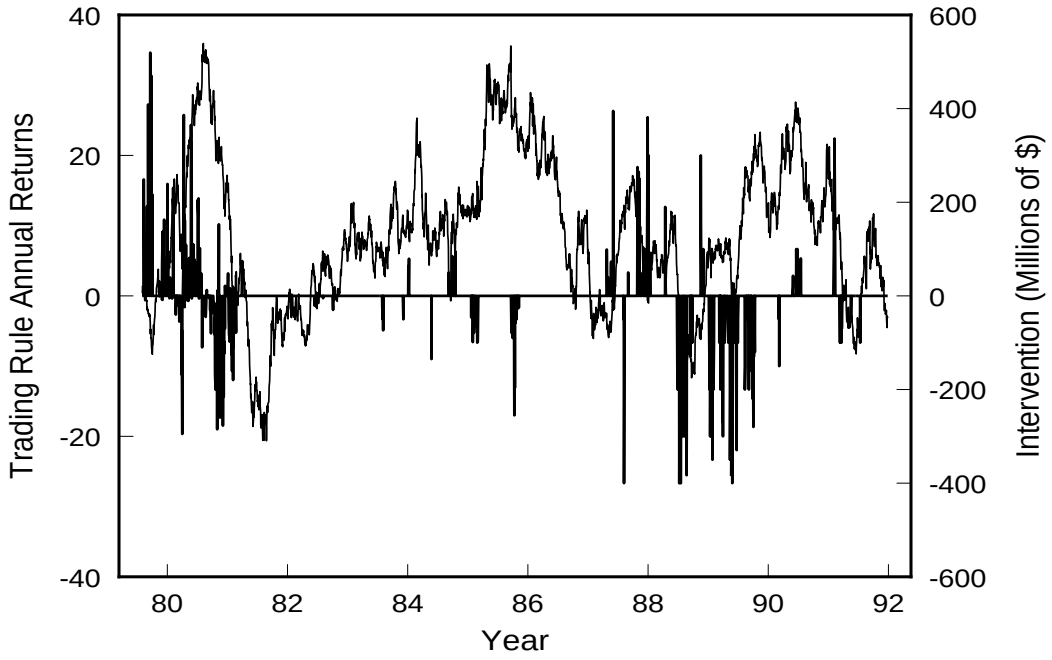

Figure 2: *Rolling 1 Year Returns and Federal Reserve Intervention for the DM*

for two of the series, and showing simulated p-values of 0.146 and 0.198 for the other two. Not a very dramatic rejection of the random walk at all.

These results are very strong in suggesting that something different is going on when the Federal Reserve is active in terms of foreign exchange predictability. Before concluding that this is the overall cause of what is going on some further experiments will be performed. First, from figure 2 it is clear that there are some long periods in which the rule works and some in which it doesn't work very well. Also, the figure shows intervention to be somewhat persistent. Using the markov process from table 2 simulated intervention series are generated, simulating only in or out of the market, not magnitudes or signs. This simulated series is aligned with the actual returns series, and the returns without intervention are estimated. Table 6 shows the results removing this stochastic

Series	N	Mean	Std.	t-ratio	Sharpe	Trade Fraction	P-Value
DM Daily: No Interest	2992	0.006	0.706	0.502	0.146	0.027	0.178
DM Daily: Interest	2992	0.008	0.707	0.635	0.185	0.027	0.202
DM Weekly: No Interest	519	0.027	1.604	0.385	0.122	0.073	0.344
DM Weekly: Interest	519	0.0351	1.606	0.498	0.158	0.073	0.218
JY Daily: No Interest	3205	0.0135	0.626	1.220	0.344	0.017	0.146
JY Daily: Interest	3205	0.017	0.627	1.543	0.434	0.017	0.080
JY Weekly: No Interest	606	0.062	1.368	1.112	0.326	0.054	0.198
JY Weekly: Interest	606	0.080	1.374	1.441	0.422	0.054	0.106

Table 5: *Trading Rule Statistical Tests: No Intervention*

	Mean	Mean No Int	Markov Mean	Markov Variance	P-value
DM Daily	0.0330	0.008	0.033	0.005	0.002
DM Weekly	0.161	0.035	0.156	0.038	0.004
JY Daily	0.039	0.017	0.040	0.003	0.002
JY Weekly	0.185	0.080	0.186	0.022	0.002

Table 6: *Markov Comparisons*
Trading returns are estimated removing a simulated intervention series. Mean and Mean No Int. repeat the earlier mean returns with and without intervention periods. Markov mean is the mean from the 500 iterations of the simulated series. The P-value shows the fraction of the simulation runs giving a mean return as large as the No Intervention series from the original intervention data.

process. The table repeats the mean returns from the original series with and without intervention as well as the mean from 500 simulations removing the simulated intervention series. In each case only the results including interest adjustment are reported. The mean and variance from these simulations show the distribution to be much closer to that from the original series than the no intervention series. Finally, the p-value records the fraction of simulations giving a return lower than the no intervention series. For all the series this is close to zero. These results suggest that there really is something different about the intervention series, and it is unlikely that randomly removing points would give the results in table 5.

A second, and more direct test is given in table 7. Here, intervention periods are removed for the *other currency*. In other words, the JY intervention days are removed from the DM series, and the DM intervention days are removed from the JY series. The purpose of this is to test whether there is something important about the direct intervention numbers or whether all intervention happens to occur in periods that are dominated by trending currencies. The table repeats the earlier results of table 5 for two daily series. The strong reduction in significance and Sharpe ratios seen before is clearly not present in these results. The significance of the mean returns is still clearly indicated by the small P-Values close to 1 percent.

Series	N	Mean	Std.	t-ratio	Sharpe	Trade Fraction	P-Value
DM Daily: Interest	3205	0.022	0.721	1.756	0.494	0.027	0.012
JY Daily: Interest	2992	0.026	0.626	2.296	0.669	0.017	0.012

Table 7: *Trading Rule Statistical Tests: Reversed Intervention Removed*
Intervention periods are removed for the other currency. DM intervention periods are removed from the Yen series, and Yen intervention periods are removed from the DM series.

The results in this section can be summarized graphically in figure 3. This picture clearly shows the dramatic reduction in Sharpe ratios for the trading rules for each of the series. While conclusions about causality cannot be made these results are very suggestive that Federal Reserve activity has something to do with the observed predictability.

5 Further Explorations

This section presents some early explorations into the dynamics of intervention periods and rule predictability to get some idea of what the mechanism is that is driving these results. Table 8 shows

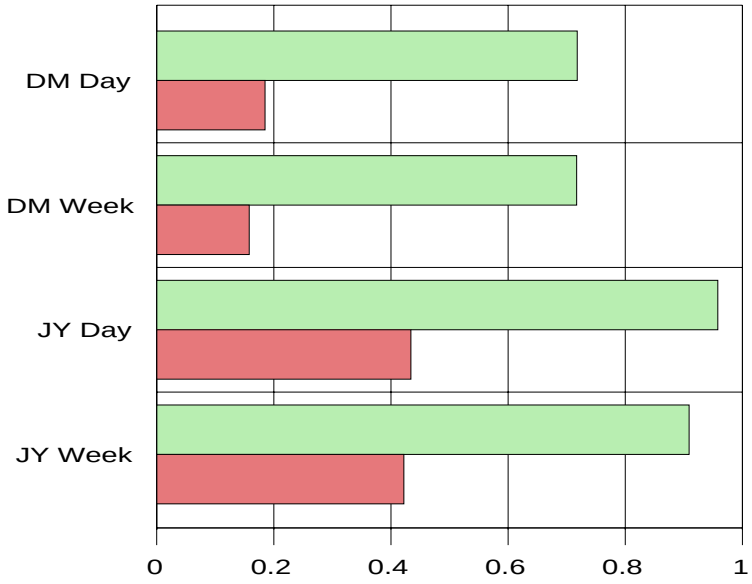

Figure 3: *Sharpe Ratios: Interest Rate adjusted series*

estimates of the probability of equal signs of s_t, I_{t+1}, and x_{t+1}, where I_t is the intervention at time t. All these results are conditioned on I_{t+1} being nonzero. The first column shows the estimated probability of equal signs between the trading rule signal and next period's intervention. The values for both the DM and JY are very large, close to 80 percent. This is clearly significantly different from independence. This connection shows that when the rule indicates to buy DM, the Federal Reserve is likely to be trying to support the dollar next period. This is consistent with the rule working because of a "leaning against the wind" policy. The second column shows the connection between the signal sign and the actual return sign next period. This connection is probably clear from some of the early tables. However, it is interesting that the sign connection is so dramatically large. Finally, the table presents the sign connection between the intervention and the return. It is again consistent with some leaning against the wind.[10]

Finally, it is interesting to see if technical trading rules can actually predict intervention periods. This is interesting because it suggests a process where the central bank feels the exchange rate has gotten too far out of some reasonable range and decides to intervene to bring it back. The sign connections above suggest that the bank is working to move the exchange in this way (against the trend). Figures 4 and 5 show the probability of daily intervention on day $t+1$ as a function of the price/moving average ratio at time t. The unconditional probability of intervention is 0.056 for the Yen and 0.118 for the DM. The conditional probabilities are estimated using a moving band which is set to contain 20% of the points in each range. The band is moved from low to high in the p/ma range, estimating the probability of future intervention for each. The confidence bands are 95% confidence bands for the binomial test using the maximum probability of intervention in each case.[11] [12] For the Yen the pattern is consistent with the story of interventions occurring when the

[10]For this last experiment the simultaneity bias may be severe in that the Federal Reserve intervention may be induced by a desire to reverse the direction of the exchange rate.

[11]The asymptotic variance is $p(1-p)/N$ for this case.

[12]This is basically a uniform kernel estimate with the bandwidth allowed to change as it moves through the data.

exchange rate "gets out of line" by the technical rule's standard. Intervention near the midrange is very unlikely with almost all intervention occurring when the exchange rate is well above or below some norm. For the DM the results are quite different. There is indication of large amounts of intervention for low p/ma, but there appears to be little evidence for lots of intervention for higher p/ma. These results show an unusual difference between intervention policies on the Yen and the DM which should be further studied.

Series	N	Signal - Intervention	Signal - Return	Intervention - Return
DM Daily	402	0.806	0.642	0.694
		(0.025)	(0.025)	(0.025)
JY Daily	189	0.868	0.661	0.630
		(0.036)	(0.026)	(0.036)

Table 8: *Sign Comparisons*
Numbers in parenthesis are standard errors under sign independence.

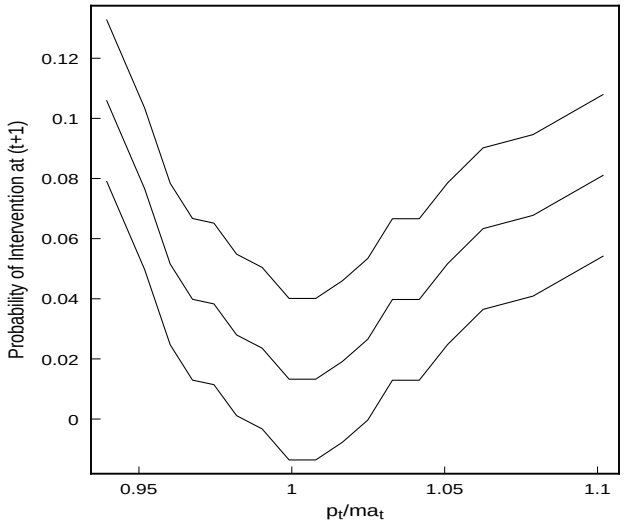

Figure 4: *Probability of Fed. Intervention: Yen*

6 Conclusions

The fact that simple trading rules produce unusually large profits in foreign exchange series presents a series challenge to efficient market hypothesis. Further, the magnitude of these returns and their resiliency to the addition of transactions costs, makes difficult to imagine a representative agent rational expectations model capable of explaining these returns.

Foreign exchange markets differ from most other major asset markets in that there are several major players around whose objectives may differ greatly from maximizing economic agents. The results in this paper show that this predictability puzzle is greatly reduced if not eliminated when

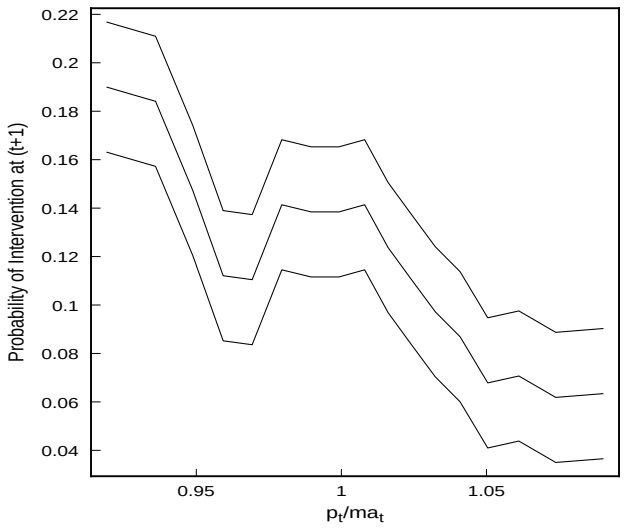

Figure 5: *Probability of Fed. Intervention: DM*

days in which the Federal Reserve was actively intervening are eliminated. There is still a serious simultaneity problem running through these results which makes strong policy recommendations difficult. It is not clear that the Federal Reserve *causes* inefficiencies in the foreign exchange market, or just happens to be around when they occur. These results are still far from implicating the Federal Reserve in this puzzle, but they may make those whose biases are toward efficient markets a little more comfortable.

If the Federal Reserve is transferring money to traders it may be worthwhile in that it has other variables in its objective function such as overall stability. If the Federal Reserve can stop a potential trade war by purchasing foreign exchange at the right time then the trade off may be good for United States. It is clear that the costs and consequences of foreign exchange need to be further analyzed. Also, more direct connections to some other work need to be made. The fact that Leahy (1989) finds intervention profitable from the central bank standpoint is an interesting puzzle in connection with the results here.

These results can only be viewed as preliminary and much more work needs to be done. Further analysis of the dynamics of intervention and possible connections with interest rate movements is necessary. Also, replacement of the actual intervention series with published news reports should reveal evidence on how much traders could have used actual available information to capitalize on potential market inefficiencies around intervention time periods.

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