

Foreign Exchange Reversals in New York Time

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ABSTRACT

We document the performance of a simple reversal strategy applied to hourly foreign exchange rates. The trading rule shows improved performance for dollar exchange rate pairs, but this improvement is most dramatic during the hours that correspond to New York trading time.

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We are grateful to EBS for providing the data sets used in this analysis.

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1. Introduction

The performance of technical trading strategies in foreign exchange markets continues to be an interesting question. Evidence is still strong that traders in these markets rely on technical signals.¹ Extensive evidence shows that technical rules provide both statistical and economically significant returns using strategies built at relatively low frequencies from daily or weekly data. Recent research shows that some of these strategies may not be working as well as in the past, and the profitability has been squeezed down to higher frequencies.² This paper looks at the performance of a simple strategy built from hourly data, and finds that it can generate significant returns subject to two caveats. First, it appears the strategy works only during periods in which the target currency is most actively traded. Second, there is weak evidence that this strategy may also be diminishing in profitability over time.

The creation of long high quality, high frequency time series has been essential to the analysis of foreign exchange dynamics. Early work by the team at Olsen and Associates built and studied a large high frequency foreign exchange data set based on Reuters quote series.³ Unfortunately, these quotes were not firm quotes, and could be viewed more as advertisements put out by traders, and less as firm tradeable prices. The appearance of electronic trading platforms such as EBS and Reuters have made data sets available which allow for more detailed testing of trading strategies.

Generally, tradeable predictability in high frequency foreign exchange series is difficult to find, but this paper documents a very simple pattern that is easily seen using very simple strategies. Curiously, the pattern is not present unconditionally over the trading day, but only appears during hours when the New York market is open. In this paper we will document this pattern, show its economic and statistical significance, and also document that it is reliable over time, but is almost completely nonexistent during periods in which the New York markets are closed.

¹ See Menkhoff and Taylor(2007) for a recent survey of trader attitudes toward technical analysis.

² Schulmeister (2007) and Neely et al. (2006) report that returns are technical trading returns are diminishing in lower frequency data, and shifting to higher frequency trading patterns. Dempster and Romahi (2002) report results of a high frequency strategy.

³ See Dacorogna et al.(2001) for a good summary of this data set.

Two recent papers examine related patterns. Hashimoto et al.(2008) look at the persistence in the tick by tick EBS data and find strong evidence that it is not a random walk. The dependence structure is complicated in that depending on the type of series used, there is evidence for either reversals or persistence. Rinaldo (2007) shows that there are interesting time of day effects in certain exchange rates when one of an exchange rate pair's market is open. Domestic currencies tend to appreciate during foreign working hours.

The cause for the appearance of predictability at this horizon, and why it appears to be time dependent is interesting. Given that the EBS system is not an open book system, it is possible that technical indicators are a proxy for market depth information contained in the book. In this way our results could be related to evidence connecting support/resistance levels to order book depths as in Kavajecz and Odders-White(2004), or evidence on the predictability of equity returns from information in the order book as in Mizrach(2008). Another possibility is that technical trading profits represent a kind of payment for order flow, and during the active trading hours order flow contains more trades from financial customers that might carry useful information.⁴

Section 2 describes the simple trading strategies that will be used in the paper. Section 3 gives a brief introduction to our data set and the EBS trading platform that it represents, along with some summary statistics on our foreign exchange series. Section 4 describes our results on a simple reversal strategy, and section 5 concludes.

2. Trading strategies

Our research methodology follows other papers such as (Brock, Lakonishok, LeBaron, 1992) which try to keep the set of strategies used very simple. Selecting simple strategies makes the predictability more compelling and minimizes inevitable data snooping issues. Here we will concentrate on only one general family of technical rules based on a moving average of past prices.

⁴ See Osler(2008) for discussion of evidence supporting this conjecture.

A moving average of past prices is formed by taking,

$$(1.1) \quad p_t^m = \frac{1}{m} \sum_{i=0}^{m-1} p_{t-i}$$

where the prices are sampled every hour. Standard trend following strategies would generate a buy signal when $p_t > p_t^m$, but we will concentrate on reversal strategies which generate the reverse of this. A position in the currency is maintained until the price again crosses the moving average at which point the position will be changed to the other currency. We adjust for transaction costs by purchasing at the appropriate ask, and selling at the bid. We also incur a small percentage cost which corresponds to \$15 per \$1,000,000 order. As a no transaction cost reference we use the average of the bid and ask prices to execute both buy and sell trades. We do not adjust for interest rates, since most positions are only held for very short intraday periods.

All these strategies are described by a single parameter, m . Time will be in units of hours, and in most cases m will vary from 4 to 12 hours in length. This strategy is therefore based on very short-term movements in these series.

3. The EBS data set

The high frequency datasets used in this study are all derived from the EBS foreign exchange trading platform. EBS and Reuters-D3000 represent the two major electronic trading platforms for foreign exchange. In recent years most foreign exchange trading activity has shifted to these electronic platforms, so these prices represent a crucial benchmark of a market that in earlier times traded in a more disaggregated fashion between dealers.⁵

The data set that we will use is known as the “price data set” since it provides second by second price information, but no information on trading volume. The data set contains a history of the best bid and ask prices over time. The quotes are displayed to all traders on the system, and are firm quotes in that they can be hit at anytime by traders on the system. Traders may either hit a

⁵ See Ito and Hashimoto(2006) for summary information on these series.

current quote, or place a limit order in the system. Limit orders are not displayed. The data includes two types of records. Quote records record the quotes at the best bid and ask over a 1 second time slice. Deal records report trading activity over the last time slice when a trade has occurred. They report whether the deal occurred at the bid or ask. When multiple deals take place in the 1 second time slice, only the highest paid price, or lowest selling price is recorded in the record.

For all our analysis we will be looking at frequencies that are significantly lower than our data set provides. Specifically, we will sample the series at hourly intervals. We will look at 3 different currency pairs, the Japanese Yen / US dollar (JPY/USD), the Swiss franc/ US dollar (CHF/USD), and the US dollar/Euro (USD/EUR). Our time period covers the years from December 28, 2003 to March 3, 2006. Table 1 reports summary statistics for returns derived from the bid/ask midpoint price sampled at each hour. They repeat the usual set of patterns for high frequency foreign exchange data. Skewness appears relatively small, while the kurtosis is very large. The return distributions are clearly “fat tailed” with too many large events relative to a normal distribution. Simple autocorrelations are reported in table 2. These are all close to zero, showing no interesting reversal or persistence patterns that would be picked up by standard time series models.

Figures 1 to 3 display some simple time patterns over the day. Statistics are recorded at each hour displaying GMT on the x-axis. Figure 1 displays the sample mean spreads for 3 currency pairs. For two pairs (USD/JPY and EUR/USD) the spreads show only a small increase around the overnight GMT hours of 20-24 GMT. The less liquid currency pair, (USD/CHF) shows a much stronger seasonal pattern with spreads widening in the overnight hours, displaying a U-shape pattern corresponding to European and NY trading activity.

Figure 2 reports the level of volatility in the series as given by the hourly return standard deviation. This value shows a strong daily pattern with the most price volatility at midday. There is also some indication in all three pairs for increased volatility at the beginning of the day around 6-8 GMT. This might be an early opening effect on the European markets. Figure 3 repeats the figure for the number of trades that are estimated using the number of deal records in

the series. The three pairs show a daily seasonality which is similar to that reported for volatility. Over the day, volatility and trading activity are contemporaneously correlated. This positive connection is common in many markets. Also, it is interesting to note that there is no strong u-shape pattern to trading activity and spreads as in equity markets.⁶

4. Returns to reversal strategies

Table 3 gives an initial picture of the critical results of the paper. It reports the performance of the simple reversal strategy executed using hourly data during the core hours of the New York market, 10AM – 3PM, Eastern Standard Time. The strategies are reported for the entire 3 year period as well as each of the 3 one year subsamples.

The top panel of table 3 shows the results for the Japanese Yen, US dollar pair. For the entire sample the strategy reports annual returns near 15 percent, net returns after transactions costs of near 10 percent, and Sharpe ratios well above 1. The reported t-statistics are all significant. This result is robust across moving average levels ranging from 4 to 12 hours. However, it is starting to weaken at the 12 hour MA length. The strategy performs equally well during the individual years of 2003 and 2004, but takes a sharp drop off in year 2005. Here, none of the t-statistics are significant, and the net returns drop to near 5 percent. The Sharpe ratios are generally much lower in this year too, but a few of the short MA ranges still yield Sharpe ratios greater than 0.60.

The results for the Swiss Franc / US dollar pair are equally strong in the entire sample. All t-statistics are significant at any reasonable level of significance while the Sharpe ratios are all between 1.4 and 2.46. The net returns are also larger than 5 percent except for the MA lengths of 4 and 6.

The final panel in table 3 presents the results for the US dollar/Euro pair. For the full sample the strategy returns are large with Sharpe ratios well above 1 for most strategies, and annualized returns net of transaction costs near 10 percent. All strategies report t-statistics which are

⁶ See Osler (2008) for a description and references. This is a key distinguishing feature of high frequency FX data.

statistically significant. The pattern across different years is a little different from the other currency pairs. The early data in 2003 shows the weakest evidence for profitability, and the returns steadily increase with the largest values coming in the subsample ending in March 2006.

Table 4 applies these strategies to a full range on the day. The New York trading hours are increased to all 24 hours except for 21-24 GMT. Eliminating the hours of 21-24 GMT is done since liquidity is low during this period when many markets are closed. In many cases the rules still show interesting profitability before transactions costs, but after the strategies are adjusted for spreads there is little interesting performance. For all 3 currencies, and most strategies, the net returns are negative. There is some small net profitability for the USD/EUR pair in 2004, but these returns are not large across the strategy set. An example of the drop off in strategies moving from the shorter time range to the full day is given in the USD/EUR pair. Consider the 4 hour reversal strategy. In this case the net return for the entire sample falls from 12.84 percent to -8.16 percent. There is also a fall in returns before transactions costs that can be seen in the drop in the Sharpe ratio from 1.87 to 1.37. The general results of table 4 show that there is no interesting tradeable predictability when the rules are applied to the entire day's prices.

Table 5 provides summary statistics for the daily returns accounting for whether they are long or short with a simple sign change. The mean daily returns are all positive. The spread between the maximum and minimum return is also quite large at about 5 percent, or 20 standard deviations. This is corroborated by the large excess kurtosis for all the strategies. In general the skewness levels are all positive, so a risk story based on extreme losses is not likely. Finally, estimated kurtosis does not change much from the unconditional returns, indicating that the dynamic strategy is not impacting the tail behavior of the returns.

Table 6 splits the strategies into buy and sell periods. From the standpoint of the means and standard deviations there is little difference between buy or sell signals. For all three currency pairs they appear to generate significantly positive returns. There is a small exception in that the USD/EUR pair generates significant positive returns only for the shorter horizon MA lengths (4-6). There is also evidence that the robust measure of sign patterns is larger on the buy side, than on the sell side.

Figure 4 displays the distribution of the hourly returns from the strategies in the different currencies. These are provided as a check to see if there are any odd features that might not be picked up by the standard summary statistics. The graphs are consistent with the earlier tables. There is little evidence for the results being driven by a few data points. The general central tendency of the distributions is to the right of zero. Also, the density clearly reflects the excess kurtosis that would be present in any high frequency foreign exchange series. Further robustness checks will be performed in the next few tables.

Up to this point, the strategies have been tested in an environment where the trader makes trades at the exact time the signal appears. This requirement may be unrealistic, and it is important to test the strategies with a small amount of time lag on trader actions. In table 7 we delay the implementation of a signal by 15 minutes. If a buy signal is received at 11:00AM, then the buy position will not be taken until 11:15AM. The returns drop off a little, but the basic properties of table 3 remain unchanged. For example, the Sharpe ratio for the JPY/USD at MA length of 6 hours goes from 1.64 to 1.25. The net returns fall from 10.16% to 6.24%. For the entire sample, all currency pairs maintain positive net returns, significant t-statistics, and Sharpe ratios which are mostly greater than 1. Analyzing the currency pairs for the individual years does yield weaker evidence in favor of the strategies. For example, for the CHF/USD the results are only consistently significant in 2003. Also, the USD/EUR pair in 2003 is generally not significant.

Given the feature that there are many extreme changes in high frequency foreign exchange series, it is important to further test the robustness of our results by dropping out the extreme values from our strategy returns. Table 8 performs a test of eliminating the largest and smallest returns. Returns at first the 2 percent, and then the 5 percent levels are removed from our trading strategy returns. Removing the 2 percent tail reduces the gross returns by a small amount, but there are no significant changes. Removing the 5 percent tails does have a bigger impact, but the returns are still positive for all our strategies. This is strong confirming evidence that a few outliers do not drive the results.

At this point we have used on a simple t-test to report statistical significance. This relies on the central limit theorem holding for the small sample estimates of mean returns from our strategies. Given the large kurtosis in the underlying series the CLT might either not hold, or convergence might be very slow. In these cases standard student-t or normal tables will not give a valid test of significance. To overcome this problem we use a bootstrap test in table 9 to generate an empirical test for our strategies. The hourly exchange rates are assumed to follow a geometric random walk with changes driven by the actual return distributions. Hourly returns are drawn with replacement using the mid-point prices as the price benchmark. These new returns are used to draw a new mid-point price series. The bid ask spread is estimated at each hour, and this is then drawn with replacement, and applied to the bootstrapped price series to generate simulated bid and ask prices. Therefore, this bootstrap is both based on assumptions of IID returns, which are independent of spreads, and of calendar time.

Table 9 reports bootstrapped p-values for all of the reversal strategies during the New York time window. The table shows a dramatic rejection of the random walk with most p-values of about zero. There are only two strategies for the JPY/USD pair in 2005 which generates relatively large p-values. It should be noted that even in cases where the t-statistic is quite small these p-values remain large. This could be due to problems in estimating the variance in the t-test statistic. Given that fourth moments are very large in these series, the estimated variance used in the t-test will be quite unstable, and convergence of the test statistic to normality may be quite slow.

Table 10 applies the strategy to prices taken from the deal records in the EBS dataset. These represent prices at which deals actually took place. When multiple deals take place in the one second time slice, only the highest paid price, or lowest selling price is recorded in the record. Our results do not change significantly in moving from the quote records (table 3) to the deal records in table 10. We still show significant predictability over the full sample, and for the subsamples our Sharpe ratios are generally between 1 and 2. Using the deal records, sampled hourly, appears to have little impact on our results.

5. Conclusions

This paper documents the returns to a simple reversal strategy applied to a high quality, high frequency foreign exchange time series. The strategy is shown to be economically and statistically significant subject to the restriction that the strategy is implemented during hours in which the New York market is open for our currency pairs including the U.S. dollar. This restriction should not greatly impact the implementation of a given strategy since these are the periods in which these exchange rates would be most actively traded, and liquidity on these markets should be good.

Our result is puzzling in that it would seem that returns to simple reversal strategies should appear when market liquidity and order depth is low. In these markets the price can move a long way from its current equilibrium value before getting pushed back. We find the reverse since the strategies pay off when one part of the currency pair is actively traded. It is possible that this payoff to a technical trading strategy is a combination of some recent empirical evidence in the microstructure literature. First, information in the order book has predictive capability over future movements in prices (Mizrach, 2008). Second, technical trading signals can give information about the structure of the current order book (Kavajecz and Odders-White, 2004). It is possible that on the closed book system that EBS uses, that the technical signals are a proxy for order book information, and liquidity information. This would make the results here consistent with evidence showing that order books can contain predictive power for future price changes.

The properties of the dynamic strategies were tested in detail for transaction costs, robustness, and possible explanations based on risk. In the first case we found that returns to the strategies exceeded reasonable estimates of trading costs based on spreads in the FX series. Second, we found that the returns are robust both to implementing positions with a lag from the signal time period, and to dropping some of the large outlier returns. Finally, in terms of risk, there appear to be few immediate explanations. The returns report large Sharpe ratios that are favorable when compared to other securities, or dynamic strategies. The returns are strongly fat tailed, as are the underlying high frequency FX series, so the question of some sensitivity to tail risk does remain

as a possible explanation. However, analyzing aggregated dynamic returns will reduce the tail risk effect.

We have looked at the results for these strategies over several years of high frequency data, and we see some evidence that the strategy performance might be getting weaker over time. However, this evidence is not consistent across our currency pairs. For one our pairs, the USD/EUR, the returns to the dynamic strategies appear to be increasing over time. It will probably require the addition of several more years of data to make any strong conclusions on the time patterns and stability of these results.

We have documented a relatively robust and stable trading strategy operating at the intraday frequency in several FX markets using a high quality, high frequency FX time series. We find that a simple reversal strategy might be effective in several foreign exchange markets, and that this strategy's returns are large enough to overcome transactions costs reported in these series. However, implementation of the strategy appears to only work effectively when it is implemented in periods in which the New York market is open. We find this an interesting, and somewhat puzzling result.

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Table 1 Risk and return characteristics at hourly frequency during the period of December 28, 2003 to March 3, 2006

	Mean	Std	Skewness	Kurtosis
JPY/USD	-0.0002%	0.1169%	-0.227	15.594
CHF/USD	-0.0004%	0.1503%	-0.057	31.990
USD/EUR	0.0007%	0.1244%	-0.098	13.149

Table 2 Autocorrelation at hourly frequency during the period of December 28, 2003 to March 3, 2006

lag	JPY/USD	CHF/USD	USD/EUR
1	-0.010	-0.048	0.007
2	-0.007	-0.003	-0.008
3	0.000	0.007	0.009
4	-0.010	0.001	0.002
5	-0.005	-0.021	-0.008
6	-0.004	-0.003	-0.001
7	0.004	0.008	0.011
8	-0.005	0.000	-0.002
9	-0.005	0.015	0.013
10	0.002	0.000	0.005

Table 5 Risk and return characteristics at hourly frequency of the simple reversal strategy returns during the New York trading hours 10AM – 3PM from December 28, 2003 to March 3, 2006

Currency	MA length	mean	median	min	max	std	skewness	kurtosis
JPY/USD	4	0.0111%	0.0048%	-1.78%	2.56%	0.24%	0.94	19.71
	5	0.0109%	0.0084%	-2.27%	2.56%	0.24%	0.30	19.83
	6	0.0113%	0.0083%	-2.27%	2.56%	0.24%	0.33	19.83
	7	0.0108%	0.0047%	-2.27%	2.56%	0.24%	0.41	19.81
	8	0.0109%	0.0047%	-2.27%	2.56%	0.24%	0.21	19.85
	9	0.0101%	0.0047%	-2.27%	2.56%	0.24%	0.15	19.85
	10	0.0090%	0.0048%	-2.27%	2.56%	0.24%	-0.02	19.87
	11	0.0083%	0.0047%	-2.27%	2.56%	0.24%	0.09	19.85
	12	0.0067%	0.0047%	-2.27%	2.56%	0.24%	-0.20	19.87
CHF/USD	4	0.0175%	0.0085%	-1.92%	2.09%	0.28%	0.42	13.72
	5	0.0190%	0.0080%	-1.73%	2.09%	0.28%	0.65	13.66
	6	0.0137%	0.0077%	-1.92%	2.09%	0.28%	0.45	13.70
	7	0.0159%	0.0078%	-1.92%	2.09%	0.28%	0.39	13.73
	8	0.0167%	0.0077%	-1.92%	2.09%	0.28%	0.41	13.72
	9	0.0141%	0.0074%	-1.92%	2.09%	0.28%	0.22	13.75
	10	0.0123%	0.0043%	-1.92%	2.09%	0.28%	0.19	13.75
	11	0.0114%	0.0042%	-1.92%	2.09%	0.28%	0.16	13.75
	12	0.0115%	0.0073%	-1.92%	2.09%	0.28%	0.11	13.76
USD/EUR	4	0.0132%	0.0043%	-1.91%	1.94%	0.25%	0.82	14.13
	5	0.0138%	0.0047%	-1.37%	1.94%	0.25%	0.80	14.13
	6	0.0130%	0.0044%	-1.64%	1.94%	0.25%	0.68	14.16
	7	0.0100%	0.0043%	-1.64%	1.94%	0.25%	0.57	14.18
	8	0.0099%	0.0043%	-1.64%	1.94%	0.25%	0.62	14.18
	9	0.0087%	0.0042%	-1.91%	1.94%	0.25%	0.26	14.23
	10	0.0093%	0.0042%	-1.91%	1.94%	0.25%	0.33	14.22
	11	0.0089%	0.0041%	-1.91%	1.94%	0.25%	0.37	14.22
	12	0.0085%	0.0041%	-1.91%	1.94%	0.25%	0.27	14.23

Table 6 Simple reversal strategy returns statistics for buy and sell signals at hourly frequency during the New York trading hours 10AM – 3PM from December 28, 2003 to March 3, 2006

Buy>0 is the fraction of buy signals which generate positive returns and **Sell>0** is the fraction of sell signals which generate positive returns.

Currency	MA length	BUY						SELL					
		Mean	Std	Skew	Kurt	t-stat	buy>0	Mean	Std	Skew	Kurt	t-stat	sell>0
JPY/USD	4	0.011%	0.24%	0.64	17.84	2.28	54.96%	0.011%	0.24%	1.22	21.40	2.31	52.27%
	5	0.010%	0.24%	-0.02	17.44	2.15	55.37%	0.011%	0.25%	0.58	21.95	2.24	52.66%
	6	0.011%	0.24%	0.00	17.51	2.22	55.25%	0.011%	0.24%	0.63	22.14	2.36	52.53%
	7	0.010%	0.23%	0.11	17.80	2.17	54.81%	0.011%	0.25%	0.63	21.05	2.22	52.20%
	8	0.010%	0.23%	-0.13	18.51	2.25	54.83%	0.011%	0.25%	0.43	20.55	2.18	52.24%
	9	0.009%	0.23%	-0.18	18.69	2.04	54.74%	0.010%	0.25%	0.42	21.03	2.07	52.18%
	10	0.009%	0.23%	-0.38	18.56	1.85	54.95%	0.009%	0.25%	0.25	21.06	1.84	52.33%
	11	0.008%	0.23%	-0.26	15.71	1.70	54.64%	0.008%	0.25%	0.33	22.44	1.65	52.08%
	12	0.006%	0.23%	-0.58	17.61	1.27	54.50%	0.007%	0.25%	0.09	21.83	1.37	51.96%
CHF/USD	4	0.016%	0.28%	0.44	13.41	2.90	54.92%	0.019%	0.28%	0.43	14.04	3.35	53.24%
	5	0.018%	0.28%	0.68	12.44	3.17	54.52%	0.021%	0.29%	0.65	14.84	3.61	52.85%
	6	0.013%	0.28%	0.48	12.85	2.25	54.00%	0.015%	0.29%	0.45	14.51	2.68	52.24%
	7	0.015%	0.28%	0.41	13.33	2.62	54.18%	0.017%	0.28%	0.40	14.11	3.03	52.34%
	8	0.016%	0.29%	0.42	13.60	2.73	54.24%	0.018%	0.28%	0.44	13.81	3.21	52.38%
	9	0.013%	0.29%	0.23	13.42	2.26	53.79%	0.015%	0.28%	0.25	14.07	2.74	51.93%
	10	0.011%	0.29%	0.20	13.66	1.95	53.73%	0.014%	0.28%	0.20	13.80	2.40	51.95%
	11	0.010%	0.29%	0.17	13.85	1.81	53.44%	0.013%	0.28%	0.18	13.62	2.27	51.68%
	12	0.010%	0.28%	0.13	14.20	1.84	53.70%	0.013%	0.28%	0.11	13.29	2.25	51.96%
USD/EUR	4	0.017%	0.25%	0.92	14.14	3.25	54.55%	0.010%	0.25%	0.72	14.04	2.04	50.63%
	5	0.018%	0.25%	0.92	14.94	3.43	54.99%	0.011%	0.25%	0.73	13.28	2.17	51.06%
	6	0.017%	0.26%	0.77	15.37	3.26	54.81%	0.010%	0.25%	0.62	12.79	2.04	50.86%
	7	0.014%	0.26%	0.64	15.29	2.61	54.51%	0.007%	0.24%	0.53	12.76	1.45	50.66%
	8	0.013%	0.26%	0.71	15.52	2.58	54.53%	0.007%	0.25%	0.57	12.65	1.42	50.68%
	9	0.012%	0.25%	0.35	14.23	2.33	54.26%	0.006%	0.25%	0.19	14.16	1.16	50.45%
	10	0.013%	0.26%	0.41	14.06	2.39	54.27%	0.006%	0.24%	0.27	14.31	1.29	50.39%
	11	0.013%	0.26%	0.46	14.36	2.38	53.88%	0.006%	0.25%	0.31	14.06	1.26	50.02%
	12	0.012%	0.26%	0.35	14.04	2.26	53.96%	0.006%	0.24%	0.22	14.36	1.17	50.10%

Table 7 Robustness check: Simple reversal strategy returns using prices lagged by 15minutes- NY trading hours 10AM – 3PM

Table 7 summarizes the annualized performance of the 3 dollar exchange rate pairs during the period of December 28, 2003 to March 3, 2006. **Gross return** is calculated using the average of the bid and ask prices lagged by 15 minutes to execute both buy and sell trades. **Net return** adjusts for transaction costs by purchasing at the ask and selling at the bid, both prices are lagged by 15 minutes; a small percentage cost which corresponds to \$15 per \$1,000,000 order is also taken into consideration. **Sharpe Ratio** is the excess return over risk-free rate divided by the standard deviation. **# of trades** is the total number of trades incurred in that period.

Currency		Whole					2003					2004					2005-March 2006					
MA	length	Gross returns	T- Stat	Sharpe ratio	# of trades	Net returns	Gross returns	T- Stat	Sharpe ratio	# of trades	Net returns	Gross returns	T- Stat	Sharpe ratio	# of trades	Net returns	Gross returns	T- Stat	Sharpe ratio	# of trades	Net returns	
JPY/USD	4	12.68%	2.40	1.13	1512	2.29%	15.12%	1.70	1.57	501	5.25%	17.57%	1.68	1.55	468	8.27%	6.57%	0.80	0.35	543	-1.41%	
	5	12.77%	2.42	1.14	1263	3.99%	20.01%	2.24	2.12	423	11.76%	16.65%	1.59	1.46	391	8.62%	3.51%	0.43	0.01	449	-3.38%	
	6	13.80%	2.61	1.25	1089	6.24%	19.46%	2.18	2.06	365	12.34%	19.39%	1.85	1.72	347	12.09%	4.44%	0.54	0.12	377	-1.35%	
	7	14.11%	2.67	1.28	867	8.27%	19.58%	2.19	2.07	289	13.91%	22.57%	2.16	2.03	277	17.65%	2.53%	0.31	-0.10	301	-1.94%	
	8	14.71%	2.78	1.34	763	9.73%	18.41%	2.06	1.94	247	13.46%	24.63%	2.36	2.23	249	18.93%	3.37%	0.41	0.00	267	-0.60%	
	9	12.86%	2.43	1.15	699	8.36%	18.60%	2.08	1.96	227	14.09%	18.22%	1.74	1.61	227	12.94%	3.64%	0.44	0.03	245	0.06%	
	10	11.46%	2.17	1.00	667	7.07%	19.54%	2.19	2.07	225	14.96%	19.08%	1.82	1.69	221	13.92%	-1.59%	-0.19	-0.55	221	-5.00%	
	11	10.92%	2.06	0.94	611	6.89%	19.44%	2.17	2.05	213	15.16%	11.55%	1.10	0.97	197	6.70%	3.34%	0.41	-0.01	201	0.21%	
	12	8.49%	1.61	0.68	593	4.57%	17.74%	1.98	1.86	207	13.56%	8.69%	0.83	0.70	183	4.09%	0.68%	0.08	-0.30	203	-2.52%	
	CHF/USD	4	19.97%	3.19	1.60	1545	-9.40%	36.63%	3.17	3.07	507	-2.50%	5.42%	0.44	0.33	468	-21.89%	18.24%	2.03	1.51	570	-0.85%
		5	22.67%	3.62	1.84	1293	-2.21%	29.58%	2.55	2.46	429	-5.96%	24.95%	2.03	1.92	406	1.95%	15.03%	1.67	1.18	458	-0.03%
		6	16.34%	2.61	1.28	1093	-4.67%	21.34%	1.84	1.74	357	-3.66%	14.87%	1.21	1.10	346	-7.39%	13.41%	1.49	1.02	390	-1.23%
7		18.95%	3.02	1.51	921	1.34%	25.97%	2.24	2.14	321	3.45%	16.19%	1.32	1.21	294	-1.62%	15.41%	1.72	1.22	306	4.56%	
8		21.02%	3.35	1.70	851	6.21%	25.47%	2.19	2.10	293	6.86%	18.35%	1.49	1.38	275	3.69%	19.56%	2.18	1.64	283	13.39%	
9		18.04%	2.88	1.43	781	5.19%	23.30%	2.00	1.91	269	8.29%	18.40%	1.50	1.39	255	5.48%	13.39%	1.49	1.02	257	7.88%	
10		16.49%	2.63	1.29	725	5.19%	23.06%	1.98	1.89	247	10.55%	12.64%	1.03	0.92	231	1.15%	14.26%	1.59	1.10	247	9.26%	
11		16.23%	2.59	1.27	681	5.21%	22.90%	1.97	1.88	239	10.27%	11.30%	0.92	0.81	205	1.13%	14.81%	1.65	1.16	237	10.30%	
12		16.10%	2.57	1.26	645	5.81%	21.71%	1.86	1.77	213	9.82%	11.73%	0.95	0.84	193	3.01%	15.09%	1.68	1.19	239	10.68%	
USD/EUR		4	20.69%	3.74	1.88	1473	12.88%	22.48%	2.19	2.08	479	15.16%	20.71%	1.92	1.80	450	14.97%	19.18%	2.39	1.80	544	13.05%
		5	20.86%	3.77	1.90	1239	14.19%	18.49%	1.80	1.69	403	12.12%	24.48%	2.28	2.15	366	19.76%	19.82%	2.47	1.87	470	14.50%
		6	20.29%	3.66	1.84	1087	14.51%	13.45%	1.31	1.20	342	7.51%	23.72%	2.21	2.08	335	19.82%	23.10%	2.88	2.24	410	18.38%
	7	16.39%	2.96	1.45	887	12.07%	8.36%	0.81	0.70	282	4.19%	24.77%	2.30	2.18	274	22.05%	16.07%	2.00	1.44	331	14.61%	
	8	16.24%	2.93	1.43	811	11.77%	8.94%	0.87	0.76	259	5.60%	24.17%	2.25	2.12	247	21.16%	15.69%	1.95	1.40	305	13.71%	
	9	13.06%	2.35	1.11	731	9.09%	9.33%	0.90	0.80	245	6.44%	13.57%	1.26	1.14	221	10.95%	15.72%	1.96	1.40	265	15.45%	
	10	13.58%	2.45	1.17	697	9.75%	8.65%	0.84	0.73	225	5.93%	11.86%	1.10	0.98	207	9.35%	19.11%	2.38	1.79	265	18.80%	
	11	12.97%	2.34	1.10	647	9.60%	12.68%	1.23	1.12	209	10.41%	10.57%	0.98	0.86	197	8.20%	15.21%	1.89	1.34	241	15.15%	
	12	12.36%	2.23	1.04	621	9.13%	8.13%	0.79	0.68	191	6.24%	11.49%	1.07	0.94	193	9.16%	16.58%	2.07	1.50	237	16.09%	

Table 8 Robustness check: Whether the Simple reversal strategy returns are resulting from outliers- NY trading hours 10AM – 3PM

Whole reports the annualized simple reversal strategy returns during New York trading hours 10AM – 3PM, **excl 2% outliers** reports the returns excluding the top 2% and bottom 2% extreme values generated by the simple reversal strategy. **excl 5% outliers** reports the returns excluding the top 5% and bottom 5% extreme values generated by the simple reversal strategy.

Currency	MA length	Whole	excl 2% outliers	excl 5% outliers
JPY/USD	4	17.22%	13.05%	11.25%
	5	16.94%	14.63%	13.04%
	6	17.66%	15.29%	13.38%
	7	16.77%	13.52%	10.65%
	8	17.04%	14.98%	12.09%
	9	15.67%	14.04%	11.78%
	10	14.08%	13.66%	11.41%
	11	12.89%	12.35%	10.11%
	12	10.49%	10.86%	9.27%
CHF/USD	4	27.21%	23.77%	19.35%
	5	29.54%	24.82%	19.33%
	6	21.36%	18.07%	14.73%
	7	24.71%	21.90%	16.95%
	8	26.04%	23.32%	18.51%
	9	22.04%	20.67%	16.26%
	10	19.19%	18.13%	14.31%
	11	17.77%	16.88%	13.44%
	12	17.91%	17.55%	14.45%
USD/EUR	4	20.58%	14.76%	10.32%
	5	21.42%	16.48%	12.94%
	6	20.27%	16.27%	12.59%
	7	15.59%	12.25%	10.21%
	8	15.44%	11.44%	9.57%
	9	13.50%	11.36%	10.16%
	10	14.46%	11.75%	9.82%
	11	13.91%	10.94%	8.59%
	12	13.19%	11.07%	8.84%

Table 9 Simulation tests from random walk bootstraps for 1000 replications

Table 9 compare the simple reversal strategy returns using actual data and simulation data, where **Fraction> Real** is the fraction of simulated simple reversal strategy returns greater than the returns generated by the actual data, which is also the Bootstrapped p-values for all of the reversal strategies.

Currency	MA length	Actual data		Simulation		Actual data		Simulation		Actual data		Simulation		Actual data		Simulation		
		Gross returns	T-stat	Gross returns	Fraction> Real	Gross returns	T-stat	Gross returns	Fraction> Real	Gross returns	T-stat	Gross returns	Fraction> Real	Gross returns	T-stat	Gross returns	Fraction> Real	
Whole																		
JPY/USD	4	17.22%	3.24	-0.24%	0.00%	20.22%	2.27	-0.04%	0.00%	21.31%	2.01	0.02%	0.00%	11.33%	1.37	-0.33%	0.20%	
	5	16.94%	3.19	-0.19%	0.00%	23.19%	2.60	-0.12%	0.00%	19.53%	1.84	-0.20%	0.00%	9.60%	1.16	-0.36%	1.00%	
	6	17.66%	3.32	-0.20%	0.00%	24.07%	2.70	-0.18%	0.00%	20.22%	1.91	-0.13%	0.00%	10.21%	1.24	-0.48%	0.30%	
	7	16.77%	3.15	-0.17%	0.00%	20.52%	2.30	-0.08%	0.00%	24.31%	2.30	-0.10%	0.00%	7.38%	0.89	-0.51%	3.50%	
	8	17.04%	3.20	-0.16%	0.00%	19.16%	2.15	-0.09%	0.00%	26.22%	2.48	-0.11%	0.00%	7.64%	0.93	-0.47%	3.00%	
	9	15.67%	2.95	-0.18%	0.00%	20.72%	2.32	-0.08%	0.00%	21.01%	1.98	-0.04%	0.00%	7.04%	0.85	-0.50%	2.90%	
	10	14.08%	2.64	-0.22%	0.00%	21.59%	2.42	-0.10%	0.00%	21.02%	1.98	-0.06%	0.00%	2.07%	0.25	-0.52%	25.30%	
	11	12.89%	2.42	-0.24%	0.00%	20.83%	2.33	-0.10%	0.00%	13.18%	1.24	-0.14%	0.30%	6.08%	0.74	-0.51%	5.20%	
	12	10.49%	1.97	-0.24%	0.00%	19.81%	2.21	-0.07%	0.00%	9.82%	0.93	-0.14%	2.00%	3.34%	0.41	-0.54%	18.50%	
	CHF/USD	4	27.21%	4.34	-0.24%	0.00%	43.83%	3.81	-0.16%	0.00%	16.30%	1.32	-0.05%	1.00%	22.49%	2.48	-0.32%	0.00%
		5	29.54%	4.71	-0.17%	0.00%	38.05%	3.30	-0.14%	0.00%	33.44%	2.72	0.18%	0.00%	19.21%	2.12	-0.34%	0.00%
		6	21.36%	3.40	-0.29%	0.00%	29.37%	2.54	-0.20%	0.00%	20.52%	1.67	0.24%	0.00%	15.40%	1.70	-0.28%	0.10%
7		24.71%	3.94	-0.34%	0.00%	34.35%	2.97	-0.51%	0.00%	23.49%	1.91	0.22%	0.00%	17.73%	1.96	-0.39%	0.10%	
8		26.04%	4.15	-0.38%	0.00%	33.59%	2.91	-0.89%	0.00%	25.03%	2.04	0.30%	0.00%	20.61%	2.27	-0.44%	0.00%	
9		22.04%	3.51	-0.43%	0.00%	28.59%	2.47	-0.80%	0.00%	25.33%	2.06	0.29%	0.00%	13.88%	1.53	-0.45%	0.00%	
10		19.19%	3.06	-0.40%	0.00%	24.84%	2.14	-0.86%	0.00%	19.11%	1.55	0.26%	0.00%	14.59%	1.61	-0.42%	0.00%	
11		17.77%	2.83	-0.43%	0.00%	23.86%	2.06	-0.87%	0.00%	16.29%	1.32	0.31%	0.50%	13.96%	1.54	-0.38%	0.20%	
12		17.91%	2.85	-0.35%	0.00%	22.23%	1.92	-0.72%	0.00%	16.50%	1.34	0.19%	0.40%	15.50%	1.71	-0.39%	0.00%	
USD/EUR		4	20.58%	3.72	-0.22%	0.00%	20.50%	2.01	-0.14%	0.00%	20.20%	1.88	-0.13%	0.00%	20.96%	2.59	-0.24%	0.00%
		5	21.42%	3.87	-0.24%	0.00%	16.66%	1.63	-0.20%	0.10%	23.82%	2.21	-0.14%	0.00%	23.38%	2.89	-0.23%	0.00%
		6	20.27%	3.66	-0.24%	0.00%	10.37%	1.02	-0.25%	2.10%	22.93%	2.13	-0.08%	0.00%	26.29%	3.25	-0.35%	0.00%
	7	15.59%	2.81	-0.24%	0.00%	7.10%	0.70	-0.26%	8.60%	23.09%	2.15	0.03%	0.00%	16.38%	2.02	-0.34%	0.00%	
	8	15.44%	2.79	-0.29%	0.00%	7.48%	0.73	-0.33%	7.40%	22.12%	2.06	0.13%	0.00%	16.47%	2.03	-0.29%	0.00%	
	9	13.50%	2.44	-0.35%	0.00%	10.64%	1.04	-0.42%	2.70%	13.16%	1.22	0.11%	0.50%	16.16%	1.99	-0.40%	0.00%	
	10	14.46%	2.61	-0.35%	0.00%	9.50%	0.93	-0.53%	3.80%	12.11%	1.12	0.16%	0.70%	20.52%	2.53	-0.47%	0.00%	
	11	13.91%	2.51	-0.31%	0.00%	12.32%	1.20	-0.48%	0.90%	11.40%	1.06	0.20%	1.70%	17.31%	2.14	-0.50%	0.00%	
	12	13.19%	2.38	-0.33%	0.00%	8.15%	0.80	-0.50%	6.00%	13.27%	1.23	0.19%	0.60%	17.29%	2.13	-0.53%	0.00%	

Table 10 Robustness check: Simple Reversal strategy returns - Using **deal** prices- NY trading hours 10AM – 3PM

Table 10 summarizes the annualized performance of the 3 dollar exchange rate pairs during the period of December 28, 2003 to March 3, 2006. **Gross return** is calculated using the average of the bid and ask prices to execute both buy and sell trades. **Net return** adjusts for transaction costs by purchasing at the ask and selling at the bid, a small percentage cost which corresponds to \$15 per \$1,000,000 order is also taken into consideration. **Sharpe Ratio** is the excess return over risk-free rate divided by the standard deviation. **# of trades** is the total number of trades incurred in that period.

Currency	MA length	Whole				2003				2004				2005-March 2006			
		Gross returns	T-Stat	Sharpe ratio	# of trades	Net returns	Gross returns	T-Stat	Sharpe ratio	# of trades	Net returns	Gross returns	T-Stat	Sharpe ratio	# of trades	Net returns	Gross returns
JPY/USD	4	17.59%	3.32	1.64	1,494	12.03%	17.61%	1.99	1.87	485	13.25%	23.63%	2.23	2.11	460	20.14%	12.53%
	5	16.36%	3.09	1.51	1,253	11.76%	15.48%	1.75	1.62	417	11.69%	21.28%	2.01	1.88	391	18.62%	13.00%
	6	17.56%	3.31	1.64	1,107	13.28%	14.69%	1.66	1.53	361	11.39%	27.47%	2.60	2.47	367	24.63%	11.68%
	7	16.63%	3.13	1.54	871	13.35%	20.21%	2.28	2.16	287	17.78%	21.71%	2.05	1.92	285	19.64%	9.43%
	8	16.48%	3.11	1.52	755	13.66%	17.66%	1.99	1.87	247	15.64%	23.87%	2.26	2.13	247	22.22%	9.33%
	9	15.05%	2.83	1.37	683	12.49%	20.24%	2.28	2.16	223	18.46%	19.84%	1.88	1.75	227	18.24%	6.74%
	10	11.49%	2.16	1.00	657	9.14%	15.86%	1.79	1.67	219	14.07%	17.36%	1.64	1.51	217	16.54%	2.97%
	11	10.56%	1.99	0.90	615	8.24%	14.95%	1.68	1.56	209	13.60%	16.08%	1.52	1.39	205	15.30%	2.32%
	12	8.15%	1.53	0.64	599	6.00%	17.02%	1.92	1.80	209	15.63%	8.94%	0.84	0.72	189	8.54%	0.16%
	4	14.00%	2.27	1.08	1,447	6.34%	12.90%	1.15	1.05	463	4.92%	15.90%	1.30	1.19	458	10.03%	13.32%
	5	16.15%	2.61	1.28	1,215	9.80%	11.05%	0.99	0.89	381	3.90%	22.09%	1.81	1.70	386	17.13%	15.43%
	6	11.38%	1.84	0.85	1,065	5.70%	7.90%	0.70	0.61	336	1.83%	12.93%	1.06	0.95	347	8.39%	12.98%
CHF/USD	7	19.12%	3.09	1.55	885	14.21%	9.22%	0.82	0.72	289	3.99%	35.81%	2.94	2.83	289	28.65%	13.43%
	8	18.13%	2.93	1.46	817	13.48%	18.97%	1.69	1.59	281	13.87%	24.33%	1.99	1.88	259	17.73%	12.26%
	9	16.03%	2.59	1.27	749	11.95%	17.27%	1.54	1.44	261	12.65%	19.17%	1.57	1.46	231	13.29%	12.39%
	10	16.09%	2.60	1.27	683	12.55%	16.73%	1.49	1.39	235	12.92%	17.22%	1.41	1.30	209	11.59%	14.62%
	11	16.38%	2.65	1.30	655	13.13%	18.87%	1.68	1.58	229	14.99%	16.50%	1.35	1.24	197	9.97%	14.21%
	12	14.27%	2.31	1.11	629	11.42%	14.45%	1.28	1.19	205	11.51%	14.14%	1.16	1.05	189	8.19%	14.21%
	4	18.01%	3.25	1.61	1,453	13.91%	14.52%	1.43	1.32	461	11.76%	21.14%	1.96	1.84	450	19.07%	18.31%
	5	20.98%	3.79	1.92	1,233	17.46%	11.04%	1.08	0.97	380	8.70%	29.49%	2.74	2.62	383	27.87%	22.15%
	6	20.22%	3.65	1.84	1,083	17.13%	8.22%	0.81	0.70	338	6.07%	26.94%	2.51	2.38	339	25.52%	24.57%
	7	17.98%	3.25	1.61	899	15.43%	7.03%	0.69	0.58	280	5.12%	28.49%	2.65	2.53	284	24.50%	18.31%
	8	15.46%	2.79	1.36	803	13.01%	4.24%	0.42	0.31	257	2.80%	21.97%	2.04	1.92	249	17.99%	19.34%
	9	15.84%	2.86	1.39	743	13.55%	9.70%	0.95	0.84	243	8.33%	18.84%	1.75	1.62	227	13.52%	18.43%
USD/EUR	10	14.16%	2.55	1.22	689	12.01%	5.16%	0.51	0.40	217	3.89%	14.84%	1.38	1.25	207	9.65%	21.05%
	11	12.74%	2.30	1.08	645	10.90%	8.66%	0.85	0.74	207	7.57%	10.53%	0.98	0.85	195	5.63%	17.94%
	12	13.68%	2.47	1.18	621	11.94%	7.74%	0.76	0.65	191	6.83%	12.77%	1.19	1.06	193	7.86%	19.36%
	4	18.01%	3.25	1.61	1,453	13.91%	14.52%	1.43	1.32	461	11.76%	21.14%	1.96	1.84	450	19.07%	18.31%
	5	20.98%	3.79	1.92	1,233	17.46%	11.04%	1.08	0.97	380	8.70%	29.49%	2.74	2.62	383	27.87%	22.15%
	6	20.22%	3.65	1.84	1,083	17.13%	8.22%	0.81	0.70	338	6.07%	26.94%	2.51	2.38	339	25.52%	24.57%
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	10	14.16%	2.55	1.22	689	12.01%	5.16%	0.51	0.40	217	3.89%	14.84%	1.38	1.25	207	9.65%	21.05%
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	12	13.68%	2.47	1.18	621	11.94%	7.74%	0.76	0.65	191	6.83%	12.77%	1.19	1.06	193	7.86%	19.36%

Figure 1 Bid-Ask spreads of the Japanese Yen / US dollar (JPY/USD), the Swiss franc/ US dollar (CHF/USD) and the US dollar/Euro (USD/EUR) during the period of December 28, 2003 to March 3, 2006.

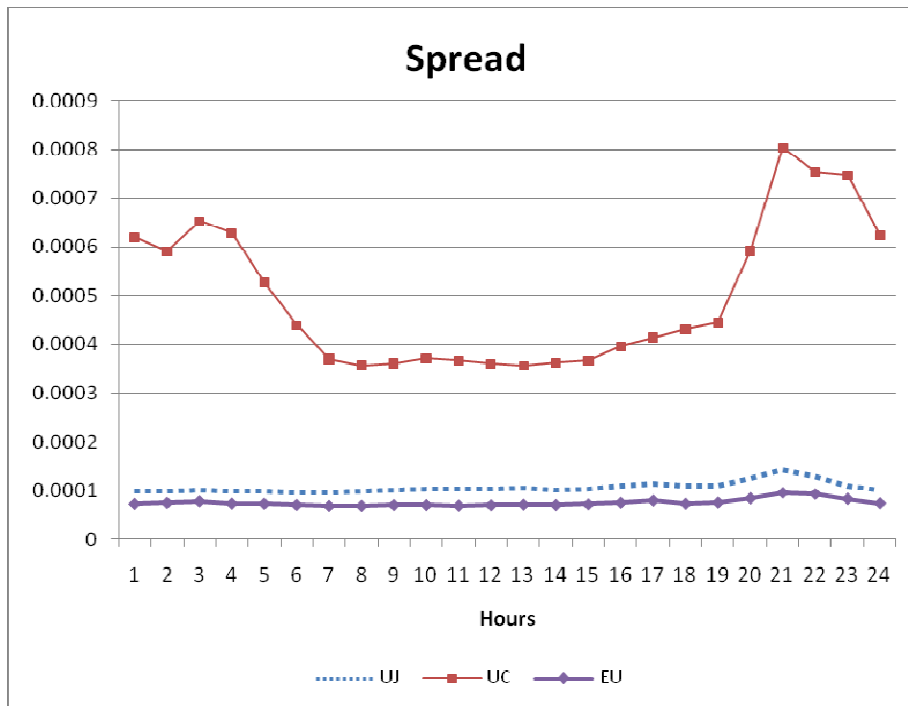


Figure 2 Standard deviation of the Japanese Yen / US dollar (JPY/USD), the Swiss franc/ US dollar (CHF/USD) and the US dollar/Euro (USD/EUR) during the period of December 28, 2003 to March 3, 2006.

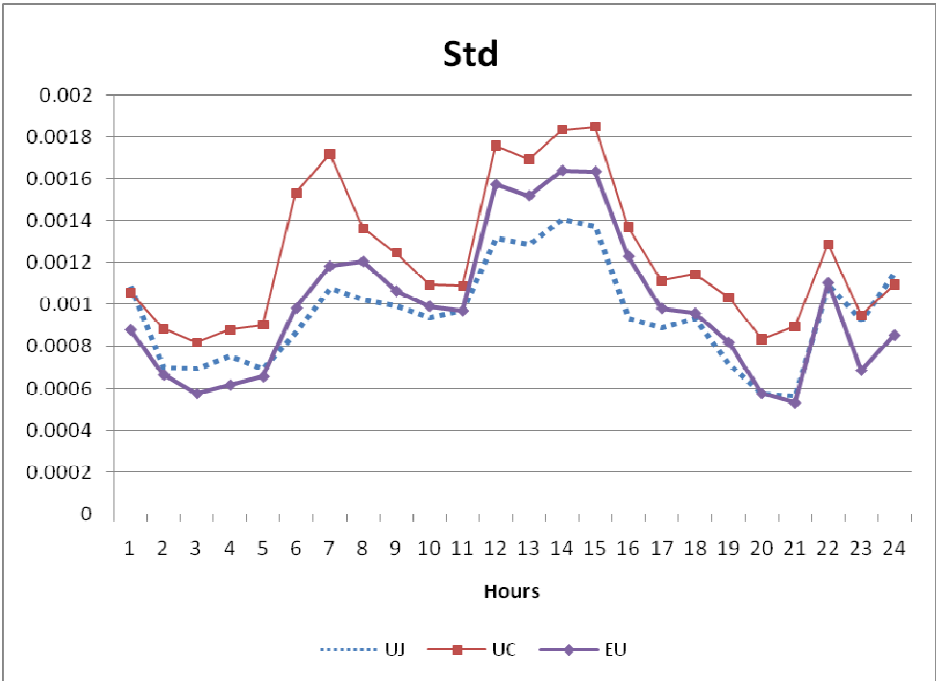


Figure 3 Number of trades of the Japanese Yen / US dollar (JPY/USD), the Swiss franc/ US dollar (CHF/USD) and the US dollar/Euro (USD/EUR) during the period of December 28, 2003 to March 3, 2006.

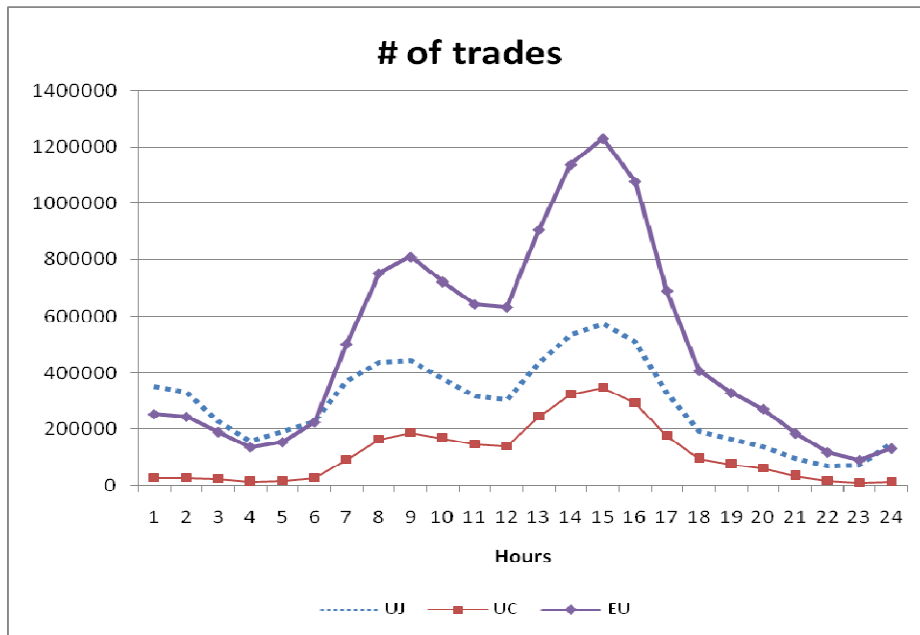


Figure 4 Distribution of the Simple reversal strategy hourly returns - NY trading hours 10AM – 3PM during the period of December 28, 2003 to March 3, 2006.

