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Abstract

The study investigates the profitability of 1024 moving average and momentum models and their components in the yen/dollar market. It turns out that all models would have been profitable between 1976 and 1999. The pattern of profitability is as follows. The models produce more single losses than single profits, however, the size of the single profits is on average much higher than the size of single losses. Hence, the profitability of technical currency trading is exclusively due to the exploitation of persistent exchange rate trends. These results hold also when technical trading is examined over subperiods. The models which perform best over the most recent subperiod are in most cases significantly profitable also ex ante. However, the profitability of technical currency trading based on daily data has declined since the late 1980s and has disappeared over the out-of-sample period between 2000 and 2004.

Keywords: Exchange rate; Technical trading; Speculation

JEL classification: F31; G14; G15

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Technical Currency Speculation and the Yen/Dollar Exchange Rate*

1. Introduction

According to survey studies technical analysis is the most widely used trading technique in foreign exchange markets. Over the 1990s the importance of technical analysis has stronger increased than other trading practices like the orientation on fundamentals or on customer orders. Nowadays between 30% and 40% of professional currency traders use technical systems as their most important trading technique (for recent survey studies see Cheung-Chinn-Marsh, 2004; Cheung-Wong, 2000; Cheung-Chinn, 2001; Oberlechner, 2001; Gehrig-Menkhoff; 2004, 2005A and 2006). However, professionals do not blindly follow technical trading signals but use this information together with other kinds of information like news about fundamentals or customer order flows (Gehrig-Menkhoff, 2005B). Hence, professional traders try to extract that information from technical analysis which might improve their overall trading performance (an excellent survey of studies on technical analysis in the foreign exchange market is Menkhoff-Taylor, 2007).

Studies testing the performance of technical analysis (have to) assume that traders follow blindly a certain rule. The difference between this assumption and the actual practice might explain the following contradiction. On the one hand, surveys of professional currency traders indicate a rising importance of technical analysis, on the other hand, profitability studies indicate that the profitability from blindly following a trading rule has declined over the past 15 years (for profitability studies see Schulmeister, 1988; Levich-Thomas, 1993; Menkhoff-Schlumberger, 1995; Neely-Weller-Dittmar, 1997; Curcio-Goodhart-Guillaume-Payne, 1997; Gencay-Stengos, 1998; Chang-Osler, 1999; Neely-Weller, 1999; Gencay, 1999; LeBaron, 1999; Osler, 2000; Maillet-Michel, 2000; Neely-Weller, 2003; Ohlson, 2004, Omrane-Van Oppens, 2005).

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As a first step towards a thorough examination of this puzzle one has to sort out the profitable and unprofitable informational content of technical trading systems. Hence, one has to answer questions like the following: What is the relation between the number of profitable and unprofitable positions produced by technical models? Is the average return per day during profitable positions greater than during unprofitable positions? Do profitable positions last significantly longer than unprofitable positions? Does the structure of profitability of technical models differ between in-sample and out-of-sample simulations?

These issues were already investigated for the DM/dollar market on the basis of the performance of 1024 moving average and momentum models (Schulmeister, 2007A). The main scope of the present study is threefold. First, it shall analyze the profitability components of the same technical models in the second most active foreign exchange market, the yen/$ market based on daily data.[1]) Second, the study shall compare the results for yen/dollar trading to the results already obtained for DM/dollar trading. Hence, this study applies the same methods as the DM/dollar study.[2]) Third, this study shall present a cluster analysis of the performance of technical models in both markets, the DM/dollar as well as the yen/dollar market.

The main results are as follows:

- Over the entire sample period 1976/99, the 1024 technical models would have produced a gross return of 9.1% per year in the yen/dollar market, slightly more than in the DM/dollar market (7.9%).
- The overall profitability of technical currency trading is exclusively due to the exploitation of persistent exchange rate trends. This is reflected by profitable positions lasting 3 to 5 times longer than unprofitable positions in either market.
- The 25 best performing models in each in-sample period examined were profitable also out of sample in most cases.
- The profitability of technical trading has been declining since the late 1980s, in the yen/dollar market even stronger than in the DM/dollar market.

2. The rationale of moving average models and momentum models

Technical analysis tries to exploit price trends which "technicians" consider the most typical feature of asset price dynamics ("the trend is your friend"). Hence, this trading technique

[1]) The exchange rates used are mid rates at noon in New York as published by the Federal Reserve Bank of New York (http://www.federalreserve.gov/releases/H10/hist).

[2]) The only difference concerns the sample period. In the DM/dollar study the sample period starts in 1973, in this study it starts only in 1976. This is so because during the first subperiod of the DM/dollar study (1973/75) the Bank of Japan frequently stabilized the yen/dollar exchange at a constant level (i. e., the yen exchange rates did not freely float over the entire period 1973/76).

derives buy and sell signals from the pattern of the most recent price movements which (purportedly) indicate the continuation of a trend or its reversal (trend-following or contrarian models). Technical traders believe that the phenomenon of trending occurs across different time scales, hence, they apply their models to different data frequencies (for an introduction into technical analysis see Neely, 1997; for a comprehensive treatment see Kaufman, 1987; Murphy, 1986).

The quantitative approaches try to identify trends using statistical transformations of past prices. These models produce clearly defined buy and sell signals. The most common trading systems are moving average models and momentum models.

The basic version of the first type of model consists of a short-term moving average (MAS) and a long-term moving average (MAL) of past prices. The trading rule is as follows: Buy (go long) when the short-term (faster) moving average crosses the long-term (slower) moving average from below and sell (go short) when the converse occurs.

The momentum model operates with the difference between the current price and that i days ago ($M(i) = P_t - P_{t-i}$). The trading rule is as follows: Buy (go long) when the momentum M(i) turns from negative into positive and sell (go short) in the opposite case.

There exist many modifications of moving average and momentum models (see, e.g., Kaufman, 1987, chapters 5 and 6). This study, however, considers only the basic version.

Price oscillations often cause technical models to produce "wrong" signals. In order to filter them out the signal execution can be delayed by n days, i. e., a signal is executed only if it remains valid over n consecutive days. In this study only the shortest possible lag of signal execution is tested (1 day).

3. The overall performance of technical trading systems in the yen/dollar market

The simulations comprise the same models as in the DM/dollar study (Schulmeister, 2007A): In the case of moving average models all combinations of a short-term moving average (MAS) between 1 and 15 days and a long-term moving average (MAL) between 5 and 40 days are tested (474 models). In the case of momentum models the time span i runs from 3 to 40 days (38 models). Each model is simulated with and without a lag of signal execution by one day (delay filter). Hence, a total of 1024 different technical trading models is analyzed.

Table 1 shows the performance of three moving average and three momentum models over the entire sample period (these are the same models as in table 1 in Schulmeister, 2007A). The fastest models operating with relatively short moving averages or time spans display an average duration of profitable positions between 15 and 30 days (they focus on short-term trends like the momentum model 9). Most of the selected models display a duration of

profitable positions between 30 and 60 days, only the moving average model 11/30 specializes on the exploitation of long-term exchange rate trends.

All of the selected models are profitable, their gross rates of return amounts to roughly 10% per year. The annual rates of return represent also the excess returns from technical currency speculation because the benchmark for excessive profitability is a return of zero (given the assumption that traders do not invest own capital).

Transaction costs are put at 0.02% per trade which implies a bid-ask spread of 4 basis points ("pips"). Hence, the net rate of return is by less than 1% smaller than the gross rate in most cases.

For any open position interest is earned from the long position and paid for the short position. If one calculates the overall interest effect using the information on the duration of the long and the short dollar positions and on the interest differential it turns out that this effect was close to zero during the sample period (this holds true for yen/dollar trading as well as for DM/dollar trading; see Schulmeister, 2000, p. 74f). A similar result is reported by LeBaron (1999).

Table 1: Pattern of yen/dollar-trading 1976/1999

	Moving average models			Momentum models		
Length i of MAS	1	3	11			
Length i of MAL	16	30	30			
Time span i				9	23	9
Lag of signal execution	0	0	0	0	0	1
Gross rate of return per year	10.2	9.7	10.1	8.3	11.0	8.1
Sum of profits per year	23.6	19.2	16.8	24.3	20.2	21.3
Profitable positions						
Number per year	8.1	4.6	3.9	12.6	8.2	7.6
Average return						
Per position	2.9	4.1	4.3	1.9	2.5	2.8
Per day	0.09	0.07	0.06	0.10	0.07	0.09
Average duration in days	32.1	57.7	67.7	18.9	33.3	31.8
Sum of losses per year	– 13.3	– 9.5	– 6.7	– 16.0	– 9.3	– 13.2
Unprofitable positions						
Number per year	19.8	8.5	4.4	22.8	11.9	12.8
Average return						
Per position	– 0.7	– 1.1	– 1.5	– 0.7	– 0.8	– 1.0
Per day	– 0.13	– 0.10	– 0.07	– 0.13	– 0.10	– 0.11
Average duration in days	5.3	11.5	22.6	5.6	7.7	9.7
Single rates of return						
Mean	0.37	0.74	1.21	0.24	0.55	0.40
t-statistic	3.73	3.62	4.06	3.26	4.26	3.11
Median	– 0.32	– 0.45	– 0.26	– 0.20	– 0.17	– 0.32
Standard deviation	2.55	3.61	4.21	2.11	2.81	2.83
Skewness	3.55	2.30	1.58	3.09	3.07	2.52
Excess kurtosis	16.86	5.74	2.88	13.10	11.75	9.37
Sample size	669	316	200	851	482	489

The gross rate of return (GRR) of any technical trading model can be split into six components, the number of profitable/unprofitable positions (NPP/NPL), the average return per day during profitable/unprofitable positions (DRP/DRL), and the average duration of profitable/unprofitable positions (DPP/DPL). The following relationship holds:

GRR = NPP*DRP*DPP – NPL*DRL*DPL

The selected models have the following trading pattern in common (table 1):

- The number of profitable trades is lower than the number of unprofitable trades.
- The average return per day during profitable positions is smaller (in absolute terms) than during unprofitable positions.
- Profitable positions last on average 3 to 6 times longer than unprofitable positions.

The overall profitability of the models is therefore due to the exploitation of persistent exchange rate trends. Smaller fluctuations often cause technical models to produce losses, which, however, are small, precisely because the fluctuations are small.

The distribution of the single rates of return reflect these properties of technical trading systems:

- The median is negative.
- The standard deviation is several times higher than the mean.
- The distribution is skewed to the right and leptokurtotic.

The riskiness of blindly following a technical trading model is estimated by testing the mean of the single rates of return against zero (only if it is negative does the trading rule produce an overall loss).[3]) Since the t-statistic of every model shown in table 1 exceeds 3.0 one can conclude that the probability of making an overall loss by following these models over the entire sample period was less than 0.1%.

[3]) The t-statistic is a better measure for the return-risk relationship of technical trading systems than the Sharpe ratio since the latter does not take the number of single returns (open positions) into account, which varies across different models (since traders are assumed not to invest own capital the risk-free rate has to be neglected when calculating the Sharpe ratio). If, e.g., two trading rules produce the same ratio between the average of single returns and their standard deviation (the Sharpe ratio) but a different number of trades, then the return relative to the risk would be greater in the case of that model which trades more frequently. This fact is reflected by the t-statistic but not by the Sharpe ratio. For the same reason the t-statistic enables one to quantify the probability of making an overall loss by following a specific trading rule.

Figure 1: Distribution of trading systems by the gross rate of return
Yen/dollar trading 1976 - 1999

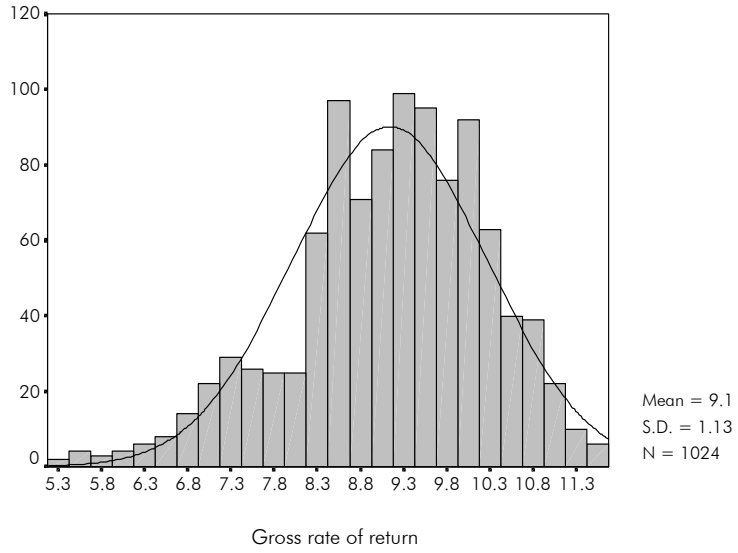
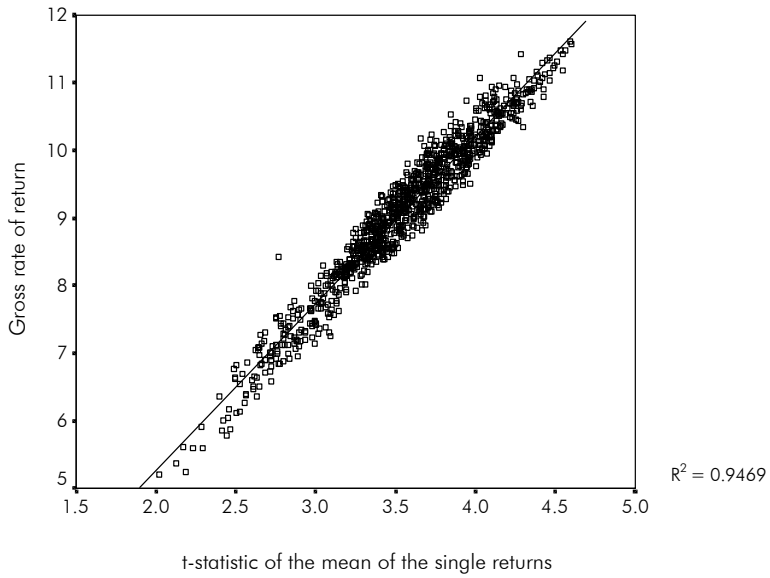


Figure 1 shows the distribution of all 1024 trading systems by their annual gross rates of return. On average they produce a mean return of 9.1% per year with a standard deviation of 1.13. The best performing models produce an annual return of roughly 12%, the worst models roughly 5%.

Figure 2: Profitability and riskiness of 1024 technical trading systems
Yen/dollar trading 1976 - 1999



The t-statistic of the mean of the single rates of return exceeds 2.5 in almost all cases (figure 2) which implies a probability of making an overall loss by blindly following these rules of less than 0.5%.

When comparing the overall performance of the same technical models in the yen/dollar market and in the DM/dollar market the following observations can be made (?see tables 1 and 2, and figures 1 and 2, in this paper as well as in Schulmeister, 2007A). First, the average gross rate of return is slightly higher in the yen/dollar market (9.1%) as compared to the DM/dollar market (7.9%). Second, the average t-statistic is almost the same in both markets (3.55 and 3.53, respectively). Third, in the yen/dollar market moving average models perform slightly better than momentum models (GRR amounts to 9.1% and 8.5%, respectively), the opposite is true for DM/dollar trading (GRR: 7.9% and 8.2%, respectively).

4. Components of the profitability of technical models

Table 2 classifies all models according to their performance as measured by the t-statistic into four groups and quantifies the components of profitability for each of them. A t-statistic greater than 4.0 is achieved by 15.4% of all models, the average rate of return per year (GRR) over these models amounts to 10.6%. The t-statistic of 41.1% of all models lies between 3.5 and 4.0 (GRR: 9.6%), 31.8% generate a t-statistic between 3.0 and 3.5% (GRR: 7.2%). The worst performing models, (t-statistic<3) still produce an average return of 7.0% per year.

Table 2: Components of the profitability of trading systems by types of models
Moving average and momentum models
Yen/dollar-trading 1976-1999

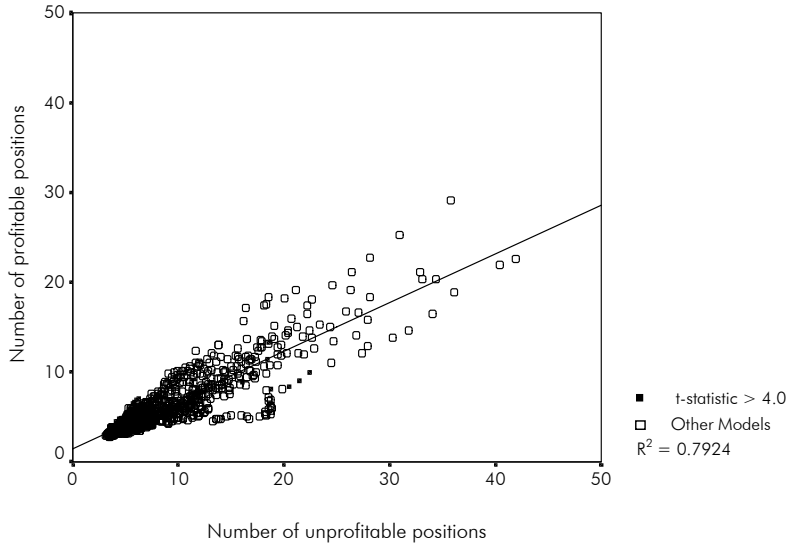
	Number of models		Mean for each class of models							
	Absolute	Share in %	Gross rate of return	t-statistic	Profitable positions			Unprofitable positions		
					Number	Return per day	Duration in days	Number	Return per day	Duration in days
t-statistic of the mean of the single returns										
< 3.0	119	11.6	7.0	2.72	9.4	0.09	36.1	14.7	– 0.11	10.9
3.0 - < 3.5	326	31.8	8.5	3.30	6.4	0.08	51.2	9.4	– 0.10	15.4
3.5 - < 4.0	421	41.1	9.6	3.73	5.4	0.07	54.7	7.3	– 0.09	16.4
> 4.0	158	15.4	10.6	4.19	4.9	0.07	57.9	6.1	– 0.08	17.7
All models	1,024	100.0	9.1	3.55	6.1	0.07	51.9	8.6	– 0.09	15.7
Moving average models	948	92.6	9.1	3.57	6.0	0.07	52.7	8.3	– 0.09	16.1
Momentum models	76	7.4	8.5	3.30	7.7	0.08	41.6	12.6	– 0.10	10.4
Models with lag = 0	512	50.0	9.2	3.60	6.6	0.08	49.8	9.9	– 0.10	14.2
Models with lag = 1	512	50.0	9.0	3.50	5.6	0.07	54.1	7.3	– 0.09	17.2
2000-2004 (out of sample period)										
All models	1024	100.0	0.1	0.01	6.0	0.06	46.0	10.2	– 0.09	17.3

The pattern of profitability is the same for each class of models (table 2). The number of single losses exceeds the number of single profits, the average return per day (in absolute terms) is higher during unprofitable positions than during profitable positions, hence, the overall profitability is only due to profitable positions lasting three to four times longer than unprofitable positions.

The profitability pattern of yen/dollar trading is almost identical to the pattern observed in DM/dollar trading (see table 2 here and in Schulmeister, 2007A). There is, however, one difference. In yen/dollar trading the profitability of the models increases with the duration of profitable positions, whereas the opposite is true in DM/dollar trading. Hence, in the yen/dollar market the best models specialize on the exploitation of relatively long-term exchange rate trends, whereas in the DM/dollar market the best models exploit primarily short-term trends. This result can be taken as indirect evidence that persistent exchange rate movements last longer in the yen/dollar market as compared to the DM/dollar market.

Figures 3 to 5 show the number, the daily return and the duration of profitable positions relative to the unprofitable positions for each of the 1024 models. The models signal in almost all cases less profitable positions than unprofitable positions (the slope of the regression in figure 3 line is much smaller than 45^0).

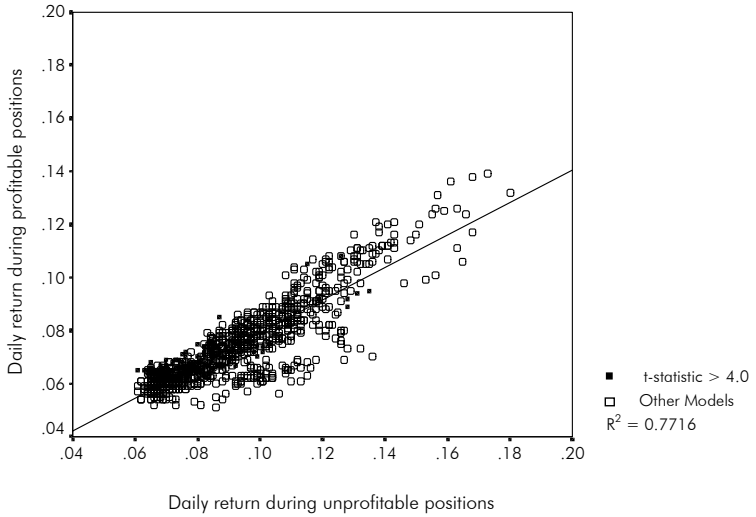
Figure 3: Frequency of profitable and unprofitable positions
Yen/dollar trading 1976 - 1999



The average return per day during profitable positions is always lower than during unprofitable positions (figure 4). What accounts for the overall profitability of technical currency trading is the fact that profitable positions last several times longer than unprofitable

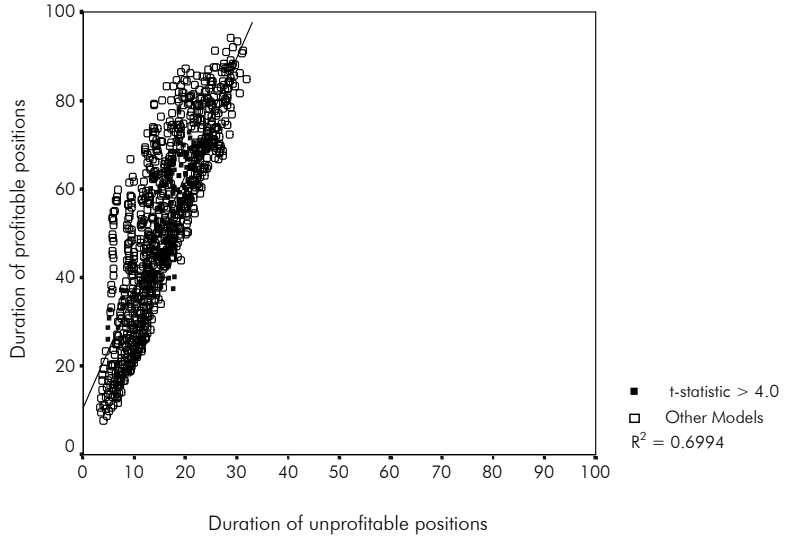
positions (figure 5). This phenomenon represents the most typical property of technical trading systems.

Figure 4: Average daily return during profitable and unprofitable positions
Yen/dollar trading 1976 - 1999



Two conclusions can be drawn from these observations. First, the profitability of technical currency trading stems from the successful exploitation of persistent exchange rate trends. Second, the best performing models maximize the duration of profitable positions relative to unprofitable positions.

Figure 5: Average duration of profitable and unprofitable positions
Yen/dollar trading 1976 - 1999



5. Clusters of technical models

In order to detect similarities in the trading behavior of certain groups of technical models, statistical clustering techniques are used. These methods classify all models into similar groups in the following way. All models characterized by a certain number of variables (profitability components in our case) are assigned to different clusters under the condition that the differences between the models are minimized within each cluster and maximized across clusters. For this (descriptive) exercise the simple approach called K-Means Cluster Analysis was adopted (provided by the SPSS software package). In this case the number of clusters has to be predetermined (here three clusters are sufficient to illustrate characteristic differences in the trading behavior of technical models).

Table 3 shows the results of the cluster analysis. When trading the yen/dollar exchange rate the 250 models of cluster 1 produce the highest number of open positions (26.6 per year on average), mainly for that reason the duration of profitable positions is relatively short (24.7 days on average). Cluster 1 comprises therefore those (fast) models which are most sensitive to price changes. The 396 models of cluster 2 signal 13.3 open positions per year, the profitable positions last 49.1 days on average. Cluster 3 comprises 378 (slow) models which produce only 8.4 open positions per year, their profitable positions last 72.9 days on average.

Table 3: Cluster of technical trading systems according to profit components
Moving average and momentum models

		Number of models	Mean of gross rate of return	Cluster center (mean) of profit components					
				Profitable positions			Unprofitable positions		
				Number	Return per day	Duration in days	Number	Return per day	Duration in day
Yen/dollar-trading 1976-1999									
Cluster	1	250	8.3	10.8	0.10	24.7	15.7	– 0.12	8.7
	2	396	9.5	5.4	0.07	49.1	7.9	– 0.09	14.4
	3	378	9.2	3.7	0.06	72.9	4.7	– 0.07	21.6
Total		1024	9.1	6.1	0.07	51.9	8.6	– 0.09	15.7
DM/dollar-trading 1973-1999									
Cluster	1	313	8.2	10.0	0.09	27.7	13.9	– 0.12	9.7
	2	373	8.3	5.0	0.06	54.6	6.5	– 0.09	15.6
	3	338	7.1	3.3	0.05	80.8	4.1	– 0.07	24.9
Total		1024	7.9	6.0	0.07	55.0	8.1	– 0.09	16.9

From these results one can conclude the following. First, the models of cluster 1 exploit primarily short-term exchange rate trends, those of cluster 2 specialize on medium-term trends, whereas the models of cluster 3 exploit mainly long-term trends. Second, the daily

returns during profitable and unprofitable positions differ significantly across the three clusters, they are the higher the shorter last the duration of the profitable and unprofitable positions.

Figure 6: Three clusters of technical trading systems according to profit components
Yen/dollar trading 1976 – 1999

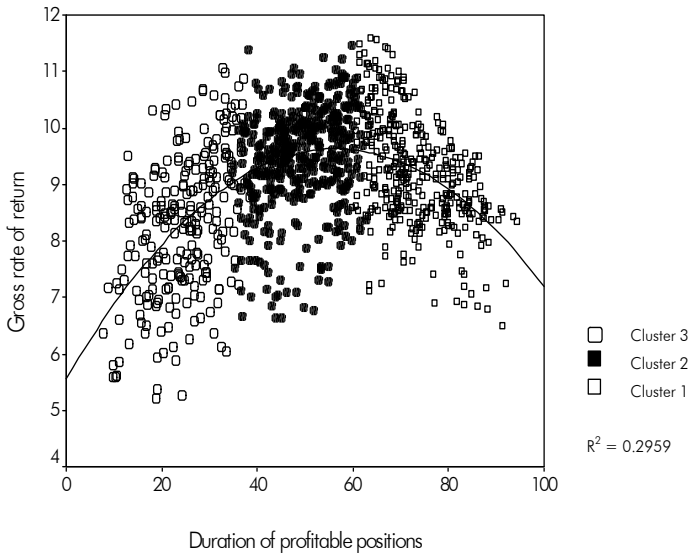
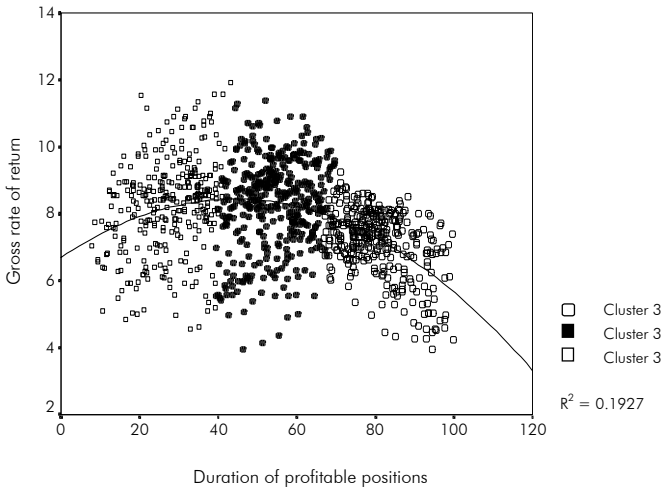


Figure 7: Three clusters of technical trading systems according to profit components
DM/dollar trading 1973 – 1999



A comparison of the results of the cluster analysis between yen/dollar trading and DM/dollar trading confirms that the profitability structure of technical models is almost identical in both

markets. The only difference concerns the relative profitability across clusters. In the yen/dollar market the most profitable models belong to cluster 2 and 3, these models exploit longer-term exchange rate trends (figure 6 and table 2). In the DM/dollar market, by contrast, the most profitable models specialize on comparatively shorter trends, and, hence, belong to clusters 1 and 2.

6. The performance of technical trading systems over subperiods

The study divides the overall sample period of 24 years into 6 subperiods each lasting 4 years and investigates the performance of the 1024 models in each of them in sample (ex post) and out of sample (ex ante).

Table 4 displays the performance of the models over these subperiods plus the out-of-sample period 2000/2004. The ex-post-performance of the 1024 models over the subperiods can be summarized as follows. First, these models would have made losses in only 783 out of 7168 cases (1024 models over 7 subperiods). Second, whereas the average profitability of technical currency trading remained roughly the same between 1976 and 1987 it has been steadily declining thereafter (as already reported by Ohlson, 2004). Over the subperiod 1996/99 the models achieve a gross rate of return of only 3.2% on average, 17.7% of the models would have produced losses (the extraordinary yen volatility in 1998 might have contributed to this result – see Cai et al, 2001). The out-of-sample test of the models over five years (2000/2004) reveals that the performance of the models has further declined. Their average gross rate of return amount to only 0.1%, exactly half of the models would have produced losses

The decline in the profitability of technical trading as reported by Ohlson (2004) for currency trading and by Schulmeister (2007B) for stock trading could be explained in two different ways. The first explanation holds that asset markets have become more efficient, in particular due to information technologies (Ohlson, 2004). The second explanation holds that technical traders have been increasingly using intraday data instead of daily data, thereby contributing to the rise in trading volume (it rose in global currency markets between 1989 and 1998 by 10.8% per year – see Bank of International Settlements, 2005). This development could have caused intraday exchange rate movements to become more persistent and, hence, exploitable by technical models. As a consequence, exchange rate changes based on daily data have become bigger and more erratic which in turn causes technical trading on the basis of daily data to become less profitable. So far, studies on the profitability of technical currency trading based on intraday data arrive at mixed results. Osler (2000),

Dempster-Jones (2002) and Gencay et al. (2003) find this type of trading to be profitable, Curcio et al. (1997) and Neely-Weller (2003) arrive at the opposite conclusion.[4])

Table 4: Performance of technical trading systems by subperiods
In sample and out of sample
Yen/dollar-trading 1976-1999

Subperiods

	All models	25 best models In sample	25 best mo Out of sample
1976 - 1979			
Gross rate of return	14.0	18.6	–
t-statistic	2.34	2.83	–
DPP	63.2	47.5	–
Share of profitable models	100.0	100.0	
1980 - 1983			
Gross rate of return	9.8	17.9	12.6
t-statistic	1.60	2.64	1.89
DPP	48.2	21.0	35.9
Share of profitable models	100.0	100.0	100.0
1984 - 1987			
Gross rate of return	15.0	21.4	17.7
t-statistic	2.03	2.79	2.48
DPP	53.4	51.0	20.2
Share of profitable models	100.0	100.0	100.0
1988 - 1991			
Gross rate of return	5.6	11.4	4.0
t-statistic	0.95	1.89	0.66
DPP	46.9	49.4	41.3
Share of profitable models	97.6	100.0	100.0
1992 - 1995			
Gross rate of return	7.5	15.8	10.2
t-statistic	1.05	2.09	1.42
DPP	50.0	46.7	52.1
Share of profitable models	93.7	100.0	100.0
1996 - 1999			
Gross rate of return	3.2	9.3	– 0.1
t-statistic	0.49	1.43	0.01
DPP	47.5	53.3	45.6
Share of profitable models	82.3	100.0	52.0
2000 - 2004			
Gross rate of return	0.1	5.8	– 0.7
t-statistic	0.01	1.32	– 0.17
DPP	46.0	23.7	53.7
Share of profitable models	50.0	100.0	16.0

[4]) As regards stock trading, Schulmeister (2007B) reports that the profitability of technical models in the stock index futures market has been declining over the 1990s when based on daily data but has remained roughly the same when based on 30-minute-data.

The fact that persistent exchange rate trends of varying lengths occur "abnormally" frequently does not ensure the profitability of technical trading ex ante. If, e. g., a trader selects a model that would have performed best over the most recent past for trading over a subsequent period, then he might become a victim of his own "model mining" for the following reason.

The ex-post profitability of the best models consists of two components. The first stems from the "normal" non-randomness of exchange rate dynamics, namely, the occurrence of persistent price trends. The second component stems from the selection or overfitting bias since a part of the ex-post profits of the best models would have been produced only by chance (Sullivan-Timmerman-White, 1999). Now, if the "optimal" profitability of a selected model is mainly the result of this "model mining" then this model will perform much worse over the subsequent period. However, if the in-sample profitability stems mainly from the exploitation of "usual" exchange rate trends then it might be reproduced out of sample.

In order to investigate this matter, the following exercise was carried out. In a first step the 25 best models are identified on the basis of their ex-post performance (measured by the net rate of return) over the most recent subperiod. Then the performance of the selected models is simulated over the subsequent subperiod.

Table 5 summarizes the means over the gross rates of returns and over the three ratios of the profitability components of all models as well as of the 25 best models in sample and out of sample. In addition, t-statistics are calculated which test for the significance of the difference between the means of the best models and the means of all models

In the yen/dollar market the mean annual rate of return of the best models (15.1%) is almost twice as high as the mean over all models (8.2%). This result holds also true for the DM/dollar market. This high profitability is due to the means of all three ratios of the profit components being significantly higher in the case of the 25 best models in sample than in the case of all models.

This profitability pattern of the best models cannot be reproduced out of sample. The mean ratio between the number of profitable and unprofitable positions is significantly lower in the case of the best models out of sample as compared to the average ratios over all models. This observation holds true for yen/$ trading as well as for DM/$ trading. The results are mixed for the mean ratio between the daily return during profitable and unprofitable positions, it is higher (yen/$) or lower (DM/$) out of sample than on average over all cases. Since the high values of these two ratios observed in sample can not be reproduced out of sample they should be considered as a result of "model mining".

However, the ratio between the duration of profitable and unprofitable positions of the best models out of sample is even slightly higher than in sample. Moreover, this ratio is significantly higher than in the case of all models (DM/dollar) or only insignificantly lower (yen/dollar). Hence, that property of technical currency trading which in general accounts for its profitability, i.e., the longer duration of profitable positions relative to unprofitable positions, is

reproduced out of sample (even though to a lesser extent in yen/dollar trading as compared to DM/dollar trading).

Table 5: Distribution of trading systems by the gross rate of return and by the ratio of profit components over subperiods

	Yen/dollar-trading 1980-1999		DM/dollar-trading 1976-1999	
Variable	Mean	t-statistic	Mean	t-statistic
		All models		
	N = 5120		N = 6144	
Gross rate of return	8.2		6.0	
NPP/NPL	0.74		0.76	
DRP/DRL	0.84		0.75	
DPP/DPL	3.37		3.41	
		The 25 most profitable models: In sample		
	N = 125		N = 150	
Gross rate of return	15.1	17.26	12.9	18.23
NPP/NPL	0.95	8.93	0.92	5.58
DRP/DRL	1.10	8.76	0.84	4.05
DPP/DPL	3.14	– 2.44	4.00	4.41
		The 25 most profitable models: Out of sample		
Gross rate of return	8.9	1.19	6.6	1.22
NPP/NPL	0.67	– 5.48	0.62	– 10.10
DRP/DRL	0.89	2.10	0.70	– 2.99
DPP/DPL	3.23	– 1.64	4.17	5.61

NPP (NPL) . . . Number of profitable (unprofitable) positions per year.
DRP (DRL) . . . Return per day during profitable (unprofitable) positions.
DPP (DPL) . . . Average duration of profitable (unprofitable) positions.

The t-statistic tests for the significance of the difference between the mean of the four variables over the 125 (150) cases of the best models (in and out of sample) and the respective mean over the 5120 (6144) cases of all models.

7. Summary

The main results of this study can be summarized as follows:

- The 1024 technical models investigated would have produced an annual gross return of 9.1% in the yen/dollar market between 1976 and 1999, slightly more than in the DM/dollar market between 1973 and 1999 (7.9%).
- The risk of making an overall loss when strictly following one of these models was close to zero in the yen/dollar market as well as in the DM/dollar market.
- The profitability of technical currency trading is exclusively due to the exploitation of persistent exchange rate trends. This is reflected by profitable positions lasting 3 to 5 times

longer than unprofitable positions. The structure of the profitability of the 1024 technical models in the yen/dollar market and in the DM/dollar market is almost identical.

- These results do not change substantially when technical currency is simulated over subperiods. In only 783 out of 7168 cases did the technical models produce losses in the yen/dollar market (the results are similar for the DM/dollar market).
- The ex-ante profitability of those models which performed best over the most recent subperiod is slightly higher than the average in-sample profitability of all models. This result holds true for the yen/dollar market as well as for the DM/dollar market.
- The profitability of technical trading has been declining since the late 1980s, in the yen/dollar market even stronger than in the DM/dollar market. E. g., in the out-of-sample period between 2000 and 2004 the 1024 technical models would have generated an average gross return of only 0.1% in yen/dollar trading as compared to 3.8% in DM/dollar trading.

It is an important challenge for future research to find out whether the decline in the profitability of technical trading based on daily data is due to asset markets becoming more efficient or due to technical trading becoming "faster", i.e., being increasingly based on intraday data.

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