II. # TECHNICAL ANALYSIS AND STOCHASTIC PROPERTIES OF EXCHANGE RATE MOVEMENTS: EMPIRICAL EVIDENCE FROM THE ROMANIAN CURRENCY MARKET

Alexandru TODEA[1]
Adrian ZOICAŞ-IENCIU[2]

Abstract

In this paper we investigate the profitability of the moving average strategy on Romanian currency market considering the episodic character of linear and/or nonlinear dependencies, between 1999 and 2008. The main conclusion is that profitability of moving average strategies is not constant over time and that is mainly due to linear and nonlinear episodic dependencies. The trading rule profits did not declined over time in the case of the Romanian currency market. Exploring the causes of profitability, it was found that it was closely related to the intensity of manifestation of episodic linear and nonlinear dependencies, the state of the market, and it was not the result of a time varying risk premium. The empirical results are consistent with the Adaptive Markets Hypothesis (Lo, 2004), but not with the Efficient Market Hypothesis.

Keyword: technical analysis, exchange rate, random walk, episodic dependencies, bicorrelation test
JEL Classification: C15, G11, G14

1. Introduction

It is a known fact that in currency markets the majority of the analysts, traders and dealers prefer using technical analysis (TA) rather than fundamental analysis, especially for short-run forecasts of the exchange rate movements. This explains the development over the last two decades of a rich literature that analyzes the profitability of the main TA strategies and the evaluation of their efficiency. Studies

[1] *Faculty of Economics and Business Administration, Babeş-Bolyai University, Str. M. Kogălniceanu, nr. 1, Email: alexandru.todea@econ.ubbcluj.ro.*
[2] *Faculty of Economics and Business Administration, Babeş-Bolyai University, Str. M. Kogălniceanu, nr. 1, Email: adrian.zoicas@econ.ubbcluj.ro.*

conducted by Sweeney (1986), Levich and Thomas (1993), Neely *et al*. (1997), Gencay (1999), Maillet and Michel (2000) and Gradojevic (2007) advocate the usage of these strategies. The stability problem for these strategies (trading rules) is essential if we want to identify long-term profit opportunities, but the results of the studies conducted in this direction are somehow contradictory. For example, Olson (2004) or Qi and Wu (2006) show that the trading rule profits in the currency markets declined over time, but at an opposite pole profit persistence is sustained by the results obtained by Okunev and White (2003) or Schulmeister (2008), who combined in their approach momentum and moving average (MA) strategies.

As a consequence, there are a series of strategies sustaining the hypothesis of temporal inefficiency in the case of the currency markets. LeBaron (1999), Saacke (2002), Shik and Chong (2007) or Tabak and Lima (2009) showed that one of the main causes for this temporal inefficiency was the intervention of central banks and the profitability of the technical trading rules was dramatically reduced when intervention days were removed from the sample. Schulmeister (2008) showed that the profitability was due exclusively to the exploitation of persistent exchange rate trends, hypothesis sustained also by Neely *et al*. (2009), who applied the test developed by Zivot and Andrews (1992) for identifying structural breaks of endogenous nature in the exchange rates evolution process.

Therefore, it becomes clearer that the profitability of TA strategies is in close relationship with the manifestation of significant changes in the evolutionary processes characterizing the exchange rates. Lee *et al*. (2001) show that serial correlation is neither a necessary nor a sufficient condition for trading rules to produce profits, because the gains depend on the type of the probability density function characterizing the exchange rate. Also, they consider that in the case of the emerging markets, currency depreciation or appreciation is another source of trading rules profitability, because when such processes appear or disappear there is an increased probability for structural breaks to occur in the exchange rate.

Some recent studies have used the Hinich-Patterson windowed-test procedure (1995) to research the temporal persistence of linear and, especially, nonlinear dependencies on the emergent stock markets. Thus, Lim and Liew (2004) for the Asian stock markets, Bonilla *et al*. (2006) for the Latin American stock markets, Todea and Zoicaş-Ienciu (2008) for the Central and Eastern European stock markets emphasized the existence of different stock price behaviors, namely long random walk sub-periods alternating with short ones, characterized by strong linear and/or nonlinear correlations. All these studies suggest that such serial dependencies have an episodic nature, being also the main cause for the low performance of the forecasting models. Such an episodic behavior was identified on the currency markets also by Brooks *et al*. (2000), Lim and Liew (2004), Bonilla *et al*. (2007) and Hinich and Serletis (2007) and it is attributed especially to certain political and social events[3].

By its topics and findings, this article contributes to the existing literature in four ways. First, it attempts to identify and analyze the evolution of the episodic behavior on the

[3] *The events archive can be downloaded from Campbell Harvey's web site. The URL is http://www.duke.edu/~charvey/Country_risk/couindex.htm .*

Romanian currency market. Secondly, the strategies' profitability is evaluated in terms of the episodic behavior of linear and nonlinear dependencies. Regarding this approach, it is expected that the TA strategies are more profitable in sub-periods in which RWH is rejected as compared to those in which it is accepted. Third, it attempts to relate the profitability of the TA strategies in excess of the buy and hold strategy to intrinsic features of the exchange rates evolution process, such as the intensity of linear and nonlinear dependencies, volatility or market trends. Finally, this article contributes by highlighting the findings related to the informational efficiency of the Romanian currency market.

2. Romanian foreign exchange market. Data description and diagnosis

2.1 Overview of the Romanian foreign exchange market

Since the re-opening of the Romanian foreign exchange market in 1990, many changes affected the market, which experienced different behaviors slowly converging to an increase in the traded amounts and a reduction in volatility. However, this trend towards a smaller volatility was often infirmed by periods of high changes affecting the exchange rates corresponding to the special events occurred in the Romanian economy.

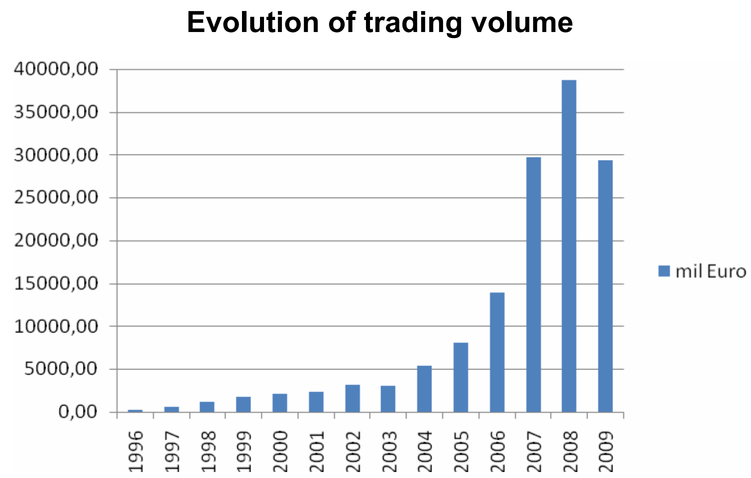
The period before 2000 was characterized by a high volatility, with the manifestation of huge unjustified bid-ask spreads between different categories of operators, a fact that led to a market segmentation and insignificant trade volumes. The high volatility could be attributed also to different psychological pressures amplified by the speculative appetite of a small number of banks. During 2001 and 2002, the currency market manifested itself as the most active part of the financial market, with an average turnover of 75.8% of the Romanian GDP. It was also characterized by an increase in the dynamism of the banking segment, this recovery being determined by the intensification of the exchanges with other countries.

During 2003, under a high volatility characterizing the euro-dollar exchange rate and the reduction of NBR interventions, the volatility of the RON/EUR exchange rate was significantly reduced as a consequence of the adoption of euro as a reference currency at the start of the year and the increased precaution of banks during trades (the average bid-ask spread being smaller as compared to previous years). The year 2004 was the first year of the transition period recording a one-digit inflation rate, the interbank currency market surpassing for the first time the GDP (108.9% as compared to 71.1% in 2003), especially as a result of spectacular increase in its liquidity. There were some main causes for this liquidity boost, among which we can specify the increase in the external commercial exchange, a solid growth of the capital inflows, direct investments and European funds, significant amounts of currencies transferred by Romanian residents working abroad and major increases in the external financing, including speculative capitals.

Considering these evolutions, until the last months of 2004, the Central Bank's goals related to the exchange rate policy focused on maintaining within normal limits the real appreciation of the national currency and on giving an unpredictable evolution of the exchange rates. These goals were set in order to discourage massive entries of speculative capital and to support the disinflation phenomenon. As a consequence of this policy, the volatility in exchange rates reached unprecedented levels in the last two months of 2004.

The evolution of the RON/EUR exchange rate starting with the end of 2004 must be interpreted from the perspective of a major shift in the monetary system consisting only in the direct targeting of the inflation, a shift launched by the NBR in August 2005. Both the evolution of the RON/EUR exchange rate and trading volumes are presented in Figure 1 and Figure 2.

Figure 1



2.2. Data description and diagnosis

The research uses daily levels of the spot exchange rate for the Romanian currency (RON) relative to the Euro zone currency (EUR) between 01.04.1999 and 09.30.2008, the sample cumulating a total volume of 2,486 observations.

In Figure 2 we notice at least two distinct sub-periods in the evolution of the RON/EUR exchange rate. A first sub-period between January 1999 and the end of 2004 is characterized by a strong depreciation of the Romanian currency, while the second sub-period is characterized by appreciation and relative stability. Such evolutions could suggest some signs of a structural break, fact confirmed after using the Zivot-Andrews (1992) unit root test[4]. Consequently, the date of 19 October 2004 was identified as a structural break point of an endogenous nature and its existence justifies a profitability analysis of the MA strategies for the two heterogeneous sub-periods identified.

[4] *The statistics of this test (-3.62) lead to the acceptance of the null hypothesis of a unit root with an intercept, the theoretical values of the test being -5.43 for a risk level of 1% and 4.80 for a risk level of 5%.*

Figure 2

Evolution of the RON/EUR exchange rate

The daily returns, R_t, derived from the exchange rates are measured as the natural logarithm of rate level on day *t* divided by the rate on day *t-1*. Table 1 provides diagnosis statistics for the daily returns for the whole period, the in-sample period and the out-of-sample period. The average annualized return clearly shows the depreciation process of the Romanian currency in the first sub-period and a weak appreciation in the second one, suggesting that the usage of a buy-and-hold strategy would not be profitable.

Table 1

Exchange rate's daily returns: Summary statistics and diagnosis

Statistics	Periods		
	01/1999 – 09/2008 (entire sample)	01/1999 – 10/2004 (1st sub period)	10/2004 – 09/2008 (2nd sub period)
Sample size (no. of obs.)	2485	1477	1008
Mean (%)	0.0423***	0.0777***	-0.00972*
Std. dev. (%)	0.6138	0.6567	0.54
Skewness	0.81**	1.08**	-0.03
Kurtosis	13.20***	12.05***	14.75***
Arch-LM (F – stat)	48.52***	18.01***	26.86***
LNS (5)	19.01***	3.26	23.65***
LNS (10)	24.72***	7.54	29.95***
LNS (20)	36.56**	15.48	36.26**
Fitted AR(p) model	AR(3)	-	AR(4)
ML (10)	433.44***	118.88***	204.31***
ML (20)	592.78***	169.62***	232.34***
Tsay test (F – stat)	7.83***	4.01***	5.21***
Hurst Exponent	-	0.58	0.77

*Note: LNS (5), LNS (10), LNS (20) are the Lobato-Nankervis-Savin Q statistics for the null hypothesis of no autocorrelation up to lag 5, 10 and 20. The nonlinearity tests are applied to the residual of an AR(p) model; *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.*

Through the standard deviation we perceive a higher volatility in the first sub-period, and the fact that we deal with a significant skewness can be explained also by the currency depreciation process. Both skewness and kurtosis are rejecting the normality hypothesis for the returns and the null-hypothesis of homoskedasticity is also significantly rejected by Engle's (1982) ARCH-LM test.

The presence of linear/nonlinear dependencies in the return series would lead to a rejection of the RWH and, implicitly, to the existence of a relatively high prediction degree which can be exploited by the TA trading rules. The linear correlation hypothesis is investigated using the Lobato, Nankervis and Savin (2002) test, which considers the heteroskedasticity effect, and whose statistics indicates the presence of linear correlations for the whole sample, but, especially, in the second sub-period. The presence of the nonlinear dynamics in the returns evolution process is underlined by the McLeod-Li (1982) and Tsay (1986) tests. By comparing the two sub-periods we can notice that the intensity of linear and nonlinear correlations is higher in the second sub-period. This is a result consistent with the behavior suggested by the values of the Hurst exponent, indicating a stronger persistency and a higher prediction degree for this particular sub-period.

3. Methodology

The profitability analysis for the TA strategies applied to the Romanian currency market will focus on the MA strategies, firstly because they are frequently used by practitioners and, secondly, for the fact that if these basic strategies are indeed profitable, then it is even more probable that more complex and sophisticated strategies will work as well. The methodological approach consists of the following steps: (1) selecting the most profitable in-sample strategy and testing it in the out-of-sample sub-period; (2) revealing the episodic behavior of linear and nonlinear dependencies and analyzing their intensity and distribution; (3) evaluating the trading rules profitability for the sub-periods of RWH acceptance and rejection; (4) investigating and identifying the main explanatory factors for the trading rules profitability.

3.1. Moving average (MA) trading rules

This research considers both long and sells positions in trading foreign currencies. Formally, an investor is considered to adopt a long position and holding Euros if the short-term moving average (STMA) is higher than the long-term moving average (LTMA) and sells Euros otherwise. Buying and selling is assumed to occur at the closing price the first day after the signal is observed. Around the LTMA, we introduced a percentage band in order to reduce possible noisy signals. Generally, empirical studies on MA strategies are limiting themselves only at several combinations between the two kinds of MA, usually those introduced in Brock *et al*. (1992), but there are studies which use profit optimization in order to identify the best MA strategy. For example, Lee *et al*. (2001) analyzed 45 strategies; Olson (2004) considered 766 combinations, while Schulmeister (2008) combined 474 MA strategies with 38 momentum strategies.

Following this direction, our approach considers a generalization of the selection process using a software application which pinpoints to the strategy offering the highest excess return (relative to a buy & hold strategy). This "optimal" strategy is thus chosen from a total of 16,610 strategies, a volume resulted from the combination of all STMA between 1 and 10 days with all LTMA between 50 and 200 days in a context of ten bands integer multiples of 0.1% between 0% and 1%.

The MA trading rules as discussed earlier represent an in-sample test of trading rules profitability. We think that the main reason for the unstable profitability is due to "data mining" biases, a reason for which their performance is also studied out-of-sample. Therefore, the "01/1999–10/2004" sub-period is used for the in-sample test, while "10/2004–09/2008" refers to the out-of-sample testing period.

3.2. Identification and analysis of the episodic behavior characterizing the linear and nonlinear dependencies

The identification of a potential episodic behavior will be attempted by using the "windowed" methodology developed by Hinich and Patterson (1995), but considering the rolling sample approach. After running in parallel the initial and the rolling sample approaches, Todea and Zoicaş-Ienciu (2008) found that the initial Hinich-Patterson methodology can be suspected of inaccurate identification of sub-periods exhibiting linear/nonlinear dependencies, because test results were depending on how the first day of the sample was chosen.

Linear correlations identification was done using the portmanteau test (*C*), while the nonlinear ones were detected using the bicorrelation test (*H*). In the rolling sample approach, *C* and *H* statistics were computed for the first window of a specified length (*n*) and, then, the sample was rolled forward eliminating the first observation and including the next one in order to re-estimate *C* and *H.* This procedure was then repeated until the last observation of the sample was used. The return sample, *R(t)*, is considered to be the realization of a stochastic process, whit *t* being the time unit. In each window, the data are standardized to have a sample mean of zero and a sample standard deviation of one, as follows:

$$Z(t) = \frac{R(t) - m_R}{\sigma_R}$$

with *t* taking values between 1 and *n* and m_R , σ_R being the mean and standard deviation within each window. The null hypothesis is that *{Z(t)}* is the realization of a white noise process with null correlations and bi-correlations, described by $C_{RR}(r) = E[Z(t)Z(t+r)]$ and $C_{RRR}(r,s) = E[Z(t)Z(t+r)Z(t+s)]$, where *r* and *s* are integers satisfying $0 < r < s < L$ and L being the number of the lags. The correlations and bi-correlations are then given by: $C_{RR}(r) = (n-r)^{-1/2}\sum_{t=1}^{n-r} Z(t)Z(t+r)$ and $C_{RRR}(r,s) = (n-s)^{-1}\sum_{t=1}^{n-s} Z(t)Z(t+r)Z(t+s)$ for 0<r<s.

The *C* and *H* statistics are distributed according to a χ^2 law of probability with *L* and $(L-1)(L/2)$, respectively, degrees of freedom, having the following formulas:

$$C = \sum_{r=1}^{L} \left[C_{RR}(r)\right]^2 \text{ and}$$

$$H = \sum_{s=2}^{L}\sum_{r=1}^{s-1} G^2(r,s)\text{, where } G(r,s) = (n-s)^{1/2} C_{RRR}(r,s)$$

Lim *et al*. (2008) indicated that in order to compute correctly the H bicorrelation statistics a prior filtering of the linear component estimated using an autoregressive AR(p) model is necessary. This fitting is being employed only as a pre-whitening operation and not to obtain a model of best fit[5]. Regarding the choosing of a particular filter model, it is important to add that Brooks and Hinich (2001) showed that the computation of the bicorrelation test did not require filtering returns through an AR-GARCH model, because the presence of GARCH effects would not cause a rejection of the pure white noise null hypothesis. Using these specifications, our research computes the C statistics from unfiltered returns and uses the residuals generated by the linear filtering as a base for computing the H statistics. The risk level used to accept or reject the null hypothesis of linear/nonlinear correlation is set to 1%.

The number of lags (L) is specified as $L = n^b$, with $0 < b < 0.5$, but Hinich and Patterson (1995) recommends the usage of $b = 0.4$ in order to maximize the power of the test, at the same time ensuring a good asymptotical approximation. Also, the window length must be long enough in order to offer robust statistical power, but short enough for the test to be able to identify the arrival and disappearance of transient dependencies. Generally, empirical studies use 35/50-day windows, but Patterson and Ashley (2000), basing themselves on Monte Carlo simulations, recommend a volume of 200 observations per window. Considering these debates and acknowledging the fact that the C and H tests are sensitive to the windows length, this research will use both windows of 50 and 200 observations.

3.3. Analysis of the TA strategies profitability

For every window we computed the cumulative return of the optimal MA strategy, the buy-and-hold strategy and the excess return as the difference between the first two. Then, by dividing these returns to the windows amount (number of daily observations) we obtained a daily average return/excess within each window. Finally, we grouped all the windows into five subsamples conditioned by the significance of the C and H tests results.

Considering the average addition property, we computed the daily average excess for each subsample and then tested its significance. In order to have a clearer image, we chosen to express the daily average return and excess as annualized percents by multiplying them with 250 (average number of trading days) and then by 100.

---

[5] *The p order of the AR(p) model is chosen between 0 and 10 as the lowest value for which the Ljung-Box Q(10) statistic is insignificant at the 10% level.*

3.4. Analyzing the causes for TA strategies profitability

Setting 1% risk level for testing the significance of C and H statistics could be interpreted as a rigid methodological approach, which can alter any potential conclusions. For example, we found windows in which the RWH is accepted at 1% risk level but rejected for the 2% level. In such situation, the excess return characterizing that window belongs to the subsample in which the RWH is accepted, although it can be guaranteed with a probability of 98% that for this particular window the null hypothesis is rejected. As a consequence, in each window we will consider the values of C and H statistics as measures of the linear/nonlinear correlations intensity and we will study how they explain the average excess returns through a simple linear regression. By choosing these models instead of multiple regression models we avoid undesirable multicolinearity effects, which are present especially when C and H are added together[6].

There are a series of studies investigating to what extent the risk taken by investors explains abnormal returns obtained using different trading rules. For example, Kho (1996) shows that, in the case of currency futures, periods of higher returns are accompanied by higher volatility suggesting thus that the abnormal returns represent a premium for bearing an additional time varying risk. Two studies on currency markets, one on four Asian markets, Cheung and Wong (1997), and the other for the North-American market, Olson (2004), showed that risk adjusted returns tend to be statistically insignificant. In this context, for the Romanian currency market we will study in each window the relation between the average excess return and the volatility estimated using the standard deviation. We will also analyze whether the linear and nonlinear dependencies quantified through C and H statistics can be explained by this volatility. After examining the correlation between H and the standard deviation, Lim *et al*. (2008) suggested that for the Asian stock markets there was no relation between the degree of market inefficiency and volatility.

As we mentioned, currency market trends (sustained appreciation or depreciation) could represent an important cause for the profitability associated to different trading rules. The time period within a window is defined as up (down) market if the average return over the corresponding 50/200 day sample period is positive (negative). Thus, a regression of the average excess return against the average return will suggest if market trends represent indeed a source of the trading rules profitability. Additionally, it could also be interesting to investigate the relation between the intensity of linear/nonlinear dependencies and the market trends.

4. Empirical results

4.1. The profitability of MA strategies

By using a software application specially designed for this methodology allowed us to identify the best strategy (the one ensuring the maximum excess return) both for the whole sample and the two sub-periods. Thus, for the whole period, the best strategy is

[6] *The correlation is 0.81.*

corresponding to a STMA of 9 days, a LTMA of 171 days and a 0.6% band around the LTMA the commission fee being 0.1% for each transaction[7].

The existence of the structural break identified with the Zivot-Andrews test has significant effects on the stability of MA strategies profitability. For the Romanian currency market, the optimum MA strategy (10, 172, 0.1%) identified in the first sub-period is then tested out-of sample in the second sub-period. Because we eliminated 172 observations from the first sub period the sample has a volume of 1306 returns, while in the second sub-period, where profitability analysis does not require observations elimination, the sample is made of 1008 returns. Intriguing at first look, this strategy is more profitable out-of-sample that in-sample, the annualized excess return being 6.325% as compared to 0.243%. The structural breakpoint identified as 10/19/2004 marks a persistent trend change of the RON/EUR exchange rate[8]. The existence of higher profit opportunities in the second sub-period can be noticed in the last row in Table 2, where the optimal strategy (4, 61, 0.3%) corresponding to this sub-period leads to an excess return of 14.275%.

Table 2

Excess return for the best MA trading rules conditioned by sub periods

Periods	Best trading rule (SMA, LMA, filter)	Buy and hold	Best trading rule	Excess return
1999 – 2008	(9, 171, 0.6%)	7.85 %	12.10 %	4.27 %
1999 – 2004	(10, 172, 0.1%)	16.87 %	17.12 %	0.24 %
2004 – 2008	(10, 172, 0.1%)	-2.60 %	3.70 %	6.32 %
2004 – 2008[(a)]	(4, 61, 0.3%)	-2.60 %	11.57 %	14.27 %

Note: (a): “new” optimal MA.

Usually, trend changes are accompanied by linear/nonlinear returns correlations and we expect that a finer analysis of trading rules profitability conditioned by the manifestations and intensity of these correlations will bring useful conclusions. It is important to add that the farthest a process moves from the random walk model the easier for the trading rules to identify profit opportunities will be. Judging the results in Table 1, we notice a higher prediction degree in the second sub period, while in the first one the non-correlation hypothesis is accepted. Moreover, the short-term dependencies are accompanied by long-term dependencies, which increase the exchange rate’s prediction degree and that are exhibited especially in the second sub-period[9].

4.2. Detecting epochs of transient linear/nonlinear dependencies

As we saw in Section 2, the RWH characterizing the RON/EUR exchange rate is rather easily rejected when a group of the main linear and nonlinear tests is used. It

7 In this case, the analyzed period starts with the 172th observation from the sample (09/01/1999), the whole sample being composed of 2315 returns.

8 This change, as Schulmeister (2008) proves in the case of the German currency market is a cause of trading rules profitability.

9 Where the value of the Hurst exponent is 0.77 compared to 0.58 in the first sub period.

could also be inferred from the mentioned section that all these tests tend to find a higher prediction degree in the second sub-period, a convergence in conclusions which could justify and back up the structural break found with the Zivot-Andrews test. In other words, we can assume that within the whole sample there is a strong possibility that the sub-periods exhibiting high correlations can appear and disappear, leading us to the conclusion that a more meaningful approach of random walk testing will have to focus on the detection of the sub-periods with transient linear/nonlinear dependencies.

The results are summarized in Table 3 and they allow us to find the number of windows in which linear/nonlinear dependencies are significant at 1% risk level, rejecting thus the RWH for the whole sample, as well for the two sub-periods separated by the structural break. It can be noticed that for the first sub-period the number of windows exhibiting either linear or nonlinear correlations is low (68/1257 and 170/1107) as compared to the second period (196/959 and 659/809), a fact that can be interpreted as evidence that the intensity of these correlations increased over time.

Table 3

The number of windows in which RW hypothesis is accepted or rejected

	No. of windows	C and H insign.	C or H sign.	C sign. H insign.	H sign. C insign.	C and H sign.
N=50						
1999 – 2008	2266	2019	247	75	114	58
1999 – 2004	1257	1189	68	38	30	0
2004 – 2008	959	763	196	20	106	70
N=200						
1999 – 2008	2116	1167	949	28	557	364
1999 – 2004	1107	937	170	0	170	0
2004 – 2008	809	150	659	27	426	206

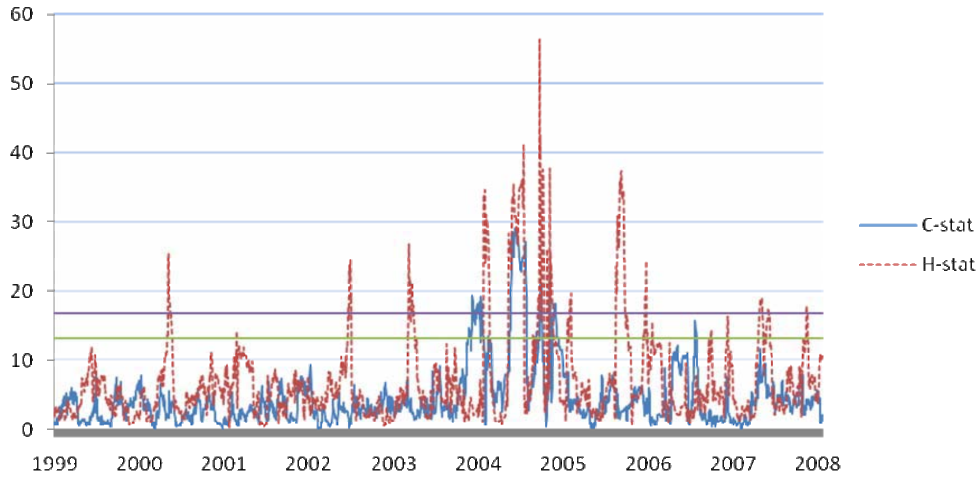
Especially during the first sub-period, the results sensitivity relative to the windows length is easily noticeable when we look at the number of windows exhibiting linear correlations solely, 38 for 50-day windows but 0 when the length becomes large enough (200), to be unable to pinpoint the manifestation of linear dependencies. We can add as an explanation that the linear dependencies from the first sub-period started to manifest themselves significantly only at its end, when the national currency depreciation process started to slow down.

Another conclusion comes from the observation that the number of windows in which nonlinear dependencies alone are rejecting the RWH is higher than those in which the rejection is based on linear dependencies solely, both for the whole sample and the second sub-period, especially for the 200-day windows case. Thus, we can state that the main factor causing the rejection of the RWH lies within the area of nonlinear dependencies.

A more detailed image of this process of transient linear/nonlinear dependencies can be obtained by plotting the C and H values over the whole sample and comparing their values with the critical values corresponding to 1% risk level[10].

Figure 3

Intensity of linear and nonlinear dependencies characterizing the RON/EUR exchange rate



4.4. Profitability analysis of the trading rules in sub-periods of linear and nonlinear correlation

Table 4 contains the annualized excess returns grouped in five classes by the significance of the C and H statistics at 1% risk level for 50- and 200-day windows. The results listed on the second column correspond to an ex-post analysis of the optimal strategy for the whole sample, highlighting a higher profitability in the sub-periods in which C and H are significantly irrelevant to the window length. Thus, the average excess returns from sub-periods rejecting the RWH are 15.15% for 50-day windows and 11.07% for 200-day windows, while in those accepting it are only 2.92% and -0.96%. Furthermore, it can be noticed that the strategy profitability is higher especially in sub-periods with simultaneous manifestation of linear and nonlinear dependencies and not in those in which only one type of dependency is exhibited.

The most profitable MA strategy from the first sub-period (characterized by a strong depreciation of the Romanian currency relative to the euro) leads to an excess return of 0.258% for windows accepting the RWH and to a null excess for those rejecting it. During the RON depreciation period we can notice only few sub-periods in which linear and nonlinear correlations coexisted, a reason for which the return of the optimal strategy is the buy-and-hold return. In the second sub-period, when the MA strategy is tested out-of sample, results are indicating a higher performance, concomitantly with a significant growth of windows rejecting the RWH. Once again, as

[10] The line for H critical value is higher than the one corresponding to the C statistic. For the 200-day windows the values of C statistic are plotted on a secondary axis on the right with the associated critical value.

it was the case with the ex-post analysis concerning the whole sample, we can observe that the strategy's profitability is due mainly to a simultaneous presence of linear and nonlinear dependencies, situation in which the excess return is 39.22% (N=50) and 11.97% (N=200). This conclusion is sustained by the results listed in the last column of Table 4, corresponding to the "new" optimal MA associated to the second sub-period.

Table 4

Annualized average excess return (%) conditioned by acceptance or rejection of the RWH

The sample	Whole Sample	RWH Acceptance	Rejection of the RWH			
		C and H Insign.	C or H sign.	C sign. H insign.	H sign. C insign.	C and H sign.
N=50						
1999 – 2008	4.275	2.925	15.15	4.625	6	46.7
1999 – 2004	0.243	0.258	0	0	0	-
2004 – 2008	6.325	4.05	15.175	29.775	-3.325	39.225
2004-2008(a)	14.275	12.775	20.15	28.575	6.525	38.5
N=200						
1999 – 2008	4.425	-0.96	11.075	4.4	6.375	18.75
1999 – 2004	0.25	0.295	0	-	0	-
2004 – 2008	4.375	0.498	5.25	-0.54	2.34	11.975
2004-2008(a)	12.15	7.7	13.125	7.7	11.15	17.775

Note: (a): "new" optimal MA.

4.5. Exploring determinants of trading rules profitability

We develop the analysis of the main causes of the profitability of MA strategies applied on the Romanian currency market as an ex-post analysis carried out for the whole sample and considering (9, 171, 0.6%) as the optimal MA strategy. The average excess return ($EXCR_t$) is first regressed against the values of the correlation and bicorrelation statistics (C_t and H_t) then against standard deviation (σ_t) as a proxy for volatility and, finally, we tested the explanatory power of the intensity of current market trends quantified through the average return within a window. We estimated and then regressed all these variables both within 50 days and 200 days intervals, resulting a total number of 2116 windows (min {2266, 2116}). The relations between these variables were analyzed by means of simple linear econometric models in which the parameters variance and covariance matrix was corrected to account for correlation and heteroskedasticity by the Newey-West (1987) method.

The results in Table 5 indicate a statistically significant direct relation between the average excess return, as a measure of the MA strategies profitability, and the values of C_t and H_t statistics, as proxies for the intensity of the linear and nonlinear correlations. This relation is exhibited especially in the case of the 200-day windows, where over 40% of the excess return variation is explained by C_t and H_t. variables. As a conclusion, we can say that the profitability of the MA strategies manifests itself episodically and depends in its turn on the episodic character of the linear and nonlinear dependencies.

Table 5

Possible determinants of trading rules profitability

Econometric model	N=50			N=200		
	$\hat{\alpha}$	$\hat{\beta}$	R^2	$\hat{\alpha}$	$\hat{\beta}$	R^2
$EXCR_t = \alpha + \beta \cdot C_t + \varepsilon_t$	-0.012**	0.000006*	0.15*	-0.00006*	0.000016*	0.57*
$EXCR_t = \alpha + \beta \cdot H_t + \varepsilon_t$	0.000016	0.000022**	0.04**	-0.00013*	0.000004*	0.45*
$EXCR_t = \alpha + \beta \cdot \sigma_t + \varepsilon_t$	0.000052	0.0223	0.005	0.00187**	-0.0017	0.00001
$C_t = \alpha + \beta \cdot \sigma_t + \varepsilon_t$	2.955*	325.7	0.027	3.256	2134.8*	0.048**
$H_t = \alpha + \beta \cdot \sigma_t + \varepsilon_t$	5.302*	330.97	0.013	52.19*	2364.1	0.0065
$EXCR_t = \alpha + \beta \cdot R_t + \varepsilon_t$	0.00033*	-0.521*	0.36*	0.00037*	-0.599*	0.64*
$C_t = \alpha + \beta \cdot R_t + \varepsilon_t$	5.22*	-1755.5*	0.11*	22.36*	-23310.3*	0.46*
$H_t = \alpha + \beta \cdot R_t + \varepsilon_t$	7.44*	-2.55**	0.025*	86.51*	-66314.1*	0.41*

*Note: The * and ** denote statistical significance at the 5% and 1% levels, respectively.*

On the other hand, the relation between the average excess return and volatility is not statistically significant regardless the window's length. Contrary to the results found by Kho (1996), our findings suggest that in the Romanian currency market the profitability of the MA trading rules is not the result of a time varying risk premium, because volatility explains only a small amount of the linear episodic dependencies and only in the case of 200-day windows. Regarding the nonlinear dependencies, we could not find a significant relation between them and volatility, result which is similar to the works of Lim *et al*. (2007) for the Asian capital markets. Anyway, this is a conclusion somehow expected, knowing previous results in Brooks and Hinich (2001) showing that the H_t statistics is independent from the heteroskedasticity effect usually characterizing the financial series.

Judging from the results from the last three rows in Table 5 we notice that market current trends have important influence both on the trading rules profitability and on the intensity with which linear/nonlinear dependencies manifest themselves. Moreover, the investigated optimal strategy is profitable especially in the sub-periods in which the national currency appreciated itself relative to the EUR, periods characterized by strong linear/nonlinear dependencies. A cause for the significant exchange rate appreciation was represented by the intervention of the National Bank of Romania, an action which usually led to temporarily inefficiencies and, implicitly, to a higher prediction degree and trading rules profitability.

5. Conclusions

The originality of this study is given by the development of a methodology which allows the analysis of the profitability for the moving average strategies with respect to the episodic behavior of linear and nonlinear dependencies. The existence of a structural break in the RON/EUR exchange rate's evolution process justifies the analysis of trading rules profitability for the two sub-periods with different behavior, namely the first sub-period of continuing depreciation of the RON currency and the second one characterized by an appreciation and a relative stability. The most profitable strategy in the first sub-period, for which the highest return in excess from the buy-and-hold strategy is recorded, is chosen from 15,000 possible strategies. Its performance is then tested out-of-sample in the second sub-period, when we find that the return excess is higher that the one from the first sub-period. This result is consistent with the results of linear and nonlinear serial correlation tests, as well as with the values of the Hurst exponent, which indicates a more significant prediction degree for the second sub-period.

The profitability of the moving average strategy is analyzed ex-post for the whole sample and for the two sub-periods with significant different evolutions, considering that the investor is either in a long or a short position. The investigated strategies resulted after a selection process which led to the identification (from 15,000 strategies) of the one for which the excess return relative to a buy-and-hold strategy is maximum in the conditions of 0.1% commission fee. The out-of-sample tests show that the return excess from the second sub period is higher than the one from the first sub period, fact which proves that the trading rule profits did not decline over time in the Romanian currency market.

The persistence over time characterizing the profits is consistent with the results of the linear and nonlinear serial correlation tests, as well as with the values of the Hurst exponent, which indicates a higher predictability degree in the second sub-period. This result is also confirmed by a higher profitability associated to the optimal strategy during the second sub-period. The correlation and bicorrelation statistics resulted after the usage of the Hinich-Patterson windowed methodology confirm for the Romanian currency market the existence (the manifestation) of an episodic behavior of the linear and nonlinear dependencies, behavior more obvious in the second sub-period in which the domestic currency appreciated itself relative to the EUR. The developed methodology proves that the important excess returns are found especially in sub-periods with linear and nonlinear correlations. Therefore, we can say that profit opportunities appear from time to time and that we are not dealing with a continuous improvement of the informational efficiency degree of the Romanian currency market, as predicted by the Efficient Market Hypothesis.

After exploring the profitability causes using simple linear econometric models we found that the trading rules profitability is strongly correlated with the intensity in the manifestation of the episodic linear and nonlinear dependencies. On the other hand, we did not identify a significant relation between profitability and volatility. This fact and the weak relation between the intensity of the linear/nonlinear correlations and volatility, suggest that trading rule profitability is not the result of a time varying risk premium. As opposed to volatility, the market trends are significantly influencing trading rules profitability. Thus, the trading rules are profitable especially in the sub-periods in which the domestic currency appreciated itself, sub-periods in which the Central Bank usually intervened in a significant way.

The results of this study plead in favor of the Adaptive Market Hypothesis developed by Lo (2004) rather than the Efficient Market Hypothesis. Conform to the evolutionist principles of this new approach, profit opportunities in the Romanian currency market are manifesting themselves in an episodic way and they do not disappear definitively. A similar conclusion is revealed for the North-American market also by the study conducted by Neely *et al*. (2009), which concentrated on a series of classical studies of the specialized literature.

References

Bonilla, C.A. Romero-Meza, R. and Hinich, M.J. (2006), "Episodic Nonlinearity in Latin American Stock Markets Indices", *Applied Economics Letters*, 13: 195-199.

Bonilla, C.A. Romero-Meza, R. and Hinich, M.J. (2007), "GARCH inadequacy for modeling exchange rates: Empirical evidence from Latin America", *Applied Economics*, 39(19): 2529-2533.

Brock, W. Lakonishok, J. and LeBaron, B. (1992), "Simple Technical Trading Rules and the Stochastic Properties of Stock Returns." *Journal of Finance*, 47: 1731-1764.

Brooks, C. Hinich, M.J. and Molyneux, R. (2000), "Episodic nonlinear event detection: Political epochs in exchange rates", In: D. Richards (Ed.), *Political complexity: Political epochs in exchange rates* , Ann Arbor, MI: Michigan University Press, pp. 83−98.

Brooks, C. and Hinich, M.J. (2001), "Bicorrelations and cross-bicorrelations as non-linearity tests and tools for exchange rate forecasting", *Journal of Forecasting*, 20: 181−196.

Cheung, Y.W. and Wong, C.Y.P. (1997), "The performance of trading rules on four Asian currency exchange rates", *Multinational Finance Journal*, 1: 1-22.

Gencay, R. (1999), "Linear, Non-Linear and Essential Foreign Exchange Rate Prediction with Simple Technical Trading Rules", *Journal of International Economics*, 47: 91-107.

Gradojevic, N. (2007), "Non-linear, hybrid exchange rate modeling and trading profitability in the foreign exchange market", *Journal of Economic Dynamics and Control*, 31: 557–574.

Hinich, M.J. and Patterson, D.M. (1995), *Detecting epochs of transient dependence in white noise, Mimeo*, University of Texas at Austin.

Hinich M.J. and Serletis A. (2007), "Episodic Nonlinear Event Detection in the Canadian Exchange Rate", *Journal of the American Statistical Association*, 102: 68-74.

Kho, B.C. (1996), "Time-varying risk premium, volatility, and technical trading rule profits: Evidence from foreign currency futures markets", *Journal of Financial Economics*, 41: 249–290.

LeBaron, B. (1999), "Technical trading rule profitability and foreign exchange intervention", *Journal of International Economics*, 49: 125-143.

Lee, C.I. Gleason, J.C. and Mathur, I. (2001), "Trading Rule Profits in Latin American Currency Spot Rates." *International Review of Financial Analysis*, 10: 135-156.

Levich, R.M. and Thomas, L. R. (1993) "The Significance of Technical Trading-Rule Profits in the Foreign Exchange Market: A Bootstrap Approach", *Journal of International Money and Finance*, 12: 451-474.

Lim, K.P. and Liew, V.K.S. (2004), "Non-linearity in financial markets: evidence from ASEAN-5 exchange rates and stock markets", *ICFAI Journal of Applied Finance*, 10(5): 5-18.

Lim, K.P. Brooks R.D. and Kim J.H. (2008), "Financial crisis and stock market efficiency: Empirical evidence from Asian countries", *International Review of Financial Analysis*, 17(3): 571-591.

Lim, K.P. Brooks R.D., Hinich, M.J. (2008), "Nonlinear serial dependence and the weak-form efficiency of Asian emerging stock markets", *Journal of International Financial Markets, Institutions and Money*, 18(5): 527-544.

Lo, A. W. (2004), "The Adaptive Markets Hypothesis: Market Efficiency from an Evolutionary Perspective", *Journal of Portfolio Management*, 30th Anniversary Issue: 15-29.

Lobato, I.N. Nankervis J.C. and Savin, N.E. (2002), "Testing for Zero Autocorrelation in the Presence of Statistical Dependence", *Econometric Theory*, 18: 730-743.

Maillet, B. and Michel, T. (2000), "Further Insights on the Puzzle of Technical Analysis Profitability." *European Journal of Finance*, 6: 196-224.

McLeod, A.I. and Li, W.K. (1983), "Diagnostic Checking ARMA Time Series Models Using Squared-Residual Autocorrelations", *Journal of Time Series Analysis*, 4: 269-273.

Neely, C.J. Weller, P. and Dittmar, R. (1997), "Is Technical Analysis in the Foreign Exchange Market Profitable? A Genetic Programming Approach", *Journal of Financial and Quantitative Analysis*, 32: 405-426.

Neely, C. J. Weller, P. A. and Ulrich, J. M. (2009), "The Adaptive Market Hypothesis: Evidence from the Foreign Exchange Market", *Journal of Financial and Quantitative Analysis*, 44:467-488.

Newey, W.K. and West, K.D. (1987), "A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix", *Econometrica*, 55(3): 73-708.

Okunev, J. and White, D. (2003), "Do Momentum Strategies Still Work in Foreign Currency Markets?", *Journal of Financial and Quantitative Analysis*, 38: 425-447.

Olson, D. (2004), "Have trading rule profits in the currency markets declined over time?", *Journal of Banking and Finance*, 28: 85–105.

Patterson, D. and Ashley, R. (2000), *A Nonlinear Time Series Workshop: A Toolkit for Detecting and Identifying Nonlinear Serial Dependence*, Kluwer Academic Publishers, Boston.

Qi, M. and Wu, Y. (2006), "Technical Trading-Rule Profitability, Data Snooping, and Reality Check: Evidence from the Foreign Exchange Market", *Journal of Money, Credit, and Banking*, 38(8): 2136-2158.

Saacke, P. (2002), “Technical analysis and the effectiveness of central bank intervention”, *Journal of International Money and Finance*, 21: 459-479.

Schulmeister, S. (2008), “Components of the profitability of technical currency trading”, *Applied Financial Economics*, 11: 917 – 930.

Shik, T.C. and Chong, T.T.L. (2007), “A comparison of MA and RSI returns with exchange rate intervention”, *Applied Economics Letters*, 14(5):371-383.

Sweeney, R. J. (1986), “Beating the Foreign Exchange Market”, *Journal of Finance*, 41: 163-182.

Tabak, B.M. and Lima E.J. (2009), “Market efficiency of Brazilian exchange rate: Evidence from variance ratio statistics and technical trading rules”, *European Journal of Operational Research*, 194: 814–820.

Todea, A. Zoicas-Ienciu, A. (2008), “Episodic Dependencies in Central and Eastern Europe Stock Markets”, *Applied Economics Letters* 15(13): 1123-1126.

Tsay, R.S. (1986), “Nonlinearity Tests for Time Series”, *Biometrika*, 73: 461-466.

Zivot, E. and Andrews, D. (1992), “Further evidence of great crash, the oil price shock and unit root hypothesis”, *Journal of Business and Economic Statistics*, 10: 251-270.