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HIGH-FREQUENCY DATA AND THE EFFECTIVENESS OF THE SPOT EXCHANGE RATE EUR/USD

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Abstract

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The boom of information technology in recent years significantly influenced the development of the financial markets. Financial markets have become accessible to the public, and increased demand for financial instruments is inevitably reflected in the advanced menu of securities dealers who currently offer a wide variety of investment in the underlying assets and through financial leverage allows investors to profit from tiny price changes of the underlying asset. Shortening of trading period and increasing the frequency of the trades clearly contributes to the growth of profits of securities dealers. The question remains whether this trading method offers the advantage to the investor himself, and whether the investor is able to take advantage of potential market inefficiencies to achieve above-average profits in the short term period. Therefore, this paper analyzes the behaviour of the spot exchange rate EUR/USD within a day, and through statistical tests examining the validity of the random walk hypothesis for the 5-minute, hourly, 4-hourly and daily changes in the spot exchange rate of the currency pair EUR/USD.

foreign exchange market, EUR/USD, high-frequency data, market efficiency

The issue of the behaviour of spot exchange rates in the foreign exchange market is a widely discussed topic within the professional community. One of the theories explaining the behaviour of exchange rates and prices of financial assets in the capital markets in general is the efficient market hypothesis. The hypothesis is connected to Eugene Fama (1969), who proposed three types of efficiency defining an efficient market as a market, where prices fully reflect available information.

The main goal of the paper is to prove randomness of price changes, or vice versa confirm the existence of dependencies between changes in exchange rates, which could be used to achieve above-average profits. The authors focus primarily on the effectiveness of foreign exchange market and specifically analyze the behavior of spot exchange rate EUR/USD in a very short time intervals through autocorrelation test and variance ratio test. These statistical methods testing relations between changes in the exchange rates have been appearing since the mid 70's of the last century. Burt *et al.* (1977), Cornell and Dietrich (1978), Hsieh (1987) tested behaviour of daily rates of most traded currencies against the U.S. dollar. They used autocorrelation and runs tests in your papers. They mostly proved that there was only small or zero correlation in daily changes of the most important spot exchange rates. They also proved that probability distributions of returns in foreign exchange rates are not of a normal distribution. The same findings appeared in Charles and Darne (2009), who stated that the behaviour of EUR/USD follows the random walk theory. Lo and MacKinlay (1988) developed a standard variance ratio test, which have become a widely used tool for analyzing the behaviour of exchange rates. The primary advantage of this test is the ability to test non-linear dependencies as well. Liu and He (1991) applied the variance ratio test to weekly changes in the following currency pairs: CAD, JPY, GBP, DEM and FRF against USD and rejected the hypothesis of an efficient market for all currency pairs in the research. Chang (2004) repeated this test for daily changes in these courses and found inefficiencies only within the JPY/USD pair. So far, most of published papers verified the random walk hypothesis for daily price changes. However, with the increasing availability of high-frequency data, a professional attention has turned to the analysis of intra-daily exchange rate behaviour.

Therefore, in addition to daily changes in the exchange rate of EUR/USD the 5-minute, 1-hour and 4-hour changes will be analyzed in spot foreign exchange rates. Intra-daily exchange rate efficiency is usually tested through another result of efficient market – possibilities to achieve above-average profits. Such as in Neely and Weller (2003) genetic programming was employed to predict the development of half-hourly price changes for CHF, DEM, JPY and GBP against to American dollar in 1996. The models considering trading hours and transaction costs failed to provide above-average income and failed to disprove the hypothesis of weak form of efficiency of the foreign exchange market during intra-daily trading. The method of genetic programming based on technical indicators was applied by Dempster (2001), who tried to use this method to predict the behaviour of the 15-minute returns of exchange rate for the GBP/USD pair. When the author has calculated transaction costs in the model, this method was not able to achieve above-average profits. The same findings were revealed by Curcio *et al.* (1997) who applied the filter tests to "tick by tick" data[1] for currency pairs of the DEM, JPY, GBP against the USD. Observations decomposed into two time intervals, and concluded that the use of filter tests on the high-frequency data does not gain more than the average for an investor. Therefore, we can assume that even intra-daily behaviour of exchange rates cannot be predicted based on historical data therefore such data are not dependent on each other. This assumption will be verified by statistical tests published in this paper.

METHODS AND RESOURCES

Data

To test the effectiveness of the EUR/USD currency pair daily, 4-hourly, hourly and 5-minute returns were used. The data used in this study come from the data centre of MetaQuotes Software Corp. available on X-Trade Brokers Czech Republic's web site. Each time series contained approximately 10,000 values, it represented a time zone for a 5-minute time period from 01. 01. 2011 to 28. 02. 2011, at the hour time zone from 03. 07. 2009 to 28. 02. 2011 and 4-hourly change interval from 22. 09. 2004 to 28. 02. 2011. For daily time zone an interval from August 11, 2003 to February 28, 2011 was studied with 2000 values only.

Autocorrelation tests

Autocorrelations are often used to test the efficient market hypothesis. If the efficient market hypothesis applies, a price of the asset absorbs newly incoming information quickly and without unnecessary delays, which results in a new market-clearing price. If new information comes randomly, exchange rate changes in financial assets will also be random and independent.

Linear dependence of members of a time series can be analysed using the autocorrelation function.

$$\rho_k = \frac{\sum_{t=1}^{n-k}(r_t-\bar{r})(r_{t-k}-\bar{r})}{\sum_{t=1}^{n}(r_t-\bar{r})^2}$$

The correlation coefficient ρ stands for a degree of relation between past r_{t-k} and the current return r_t, where k represents a "time shift". The higher absolute value of the correlation coefficient implies a higher correlation between current and lagged members of a time series and increases the probability of an inefficient market, and vice versa. As the variability of price changes of financial assets (returns) is an increasing function of the price of these assets, it is necessary to adjust the price changes using a logarithmic transformation.

$$r_t = \ln\frac{p_t}{p_{t-1}} = \ln p_t - \ln p_{t-1} \cong \frac{p_t}{p_{t-1}} - 1$$

In testing the character of the time series, it is necessary to define testing hypothesis and confidence interval for individual correlation coefficient. It can be argued that the market is efficient if there is no linear dependency between the prices of securities. Defined as:

$$H_0 : \rho_k = 0$$

$$H_A : \rho_k \neq 0$$

In addition to testing of autocorrelation coefficients for the various lags a single hypothesis that all autocorrelation coefficients for varying the lags length in the time series are simultaneously equal to zero can be tested.

$$H_0 : \rho_1 = \rho_2 = \ldots = \rho_m = 0$$

$$H_A : \rho_k \neq 0 \text{ for } k \in 1, \ldots m$$

In such cases, Ljung and Box (1978) defined test statistic, where N represents the sample size, m is the number of tested lags and indicates the individual autocorrelation coefficient for lag k.

1 High-frequency data, which record every change in quotation of a currency pair.

$$Q = N(N+2)\sum_{k=1}^{m}\left(\frac{\hat{\rho}_k^2}{N-k}\right)$$

The test statistic Q is compared to the chi-square distribution with *m* degrees of freedom. The null hypothesis H_0 of residue randomness is rejected if the test statistic lies within the critical region.

$$Q > \chi^2_{1-\alpha}, m$$

Variance ratio test

The variance ratio test was defined by Lo a MacKinlay (1989). This test is based on the definition of the random walk, where the variance of returns is a linear function of time. For example, the variance of return logarithms for two days $k = 2$ must be equal to twice the variance of logarithms of daily returns. The ratio of variance *VR (k)* is defined as follows:

$$VR(k) = \frac{\sigma^2(k)}{\sigma^2(1)},$$

where $\sigma^2(k)$ is the variance of returns calculated from periods with the length of the *k* divided by the length of time *q*. $\sigma^2(1)$ is a variance of returns calculated from the immediately consecutive prices, see Lo and MacKinlay (1989):

$$\sigma^2(k) = \frac{1}{m}\sum_{t=1}^{T}\left(r_t + r_{t-1} + ... + r_{t-k+1} - k\hat{\mu}\right) = \frac{1}{m}\sum_{t=k}^{T}\left(\left(\ln p_t - \ln p_{t-k}\right) - k\hat{\mu}\right)^2$$

$$\sigma^2(1) = \frac{1}{(T-1)}\sum_{t=1}^{T}\left(r_t - \hat{\mu}\right) = \frac{1}{(T-1)}\sum_{t=1}^{T}\left(\left(\ln p_t - \ln p_{t-1}\right) - \hat{\mu}\right)^2,$$

where

$$m = k\left(T - k + 1\right)\left(1 - \frac{k}{T}\right)$$

$$\hat{\mu} = \frac{1}{T}\left(\ln p_T - \ln p_0\right)$$

p_0 and p_T are the first and the last values of the price time series. The random walk hypothesis can be rejected if the variance ratio is equal to one[2]:

$$H_0 : \hat{V}R(q) = 1$$

$$H_A : \hat{V}R(q) \neq 1.$$

Using this test the correlation of price changes (returns), but also other forms of non-linear dependence are possible to be tested. This test is applicable to all forms of random walks. However, there is a need to consider two different test statistics – z (q) for constant variance (homoskedasticity) of exchange rate changes and * (q) for variable variance (heteroskedasticity) of exchange rate changes. Test statistics z (q) and * (q) asymptotically follow normal standard distribution and are defined as follows.

Test statistic derived for price changes with a constant variance is defined as:

$$z(q) = \frac{VR(q) - 1}{\sqrt{\varphi(q)}} \sim N(0,1)$$

$$\varphi(q) = \frac{2(2q-1)(q-1)}{3q(nq)}.$$

Test statistic derived for price changes with a variable variance is defined as:

$$z^*(q) = \frac{VR(q) - 1}{\sqrt{\varphi^*(q)}} \sim N(0,1)$$

$$\varphi^*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2 \hat{\delta}(j)$$

$$\hat{\delta}(j) = \frac{\sum_{t=j+1}^{nq}\left(\left(\ln p_t - \ln p_{t-1}\right) - \hat{\mu}\right)^2\left(\left(\ln p_{t-j} - \ln p_{t-j-1}\right) - \hat{\mu}\right)^2}{\sum_{t=1}^{nq}\left[\left(\left(\ln p_t - \ln p_{t-1}\right) - \hat{\mu}^2\right)\right]^2}$$

When using test statistics *(q)* it is necessary to know, that it has been defined for the hypothesis RW1 and is therefore it is necessary to test that the logarithm increments of exchange rates increases are based on the same probability distribution of *IID* additionally. In contrast, the independence, or un-correlation is significant enough using the *z'(q)*, statistic applicable for RW2 and RW3 hypotheses.

RESULTS AND DISCUSSION

Tab. I revealed the descriptive characteristics of the 5-minute, 1-hours, 4-hours and daily changes in the exchange rate, defined as the difference between the logarithms of the closing exchange rates of a current and previous period - $Ln(Close_1)$-$Ln(Close_0)$. Daily changes in the exchange rate of EUR/USD were influenced by the depreciation of the U.S. dollar in the reference period. It is evident from the positive daily average returns. The long-term trend probably influenced returns in shorter periods as well. Only a 1-hour average exchange rate of the EUR/USD changes revealed the opposite value compared to

2 The variance ratio VR (q) of less than one proves negative dependency. On the contrary, value greater than one indicates positive dependence.

I: *Descriptive statistics for ln exchange rate returns of EUR/USD*

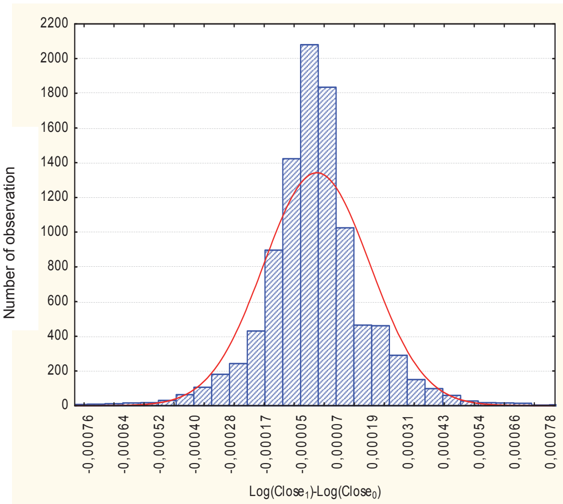
Return	Number	Mean return	Risk	Skewness	Kurtosis	Jargue-Bera test
5 min	9,999	0.000003	0.000176	0.265319	6.000739	15101.47*
1 hour	9,999	–0.000001	0.000625	–1.229088	42.873753	767552.58*
4 hour	9,999	0.000005	0.001173	–0.166935	8.977062	33583.20*
1 day	1,999	0.000042	0.002914	–0.001480	2.104297	365.93*

* significant at the 0.01 level
Source: authors'calculation

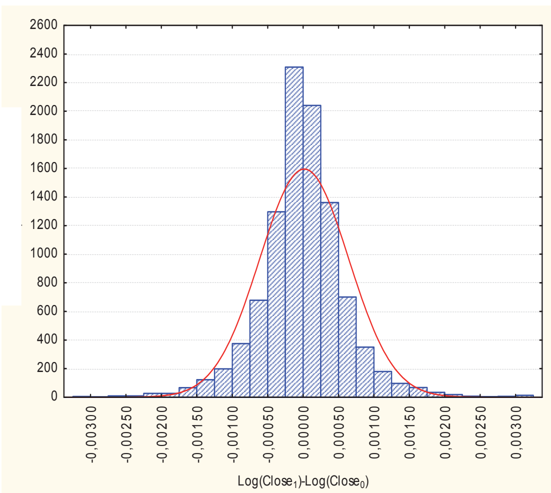
daily returns probably due to different lengths of the research periods for differently long exchange rate changes. Variability of changes in spot exchange rates, as measured by standard deviation, increased for all of the observed rates along with the length of exchange rate changes. The probability distribution of exchange rate changes revealed a high degree of kurtosis in all measured returns compared to normal distribution. Kurtosis coefficient of the highest value was revealed for 1-hour returns and the lowest value was observed in daily returns. The last column showed the Jarque-Bera test statistic, which rejected the hypothesis of normal distribution. This phenomenon was also revealed by 1–4 figures. Changes in spot exchange rates revealed of the extreme number of small changes and also a higher number of extreme values, which was reflected in fat tails of the observed distribution compared to normal distribution.

Autocorrelations

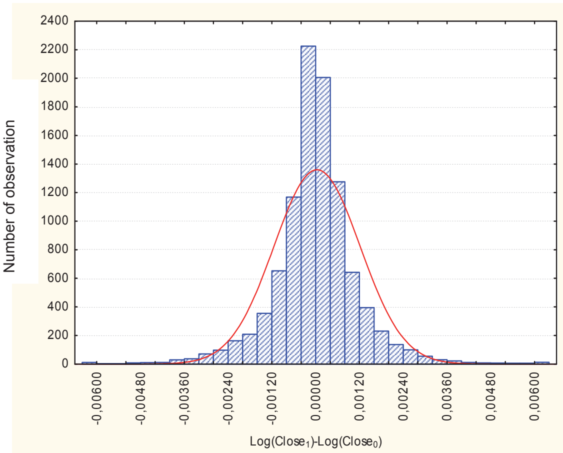
Tab. II revealed results of tests testing linear dependency of exchange rate returns. The first half of the table described the values of the correlation



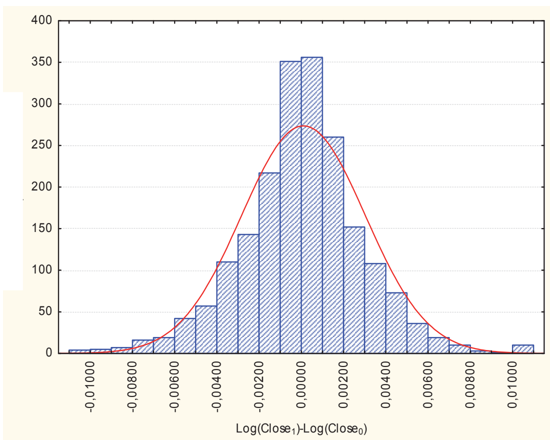
1: *Histogram of log returns EUR/USD 5-Min*



2: *Histogram of log returns EUR/USD 1-Hour*



3: *Histogram of log returnsEUR/USD 4-Hour*



4: *Histogram of log returns EUR/USD 1-Day* coefficient ρ for 1 to 20 lag. Correlation coefficients showed very low values. All values of coefficients were less than 0.1. But Ljung-Box test showed a significant negative dependence within 5-minute exchange rate changes with lag 1 and within 1-hour and 4-hour exchange rate changes with lag 5 was prove positive linear dependence. Negative correlation of 5-minute returns of currency pairs or equities with a time lag were described by Lo and Mackinlay (1990), Baillie and Bollerslev (1991) and Neely and Weller (2003). The effect is explained by asynchronous trading. Asynchronous trading is typical for less liquid markets, with accumulation of trading orders in some intervals, alternated with intervals with realizing some of those orders. Zero change in the rate is followed by a positive change, and if there is trade realized in the next period another zero change will follow. Although the foreign exchange markets are characterized by high liquidity, this effect may occur especially at night. Negative correlations in short time intervals can be influenced by the "ask-bid bounce effect which occurs when orders to buy and sell currencies shift and the market price fluctuates between demanded and offered price. Positive autocorrelation for the hourly and four-hourly returns of lag 5 might be due to the time lag in trading hours of different business centres. The effect was described by Bredon and Ronaldo (2011), who argued that the flow of orders to buy and sell currencies and their returns was not affected by asynchronous information, but it is the difference between trading hours in Europe and the USA.

Variance ratio test

Tab. III revealed the results of the variance ratio test, which had considered nonlinear relations between spot exchange rate returns. Periods with length of two, five, ten and twenty were successively applied for this test. Random walk of RW1 type supposing constant mean value, homoskedasticity and IID returns was tested in the first part of the table. For longer time series, however, we can assume neither constant mean value nor homoskedasticity. That's why the other half of the table tested random walks of RW2 and RW3 type for which the assumption of independent returns was sufficient.

A strict definition of random walk of the RW1 type, rejected the hypotheses of a random walk at the significance level of 0.01 in three cases for 5-minute price change for the length of the period of two, five and ten. Testing the random walk hypothesis for the RWE2 and RWE3 the null hypotheses of a random walk were rejected in two cases for 5-minute returns with the length of two and five. Behaviour one and four-hourly and daily return was consistent with the random walk. The result agrees to Charles and Darne's (2011) findings that proved the independence of daily and weekly

II: *Autocorrelations of ln returns to EUR/USD exchange rate*

Lag	Correlation coefficient				Ljung-Box statistics			
	5 Min	1 Hour	4 Hour	1 Day	5 Min	1 Hour	4 Hour	1 Day
1	–0.0486	–0.0106	0.0011	–0.0090	23.6423*	1.1257	0.0121	0.1612
2	–0.0108	0.0041	0.0072	–0.0315	24.8107*	1.2934	0.5245	2.1484
3	–0.0236	–0.0082	–0.0250	0.0283	30.3925*	1.9662	6.7617	3.7551
4	0.0129	–0.0113	0.0129	–0.0266	32.0561*	3.2504	8.4195	5.1728
5	0.0121	0.0410	0.0395	0.0078	33.5259*	20.0789*	24.0392*	5.2944
6	0.0052	–0.0046	–0.0137	0.0102	33.7985*	20.2885*	25.9133*	5.5027
7	–0.0076	–0.0190	0.0002	0.0198	34.3799*	23.8942*	25.9137*	6.2869
8	0.0157	–0.0100	–0.0039	0.0566	36.8341*	24.8947*	26.0656*	12.6885
9	–0.0190	0.0066	–0.0104	–0.0394	40.4608*	25.3245*	27.1420*	15.7824
10	–0.0011	0.0186	0.0109	0.0097	40.4737*	28.7873*	28.3383*	15.9702
11	–0.0105	–0.0002	0.0277	–0.0378	41.5714*	28.7876*	36.0034*	18.8298
12	–0.0018	–0.0171	–0.0254	0.0104	41.6052*	31.6990*	42.4387*	19.0468
13	0.0087	–0.0161	–0.0078	0.0117	42.3665*	34.3016*	43.0405*	19.3186
14	0.0078	–0.0226	0.0052	0.0051	42.9751*	39.4081*	43.3094*	19.3699
15	–0.0044	0.0095	0.0080	0.0567	43.1694*	40.3139*	43.9416*	25.7893
16	–0.0046	0.0029	–0.0104	0.0028	43.3837*	40.4005*	45.0236*	25.8052
17	–0.0077	–0.0153	–0.0229	0.0153	43.9720*	42.7329*	50.2691*	26.2723
18	0.0142	0.0245	0.0051	0.0241	45.9863*	48.7127*	50.5249*	27.4296
19	0.0002	0.0001	–0.0209	0.0025	45.9866*	48.7128*	54.8824*	27.4422
20	0.0083	–0.0162	0.0167	0.0225	46.6708*	51.3449*	57.6695*	28.4457

* significant at the 0.01 level
Source: authors' calculation

III: *Variance ratio test of ln returns to EUR/USD exchange rate*

Return	VR	Period lenght (q)							
		RW1				RW2 (3)			
		2	5	10	20	2	5	10	20
5-Min	Ratio diff.	0.951	0.896	0.893	0.880	0.951	0.896	0.893	0.880
	VR stat	–4.842*	–4.737*	–3.154*	–2.395	–3.519*	–3.418*	–2.337	–1.837
1-Hour	Ratio diff.	0.989	0.977	0.987	0.970	0.989	0.977	0.987	0.970
	VR stat	–1.049	–1.023	–0.372	–0.593	–0.809	–0.831	–0.317	–0.526
4-Hour	Ratio diff.	1.001	0.996	1.021	1.026	1.001	0.996	1.021	1.026
	VR stat	0.129	–0.164	0.622	0.535	0.090	–0.119	0.450	0.388
1-Day	Ratio diff.	0.991	0.963	0.986	1.050	0.991	0.963	0.986	1.050
	VR stat	–0.370	–0.751	–0.183	0.450	–0.306	–0.605	–0.147	0.361

* significant at the 0.01 level
Source: authors' calculation

rates of the EUR/USD. The variance ratio test revealed that the exchange rate of the EUR/USD is inefficient only in very short time intervals and that it is able to absorb new information within one hour since their publishing. Therefore, the random walk hypothesis condition has already been fulfilled for hourly returns.

CONCLUSION

Ljung-Box test and Variance ratio test consistently reject the null hypothesis of a random walk in 5-minute exchange rate changes and pointed to the existence of a negative relationship between immediately successive exchange rate changes, which were most likely due to asynchronous trading. Ljung-Box test to a lesser extent, demonstrated a statistically significant correlation with a 1-hourly and 4-hourly exchange rate changes. Although statistical tests indicate inefficiency of the foreign exchange market in the short term, it is necessary to consider the extent to which the test results were affected as the sample size or the chosen level of significance. Remains a question, whether positive correlation are strong enough and stable enough that they can be used to predict the future development of the foreign exchange rate and achieve above average earnings. This issue will be the subject of further research of both authors.

SUMMARY

Therefore, this paper analyzed the behaviour of the spot exchange rate EUR/USD within a for 5-minute, hourly, 4-hourly and daily changes. The aim of the paper was to describe the distribution of returns in time intervals using autocorrelation and variance ratio tests and to assess of the condition of low-efficiency is fulfilled even for short-time intervals.

Distribution of the returns in exchange rates was symmetric for all the observed lengths with higher degree of kurtosis compared to normal distribution. Degree of skewness for all lengths of returns was close to zero, indicating the absence of long-term trend. High degree of kurtosis (the highest rate of kurtosis was recorded for hourly returns) was the evidence of a large number of small price changes and continuous adaptation to new internal value.

The variance ratio test revealed that hourly, 4-hourly and daily changes in the spot exchange rate EUR/USD were independent fulfilling the conditions of weak market efficiency. The random walk hypothesis was rejected only for 5-minute returns. This fact was also confirmed by autocorrelation tests, which revealed a significant dependence on the length of the lag 1. Negative autocorrelation for two immediately consecutive 5-minute returns can be explained by asynchronous trading especially at night, and partly also by bid-ask bounce effect. Tests of autocorrelation, unlike the ratio variance test proved a possible relation between hourly and 4-hourly returns with the length of lag of five. This dependence was most likely caused by a shift in trading hours between Europe and the USA.

Randomness of hourly and longer-time price changes is caused by the heterogeneous expectations of market participants and the varying length of the investment horizon. The randomness of price changes should result in the inability to achieve above-average returns of retail merchants. This statement does not apply to market makers and large financial institutions in the currency market. Inability to achieve above-average returns in intra-daily trading is another condition for the effective functioning of the money market. The authors will pay attention to this issue in their further research.

REFERENCES

BAILLIE, R. T., BOLLERSEV, T., 1991: Intra-day and Inter-market Volatility in Foreign Exchange Rates, *Review of Economic Studies,* 58, 3: 565–585. ISSN 0034-6527.

BREEDON, F., RONALDO, A., 2010: *Intraday patterns in FX returns and order flow*, Swiss National Bank Working Papers, 1–28. Available from: http://www.snb.ch/n/mmr/reference/working_paper_2011_04/source.

BURT, J., KEEN, F. R., BOOTH, G. G., 1979: Foreign Exchange Market Efficiency Under Flexible Exchnage Rates. *The Journal of Finance,* 32, 4: 1325–1330. ISSN 1540-6261.

CHANG, Y., 2004: A re-examination of variance-ratio test of random walks in foreign exchange rates, *Applied Financial Economics,* 14, 9: 671–679. ISSN 0960-3107.

CHARLES, A., DARNE, O., 2009: Testing for random walk behavior in euro exchange rates, *Économie internationale*, 119, 3/2009: 25–45. ISSN 2110-7017.

CORNELL, W. B., DIETRICH, J. K., 1978: The Efficiency of the Market for Foreign Exchange Under Floating Exchange Rates. *Review of Economics and Statistics,* 60, 1/1978: 111–120. ISSN 0034-6535.

CURCIO, R., GOODHART, CH., GUILLAUME, D., PAYNE, R., 1997: Do technical trading rules generate profits? Conclusions from the intra-day foreign exchange market, *International Journal of Finance & Economics,* 4, 2: 267–280. ISSN 1099-1158.

DEMPSTER, M. A. H., PAYNE, T. V., ROMAHI, Y., THOMPSON, G. W. P., 2001: Computational learning techniques for intraday FX trading using popular technical indicators, *Ieee transactions on neural networks,* 12, 4: 744–754. ISSN: 1045-9227.

FAMA, E. F., 1969: Efficient capital markets: A review of theory and empirical work. *Journal of Finance,* 25, 2: 383–417. ISSN 1540-6261.

HSIEH, D., 1988: The statistical property of daily foreign exchange rates: 1974-1983. *Journal of International Economics,* 24, 1: 129–145. ISSN 0022-1996.

LIU, C. Y., HE, J., 1991: A variance ratio test of random walks in foreign exchange rate, *Journal of Finance,* 46, 2: 773–785. ISSN 1540-6261.

LJUNG, G. M., BOX, G. E. P., 1978: On a measure of lack of fit in time series models, *Biometrika*, 6, 2: 297–303. ISSN 0006-3444.

LO, A. W., MACKINLAY, A. C., 1988: Stock Market Prices do not Follow Random Walks: Evidence from a Simple Specification Test. *The Review of Financial Studies,* 1, 1: 41–66. ISSN 0893-9454.

LO, A. W., MACKILAY, A. C., 1989: The size and power of the variance ratio test infinite samples: A Monte Carlo investigation, *Journal of Econometrics,* 40, 2: 203–238. ISSN 0304-4076.

LO, A. W., MACKILAY, A. C., 1990: When are contrarian profits due to stock market overreaction?, *The Review of Financial Studies,* 3, 2: 175–205. ISSN 0893-9454.

NEELY, CH. J., WELLER, P. A., 2003: Intraday technical trading in the foreign exchange market, *Journal of International Money and Finance,* 22, 2: 223–237. ISSN 0261-5606.

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