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Market Efficiency Hypothesis in the Czech Foreign Exchange Market: CZK/EUR Case[1]

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Abstract

Although Fama´s formula of market efficiency hypothesis was rejected soon after its publishing in 1970s, it is being discussed heavily since then till nowadays. The main purpose of this topic is to confirm an option about existence of long run arbitrary riskless profits able to be achieved by simple trading rules on the current financial market. Despite the statistical rejections in many studies of the market hypothesis efficiency, this analysis provides useful information about the level of "efficiency" behavior of current financial asset. Moreover day trading is being recommended. The market efficiency hypothesis test on the real Czech data deducted from the covered and uncovered interest rates parity is the main task in this paper. Forward rate (with particular maturity) is expected to be an unbiased predictor of the future spot exchange rate. The expectations about the future spot exchange rate follow the stable probabilistic distribution and the forward rate that has appeared before is assumed to be a mean value of this distribution. The whole case is tested on the real data gathered by the Czech national bank in the period between 2001 and 2011.

Keywords*: : forward rate, efficient market hypothesis, unbiased predictor, spurious regression*
JEL classification: E37, E47

1. Introduction

This contribution deals with both theoretical interpretation of fundamentals for exchange rate factors and practical econometrical analysis of the exchange rate CZK/EUR evolution for the last ten years. According to Fama´s formula the forward rate in particular time serves as unbiased predictor for the expected spot exchange rate in time of the forward rate maturity. In this contribution we are analyzing the way in which there is the relation between the forward rate and the future maturity spot exchange rate observed in dataset of the CZK/EUR exchange rate and the 3M forward rate (3M means three months maturity of forward rate) of this contract. The main task in this article is to answer the problematic question about the exchange rate asset in a form, as if it is able for this market to be supposed as an efficient market (efficient market hypothesis confirmation).

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2. Theoretic background

As if the market for any financial asset is supposed to be efficient, anyone could not expected long term regular riskless abnormal profits from simple speculation with this financial asset. Moreover it is implicitly assumed that there is no asymmetric information, so that all the market participants are using the perfect information. Additional main assumptions are the rational expectation assumption and the risk neutral relation to risk itself for any market participant on the financial asset market. Then it is rational for any market participant (able to optimize) to compare expected rate of return in the domestic currency and alternatively in the foreign currency. Alternative yields are calculated due to different interest rate in the foreign economy.

The philosophy described in the previous paragraph is the basic element in the exchange rate determination theory. This approach is called the interest rate parity and is additionally reformulated in two ways – the covered and uncovered form. The uncovered interest rate parity is described according to formula (1). This formula assumes the equal value between the expected change in the exchange rate and the domestic interest rate and foreign interest rate to financial assets differentiated just with the country of issue bet with the other factors they these financial assets are identical.

$$\Delta_k s_{t+k}^e = i_t^d - i_t^f \tag{1}$$

In the interest rate parity condition (1) s_t means the natural logarithm, t represents time, i_t represents the domestic (foreign) interest rate, k is the time to maturity and e represents the market expectation in time t. The covered interest rate parity expand the philosophy with the idea of the equal value of the expected forward discount (forward premium) and the difference between the domestic interest rate and the foreign interest rate to identical financial asset.

3. Prediction ability of forward rate to foresee the future spot exchange rate

After integration the uncovered and interest rate parity together we gain the solution for the practical empirical econometrical testing the forward rate as unbiased predictor for future spot exchange rate. This solution is described in the formula (2).

$$F_t^{(k)} = E_t(S_{t+k}) \tag{2}$$

The idea in the formula (2) is being tested in many serious researches in the form of regression or just the testing the data difference between forward rate and relevant spot rates in future to follow the orthogonality condition. The formula (2) is always being rejected, even in the "weak" version market efficiency. Practically it is impossible to exclude the transaction costs, which leads to anytime deviations from the formula (2). There is "a neutral band" supposed which should be stable in time. For instance Frenkel and Levinch (1977) have made observations that almost 80 % of profit contracts with treasury bonds are lying in this band. Moreover when we assume ECB rates we gain the solution that 100 % profit contracts are lying in this „neutral band". Frenkel and Levinch (1977) state that during the times of financial instabilities profit contracts for basic currencies are going outside this neutral band. In the other words the

deviations from formula (2) are impossible to be explained with the existence of transaction costs.

Taylor (1989) assumes the "maturity effect", which shows positive dependence between the time to maturity of financial asset and the deviation from the formula (2) (profit opportunities according to the interest rate parity condition which is being rejected).

4. Other approaches to interest rate parity conditions – regression analysis

In this approach authors are always solving the regression formula shown in the formula (3).

$$f_t^{(k)} - s_t = \alpha + \beta \times (i_t^D - i_t^F) + \mu_t \quad (3)$$

Where α, β represent regression parameters and μ_t represents residuals. Practically in most important studies there is not α parameter estimation a null value, which represents the existence of transaction costs. Moreover the parameter β estimation is statistically significant from the value of one. These results are not confirming the theory of interest rates parity for exchange rate determination.

When the parameter β estimation is a minus one value, then appears a situation called "forward discount bias" which means in the other words that for instance forward premium influence the future spot exchange rate inverse than the theory would expected. Anyway the more is currency sold with the forward premium, the more this currency will be depreciating in contrary with expected appreciating.

Results of many exchange rate studies concluded that either the efficiency market hypothesis is rejected (orthogonality rejection for the residuals) or the covered interest rate parity is rejected (according to the regression analysis). In the other word it means that it is possible to achieve a long run regular riskless abnormal profit for many market participants.

5. Rethinking efficiency – risk premium

In general there are two main reasons for the market efficiency rejection on real dada either the assumption of risk neutral preferences or the pure rational expectation assumption. For the first reason we need to modify basic formula for interest rate parity according to equation (4).

$$\Delta_k s_{t+k}^e + \rho_t = i_t^d - i_t^f \quad (4)$$

Market participants then calculate risk premium ρ_t as a satisfaction (abnormal return) for risky financial foreign exchange asset. Moreover forward premium (discount) is divided into the expected depreciation (appreciation) and the risk premium (5).

$$f_t^{(k)} - s_t = \Delta_k s_{t+k}^e + \rho_t \quad (5)$$

Sarno a Taylor (2002) explain the risk premium as a part of Lucas model. This model is DSGE model for two economies. Market participant are endowed with the same preferences, but with different stochastic distribution of goods for consumption between these two economies. Finally conclusions of Lucas model are that it is not so suitable to explain abnormal profit of foreign exchange market with the risk premium. In order to be able to confirm the risk premium

model we need to take into account very high coefficient of risk averse or conditional covariance between spot rate and consumption has to be very high. Moreover in the developed countries the consumptions is stable in time in comparison with very volatile exchange rate, so that covariance between these two variables is really low.

6. Rethinking efficiency – speculative bubbles in the financial markets

As we have assumed the risk neutral preference to risk for market participants, market bubbles are then able to be supposed as a reason for long run riskless abnormal profits. Investors are expecting the rise in market even though the current price is above its equilibrium. In the other words they are expecting additional blow in the bubble. According to these factors the psychology financial theories have appeared.

$$s_t = \lambda E_t s_{t+1} + v_t \tag{6}$$

The equation number 6 explains the current exchange rate as dependent variable on the future expected exchange rate (discounted with lambda) and on the other economic factors known v_t. This equation is simple forward looking differential equation with the solution in form (there are many others solutions).

$$\dot{s}_t = \sum_{i=0}^{\infty} \lambda^i E_t v_{t+i} \tag{7}$$

$$s_t = \dot{s}_t + B_t \tag{8}$$

$$B_t = \lambda E_t B_{t+1} \tag{9}$$

B_t is the reason for "blow" into the bubble of the foreign exchange asset (exchange rate). Investors are making their decision under the risk of blow or burst the speculative bubble. The probability distribution is asymmetrical and is able to be described as following.

$$B_t = (\pi\lambda)^{-1} B_{t-1}, \text{ with probability: } \pi \tag{10}$$

$$B_t = 0, \text{ with probability: } 1\text{-}\pi \tag{11}$$

Is distinct that there is skewness in this distribution, so that the deviations from the parity conditions are expected. In order to introduce complex view of this chapter we should discuss moreover "*peso problem*" "*asymmetric information*" and "*learning by doing problem*". Due to shortage in space in article we would advise anyone to study Sarno and Taylor (2002) from further references.

7. Empirical part – the evolution in the EUR/CZK foreign exchange rate

The basic dataset consist of the time series of the forward rate points and the spot exchange rate time series. These data are able to be downloaded on the Czech National Bank web pages (http://www.cnb.cz/cs/financni_trhy/devizovy_trh/).

For the risk premium analysis we have gained the time series from 2.5. 2001 t 8.11.2011, that is 2654 observations. In order to achieve statistical excellence we have transformed these data in the month averages (finally 126 month averages). The forward contract is of type 3M, which means that forward contract has the three months maturity. The data structure is presented in the following graph. Forward rate points are divided by hundred and then sum up with the current exchange rate in order to gain the forward rate F_k.

Date	***Exchange rate***	***maturity***	***Forward rate points***	S_k	F_k
02.05.2001	EUR/CZK	3M	*7,95*	*34,545*	*34,55295*
03.05.2001	EUR/CZK	3M	*7,9*	*34,6*	*34,6079*
04.05.2001	EUR/CZK	3M	*4,45*	*34,645*	*34,64945*
07.05.2001	EUR/CZK	3M	*6,55*	*34,63*	*34,63655*
09.05.2001	EUR/CZK	3M	*4,6*	*34,625*	*34,6296*
10.05.2001	EUR/CZK	3M	*8,2*	*34,455*	*34,4632*
11.05.2001	EUR/CZK	3M	*25,75*	*34,4*	*34,42575*
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…
01.11.2011	EUR/CZK	3M	*-36,47*	*25,035*	*24,99853*
02.11.2011	EUR/CZK	3M	*-37,07*	*25,15*	*25,11293*
03.11.2011	EUR/CZK	3M	*-35,03*	*24,915*	*24,87997*
04.11.2011	EUR/CZK	3M	*-33,1*	*24,995*	*24,9619*
07.11.2011	EUR/CZK	3M	*-31,5*	*24,995*	*24,9635*
08.11.2011	EUR/CZK	3M	*-33,46*	*25,175*	*25,14154*
09.11.2011	EUR/CZK	3M	*-30,24*	*25,44*	*25,40976*

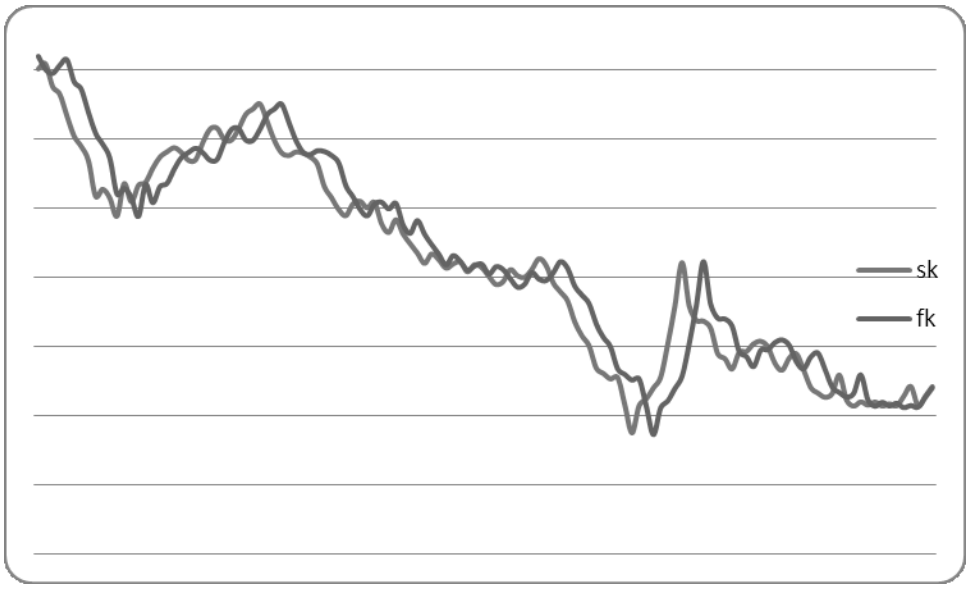
Source: author work based on the www.cnb.cz

The basic hypothesis is deducted from the equation:

$$s_{t+1} = f_{t+1} + \varepsilon_{t+1} \tag{12}$$

$$H_0: \varepsilon_{t+1} = 0 \tag{13}$$

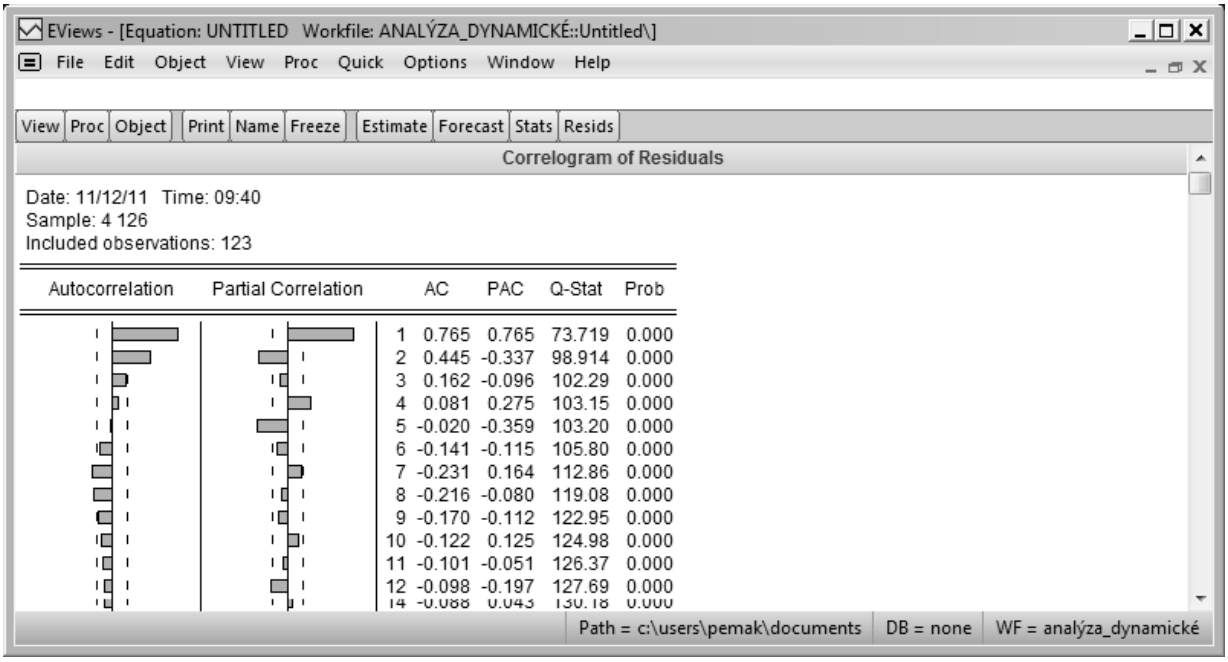
The purpose in this work is to confirm or reject the orthogonality of $\varepsilon_{t+1.}$ In the other words the forward rate in presence is in average identical as expect spot exchange rate in the future in the time of maturity. The Efficiency market hypothesis is the joint hypothesis. Moreover we assume and test the stationarity of the residuals time series (stable mean value and limited variance). According to graph of times series we make conclusion that the forward rate evolution is followed with the spot exchange rate. But as we will see further statistically it is not so simple.



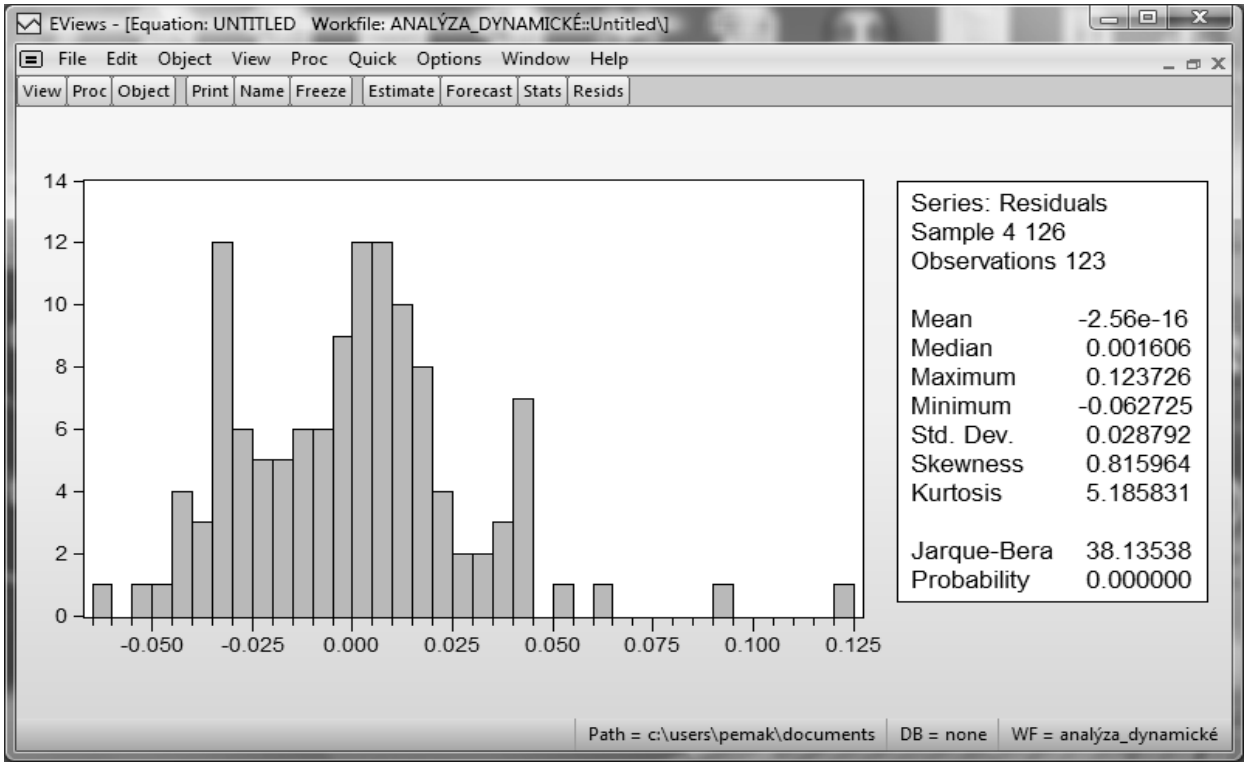
Graph. 1. Graphical analysis (Source: author)

Nevertheless as visible on the previous graph increases are followed with other increases and decreases are followed with other decreases. These time series need to be tested for stationarity. The most famous test for this characteristic of time series is the Augmented Dickey Fuller statistical test (ADF test). Null hypothesis H_0 is about the non-stationarity of time series. For forward rate time series the p-value is calculated on the value of 0,5577. It means that the null hypothesis is not allowed to be rejected on 5 % statistical significance. Or in other words H_0 about non-stationarity could be rejected on the 55,77 % statistical significance.

The spot exchange rate time series is by the test evaluated on the p-value 0,5625 so that again the null hypothesis is not able to be rejected for the spot exchange rate as well. Both time series are non-stationary, but the common equilibrium might be stationary or even orthogonal (stationary on the null value). When we use regression analysis we do observe the spurious regression because of autocorrelation (Durbin Watson statistics is of value 0,4653). This statement is confirmed with the values of autocorrelation function (ACF) or with partial correlation function (PACF). Autocorrelation is significant to *t-3* lagged observations as it is viewed on the following graph.

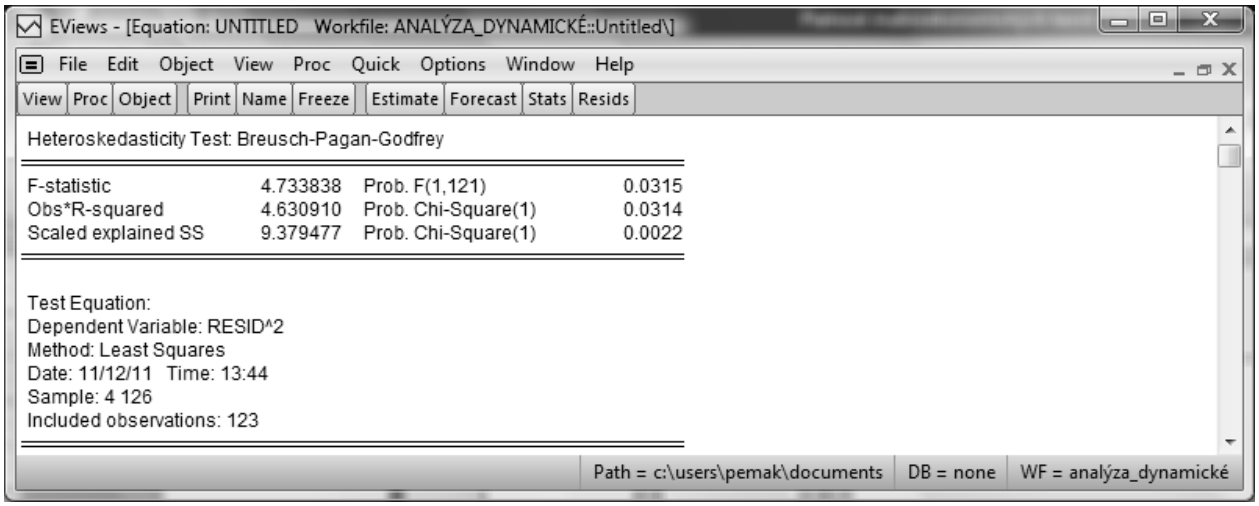


Graph. 2. ACF and ACF (Source: author in E-views)



Graph. 3. Jarque-Bera test of normality (Source: author in E-views)

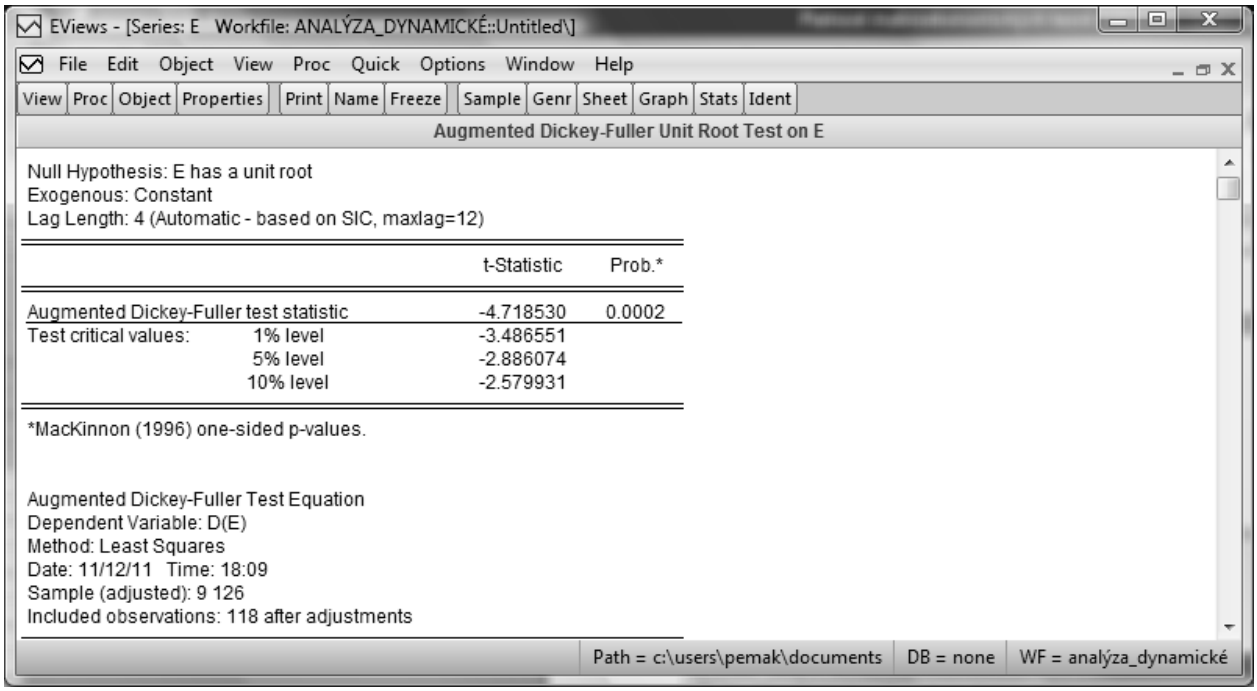
Moreover it is visible that the residuals themselves do not follow the normal probabilistic distribution as it is shown on the Graph 3. The null hypothesis about normality is rejected on any low value of statistical significance. Even further, the heteroscedasticity test (Breusch-Pagan-Godfrey) rejects the homoscedasticity (p-values are lower than 0,05). It is also visible on the graph 4. Autocorrelation, non-normality and heterescedasticity of residuals are reasons for inaptitude of created regression equation. It is just spurious regression.



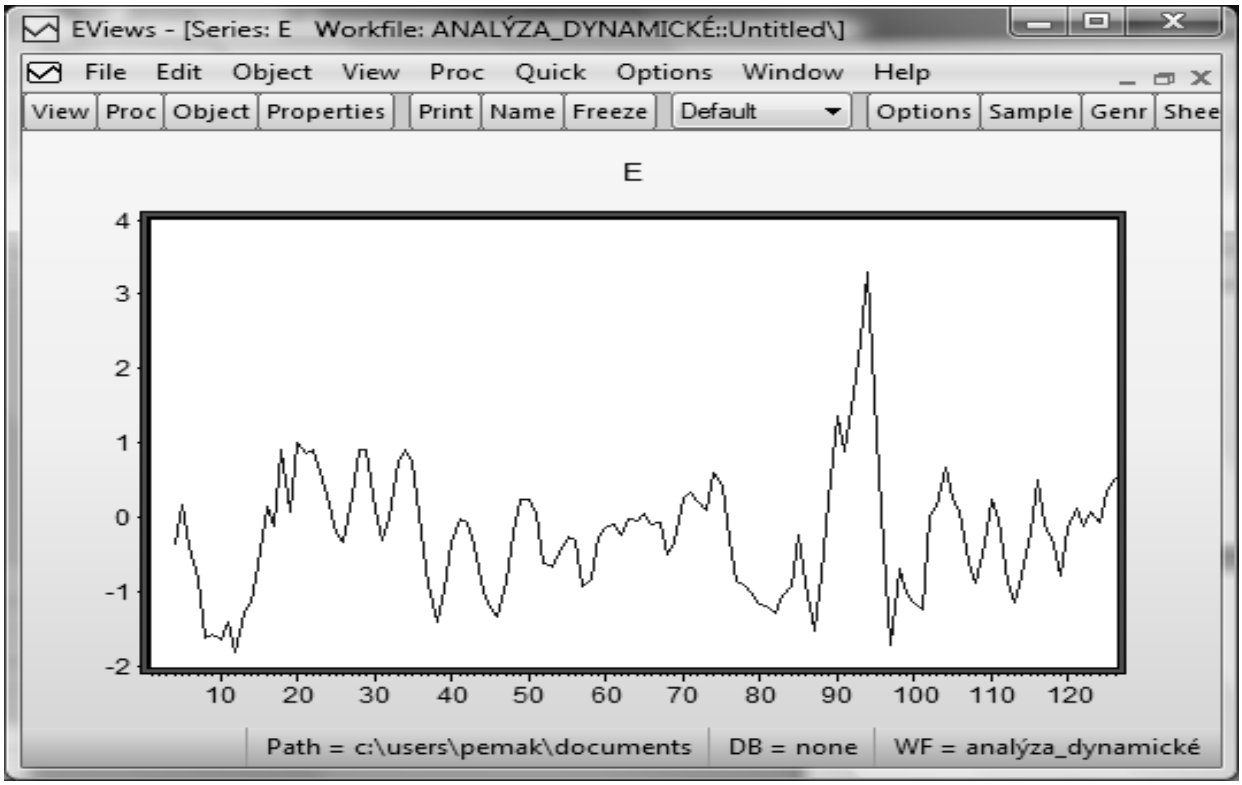
Graph. 4. Jarque-Bera test of normality (Source: author in E-views)

In order to answer the main task of this work we need to test the stationarity for the time series of differences between forward rate (*t-3* lagged) and the spot exchange rate. As we have said before both the forward rate time series and spot exchange rate time series are non-stationary (according to ADF test). The analysis will be made simple as before. The null hypothesis about non-stationarity is tested on the time series of differences with ADF test. The results are shown on the graph 5. The null hypothesis about non/stationarity is rejected on the 5 % statistical significance. Moreover according to p/value it could be rejected on the 2 % statistical significance. The difference time series is stationary as it is shown on the Graph 6.

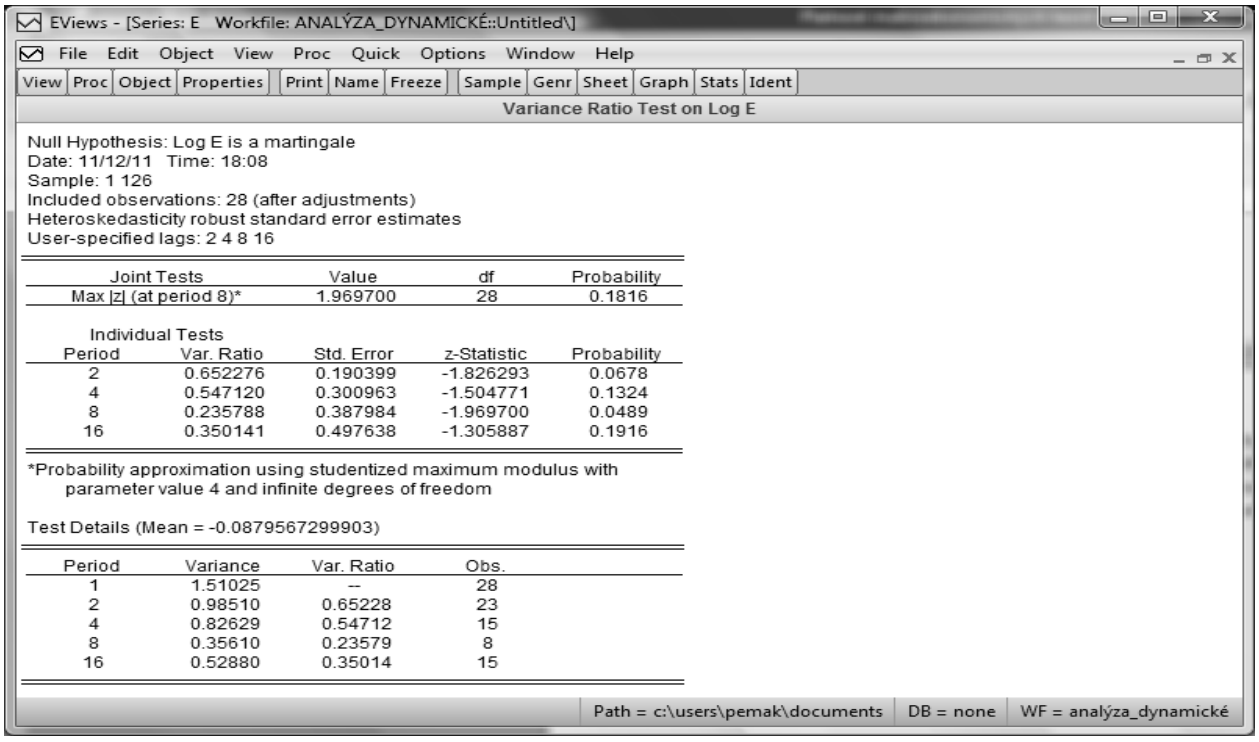
The heteroscedasticity statistical test is analyzing the null hypothesis H_0 that the differences in the parity conditions follow the stochastic process called martingale. This means that there is a stable mean value but unlimited variance. According to joint hypothesis we deduce that on 18,16 % statistical significance we can reject the null hypothesis that the time series is a martingale process. According to the level of "martingality" we can expect option for long run riskless abnormal profits in the market for the foreign exchange asset and rejection the efficiency market hypothesis.



Graph. 5. Market efficiency of foreign Exchange financial asset test (Source: author in E-views)



Graph. 6. Time series of differences in parity conditions (Source: author in E-views)



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Variance Ratio Test on Log E

Null Hypothesis: Log E is a martingale
Date: 11/12/11 Time: 18:08
Sample: 1 126
Included observations: 28 (after adjustments)
Heteroskedasticity robust standard error estimates
User-specified lags: 2 4 8 16

Joint Tests	Value	df	Probability
Max |z| (at period 8)*	1.969700	28	0.1816

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.652276	0.190399	-1.826293	0.0678
4	0.547120	0.300963	-1.504771	0.1324
8	0.235788	0.387984	-1.969700	0.0489
16	0.350141	0.497638	-1.305887	0.1916

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom

Test Details (Mean = -0.0879567299903)

Period	Variance	Var. Ratio	Obs.
1	1.51025	--	28
2	0.98510	0.65228	23
4	0.82629	0.54712	15
8	0.35610	0.23579	8
16	0.52880	0.35014	15

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Graph. 7. Martingale test in the parity conditions (Source: author in E-views)

8. Conclusions

The main task in this article is to answer the problematic question about the exchange rate asset in a form, as if it is able for this market to be supposed as an efficient market (efficient market hypothesis confirmation). In the theoretical part we have shown recent approaches to the fundamentals of the exchange rates in the form of parity conditions of interest rates and the joint hypothesis of the market efficiency in the foreign exchange financial assets. We have tested the weak form of the market efficiency hypothesis which was rejected on the real data. The differences supposed to be orthogonal have the stable null mean but data provide unlimited increasing variance. In the other words the stochastic process provides the martingale behavior.

In the part of regression analysis we have tested normality, autocorrelation and heteroscedasticity of residuals in the regression model. All these factors have been confirmed in the model so that the regression itself is just spurious regression which would have been eliminated with autoregression parameters and the GARCH method. Finally we have to make statement that trading according simple stable methods we can achieve riskless long run abnormal profits on the level of statistical significance of 5 % (martingale behavior). But with 18 % statistical significance the null hypothesis is rejected and stochastic process has stable variance so that there would have been no space for abnormal profits in the foreign exchange market CZK/EUR.

References

Frenkel, J.A.; Levinch R.M. (1977) Transactions Costs and Covered Interest Arbitrage: Tranquil versus Turbulent Periods. Journal of Political Economy, 85,s.1209-26.

Clinton, K. (1988) Transactions Costs and Covered Interest Arbitrage: Theory and Evidence. Journal of Political Economy, 96,s.358-70.

McCormic, F. (1979) *Covered Interest Arbitrage: Theory and Evidence.* Journal of Political Economy, 87,s.411-17.

Taylor, M.P. (1987) Covered Interest Parity: A High Frequency, High Quality Data Study. Economica, 54 s.429-38.

Fama, E.F. (1976) *Forward Rates as Predictors of Future Spot Rates.* Journal of Financial Economics., 3, s. 361-77.

Geweke, J.F.; Feige, E.L. (1979) *Some Joint Tests of the Efficiency of the Markets for Forward Foreign Exchange.* Review of Economics and Statistics, 61, s. 334-41.

Frenkel, J.A.(1976) A Monetary Approach to the Exchange Rate: Doctrinal Aspects an Empirical Evidence. Scandinavian Journal of Economics, 78, s. 200-24.

Sarno a Taylor (2002)

Hansen, L.P.; Hodrick, R.J. (1980) Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis. Journal of Political Economy. 88, s.829-53

Phillips, P.C.B; Hansen, B.E. (1990) Statistical Inference in Instrumental Variables Regression with I(1) Processes. Review of Economic Studies. 57, s.99-125.

Clarida, R.H.; Taylor, M.P. (1997) The Term Structure of Forward Exchange Premium and Forecastability of Spot Exchange Rates: Correcting the Errors. Reviex of Economics and Statistics. 79, s.353-61.

Froot, K.A; Frankel, J.A. (1989) *Forward Discount Bias: Is It an Exchange Risk Premium?* Quaterly Journal of Economics. 104, s.139-61.

Pošta, V. (2012) Estimation of the Time-Varying Risk Premium in the Czech Foreign Exchange Market. Prague Economic Papers. 1/2012, s. 3-17.

Liu, P.C; Maddala, G.S. (1992a) Using Survey Data to Test Market Efficiency in the Foreign Exchange Markets. Empirical Economics. 17, s.303-14.

Soukup, J. a kol. (2007) *Makroekonomie –moderní přístup*. Management Press. Praha

Sarno, L; Taylor, M.P. (2006) *The Economics of Exchange Rates.* Cambridge University Press. Cambridge.

Colander, D. (2006) *Post Walrasian Macroeconomics.* Cambridge University Press. Cambridge.

Hindls, R.; Hronová, S.; Seger, J. (2006) *Statistika pro ekonomy.* Professional Publishing. Praha.