MARKET EFFICIENCY HYPOTHESIS APPLICATION IN THE CZECH REPUBLIC – THE FOREX CASE

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Abstract

The Market Efficiency Hypothesis (MEH) in its weak form assumes that stock prices already reflect all the available past information. In the other words in the absence of the new information stock should remain unchanged. It is impossible to achieve abnormal long-term returns. More the technical analysis seems to be useless in contrary with the fundamental analysis. It is necessary to say that the MEH is an essential part of rational economics.

The MEH hypothesis is opposite to the behavioural finance approach. It is very interesting to observe the increasing interest in the behavioural finance despite the stable primary approach in the MEH hypothesis.

In this paper, we demonstrate on the data sample of the Czech FOREX market verification/falsification of the MEH. We run analysis more than ten years from the Great Financial Crisis (GFC) in the 2008 (Lehman Brothers Crash). Now there are many signals for the further recession or other phenomena fur from equilibrium (overheated economy, inefficient labour market, bubbles etc.). Need to say that rational economics is equilibrium economics and do not expect disequilibrium. In our analysis, we provide clear answers on the questions about useless of the technical analysis, market efficiency, stock market regulation and other important problems of financial economics in the 21st century.

Key words: Market Efficiency Hypothesis, Technical analysis, Market bubbles

JEL Code: G14, G15

Introduction

The economics of the Exchange Rates starts with the (un) covered interest rates parity as the basic point for the explanation of spot exchange rate evolution. More the purchasing power parity explains the development of the expected exchange rate (Sarno and Taylor, 2002). The development of the expected exchange rate (the stochastic trend of the spot exchange rate) is driven with the convergence between national economies. Further logic deduction leads to the condition that the forward rate is an unbiased predictor of the future spot exchange rate. This approach assumes the FOREX market equilibrium, so we cannot be able to use its conclusion

to any fundamental analysis. It makes no sense to make statements about over or under valued FOREX financial instruments from its fundamentals. These models are build on the equilibrium approach. The last option how seriously analyse the FOREX instrument is the technical analysis.

The main aim of this paper is to confirm or reject standard market efficiency hypothesis in the data sample of the CZK/EUR exchange rates time series.

1 Methodology

This article stays on few approaches. Originally, the efficient market hypothesis (the perfect competition for financial securities) was for the exchange rates at first introduced by Fama (Fama, 1976). Implicitly all the assumptions are comprehensive related to the law of one price, (un)covered interest rates parity, Fama´s Regression and the purchasing power parity. This is the first, let´s say "economic" way of thinking about the exchange rates mechanism. The second methodological approach is the statistical analysis of the time series. We have to be able to confirm our theoretical conclusions with empirical observations. To conclude this, we need to be able to run few statistical tests in the linear regression, ARMA methodology, Vector Error Correction Method, General Method of Moments etc. Detailed introduction of these methods explains Hamilton (Hamilton, 1994).

For the purposes of our main aim, we start with the Fama´s regression (Fama, 1976). This enables us to specify the risk premium of the FOREX under the assumption of the weak form of the MEH. The risk premium itself is on the FOREX market based on the equity puzzle approach. More of this, it is described in Wickens (Wickens, 2012) or Lucas (1978). These authors define the structure of the FOREX risk premium as the covariance of the stochastic discount factor with the exchange rate evolution, and the evolution of inflation rate. There are two structural components of the risk premium. The further consequences of the concretization of the risk premium by the log normal approximation and effects is in detail explained in Cochrane (Cochrane, 2005) or in Cuthberson (Cuthbertson, Nitzsche, 2005). Other risk market premium analysis description puzzles and empirical observations are available in Baillie and Bollerslev (2000) or in Canova and Ito (1991).

2 Risk Premium puzzle in the FOREX market

The rational economics theory assumes the present forward rate to be the unbiased predictor of the future spot Exchange rate. In other words, for the differences between the future spot

exchange rate and the corresponding forward rate, these residuals must follow standard Gauss - Markov assumptions. Unlike these, there are many empirical studies with a conclusion that there is an unexplainable risk premium in the FOREX market. For instance Hansen and Hodrick (1980) and Hau (2000). This explanation is caused with the relatively high-risk aversion parameter in the utility function or the very high-risk free rates. In the Czech economy the studies significant studies are mainly Kočenda and Poghosyan, (2009, 2010). There we observe empirical features of the Czech FOREX market in which the exchange risk is derived from the macroeconomic factors as the consumption and inflation. Kočenda and Moravcová (2018) provided comprehensive analysis of the reaction of selected new EU FOREX markets to a wide array of macroeconomic information during post-GFC period. They show strong and specific reactions along with temporary inefficiencies present on these forex markets. The biggest impact, in terms of the highest abnormal returns, in euro-denominated currency pairs, occurs on PMI indices, the Ifo Index, and the GDP release. With respect to the U.S. dollar-denominated currency pairs, the highest abnormal returns are linked with the NFP and GDP releases. The exchange rates with respect to the U.S. dollar exhibit higher abnormal returns than euro-denominated currency pairs in central FOREX markets. Larger abnormal returns after Eurozone/German news announcements are in general linked with the good news than to bad or neutral news. Conversely, in the U.S. dollar-denominated exchange rates, larger abnormal returns are linked to bad news. The last significant effect to the abnormal returns in FOREX markets is the communication of the monetary settings of the ECB (despite the FED communication does not matter).

For further deduction, we start with the formula (1) which is explained from the law of one price (LOOP). This is the standard uncovered interest rates parity.

$$\frac{E_t(S_{t+k})}{S_t} = \frac{1+i_{t+1}^D}{1+i_{t+1}^F} \tag{1}$$

The logarithmic transformation provides the following formula.

$$E_t(s_{t+k}) - s_t = i_{t+1}^D - i_{t+1}^F \tag{2}$$

Fama´s statistical test is described with the regression (3).

$$\Delta s_{t+k} = a_0 + a_1(f_{t+k} - s_t) + \eta_t \tag{3}$$

The probability limit of the previous linear parameter is:

$$a_1 = \frac{\text{cov}(\Delta s_{t+k},\, f_{t+k} - s_t)}{\text{var}(f_{t+k} - s_t)} \tag{4}$$

Or more simply

$$E_t(s_{t+k}) = f_{t+k} + \varepsilon_t \tag{5}$$

We expect the linear regression parameter a_1 to be the unity. More we can test the relationship through testing the residual term ε_t to be i.i.d. (independent identically distributed random variables). In the equation No. 4 all variables are logarithms.

Precisely, we follow Wickens (2012), who assumes the time series of FOREX variables to follow the logarithmic – normal probabilistic distribution. Then the risk premium of the FOREX market using the C-CAPM is transformed (6).

$$E_t(\Delta s_{t+1} - i^D_{t+1} - i^F_{t+1}) + \frac{1}{2} V_t(\Delta s_{t+1}) = \sigma_t \,\text{cov}_t(\Delta c_{t+1}, \Delta s_{t+1}) + \text{cov}_t(\pi_{t+1}, \Delta c_{t+1}) \tag{6}$$

Finally, when we falsify the Fama´s Regression we implicitly confirm the FOREX market puzzle. This is being explained using covariance between the relative change in the consumption and the relative change in the spot exchange rate and the covariance between the expected inflation rate and the relative change in the spot exchange rate. The first factor is also strengthened with the coefficient of the relative risk aversion. The C-CAPM approach is based on representative agent not market equilibrium model. In the absence of equilibrium assumption, we can then concerning C-CAPM over or under valuate the FOREX market financial instruments and use this model for fundamental analysis evaluation.

3 Data

Our dataset are time series from the Czech National Bank. These time series are the CZK/EUR spot exchange rate evolution and the 3M Forward rate CZK/EUR. The data sample range is from the 05/2001 to the 02/2019. The original daily time series were transformed into month averages. Finally, our data sample consists of 2014 observations. In order to achieve better statistical features we transformed the day averages into logarithms, which fit the economic interpretations of relative changes. All calculations and statistical test are made in the MS Excel and in Eviews statistical software.

Tab. 1: Time series features

	Mean	Median	Standard Deviation	Jarque-Bera (p-value)	Unit Root test (p-value)
s_t	3.32	3.30	0.09	0.00	0.20
f_t	3.32	3.31	0.09	0.00	0.19
residuals	-0.004	-0.003	0.026	0.00	0.00

Source: Eviews output

4. Analysis – linear regression and cointegration

From the previous Tab. 1 it is clear that the standard OLS linear regression methods are useless even these methods would, for the first sight, provide useful coefficients (more in the Tab.2). For nonstationary time series, we expect so called spurious regression. We do see too high level of autocorrelation and not normal distributed residual. Nevertheless, there is a suitable low level of heteroscedasticity in residuals. These all together confirms a strong relationship between forward rate and future spot exchange rate, which unfortunately we are not able to confirm using standard statistical methods.

Tab. 2: OLS linear regression – p values in brackets

Constant (p-value)	Linear coefficient (p-value)	Durbin – Watson	Prob (F-statistic)	Residuals Jarque-Bera prob.	Residuals Breusch-Godfrey prob.	Residuals Test White prob.
0.009 (0.0401)	*0.997 (0.000)*	*(0.18)*	*(0.00)*	*(0.52)*	*(0.00)*	*(0.88)*

Source: Eviews output

Also from the Tab. 1, it is clear that the time series analysed are both nonstationary. We see that the evolution of the spot exchange rate and forward rate is very similar. Nonstationary time series can have the stationary common equilibrium (cointegration equation). Their residuals

must be tested to be i.i.d (difference between the spot exchange rate and three months lagged forward rate). The descriptive statistics are calculated in the third row of the Tab.1. In the end the residuals time series are stationary. We see the null expected values of residuals, but we do observed not normality and autocorrelation in the residuals time series.

Johansen cointegration test indicates total number of possible cointegration vectors. We did assume all trends stochastic. Under these assumptions, we confirm the existence of relationship between the two nonstationary time series analysed. Johansen cointegration test together with Trace test confirm one cointegration equation.

5. Analysis – ARMA, VAR and Error Correction Method

In the situation, where there are nonstationary time series of variables, which are empirical difficult to verify the economic consequences, there is much better to explain the variable with its lagged values. The solution usually achieves higher degree of statistical significance but the disadvantage of this solution is that there is no argument for this technical point of view in the economic theory. In this part, we have followed the Hamilton´s explanation of the statistical tools (Hamilton, 1994).

For the ARMA approach we achieved very useful solution in concrete representation AR(1) together with MA (1). According to achieved values, the process is stationary and more invertible. Need to say that impulse response output and correlogram confirm the suitable model. Here, we totally avoid the forward rate effects to the spot exchange rate. This disadvantage is compensated in the so-called Vector Autoregression Method.

Tab. 3: ARMA(1,1) for the spot exchange rate – p values in brackets

Constant (p-value)	AR(1) term	MA (1) term	Prob (F-statistic)	Durbin - Watson	AR root	MA root
3.264 (0.000)	*0.973 (0.000)*	*0.227 (0.001)*	*(0.000)*	*1.98*	*0.973*	*0.227*

Source: Eviews output

Unfortunately, in economic theory we usually do not see sophisticated approach to explain dynamics in the economic variables. In the economic consequences, it is frequent that the variables are both endogenous. It means that these variables influencing themselves not like in

the natural sciences where the direction of relationship is clear. The Vector Auto Regression (VAR) analysis reflects that all the variables are endogenous. This approach models the influence of shock as a whole.

We tested several VAR model different due to the lag structure. The output was always similar for the first sight. Both coefficients in the spot exchange rates and forward rates (logarithms, VAR approach assumes the stationary time series) were achieved with no such efficient standard errors and t-statistics. There is necessary further diagnosis, which Eviews software fortunately is able to provide.

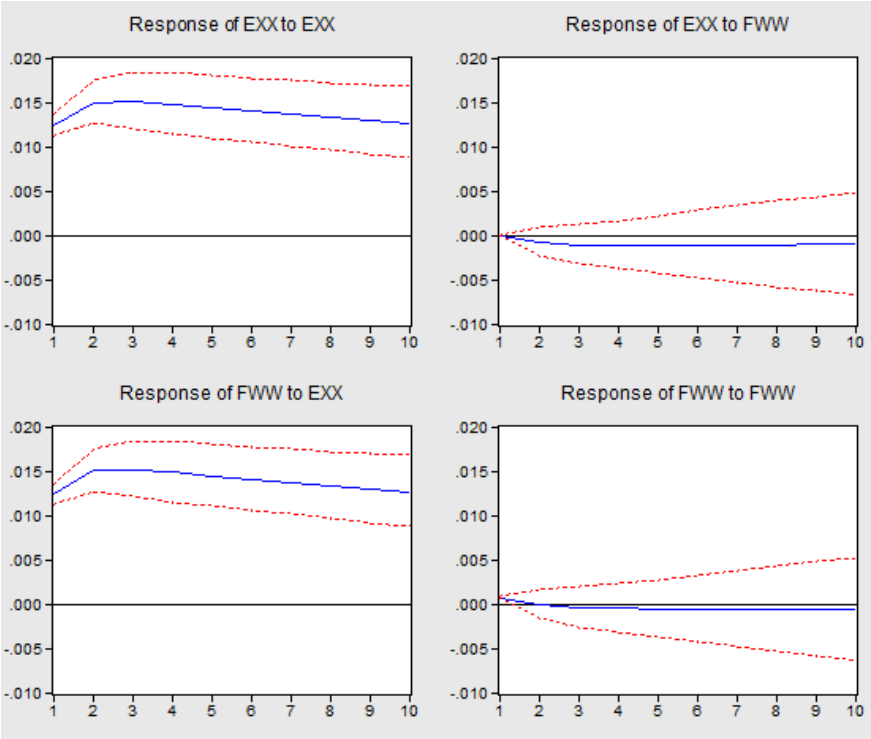
First, we must decide whether the concretized VAR model is stationary. From the table or graph of the AR roots, we see that all the roots lie inside the unit circle (in the other words their maximum modulus is one). This is the condition needed for further impulse – response diagnosis.

More from the lag exclusion tests, we exclude the lag in the level of three. In the other words in our VAR model, it is better to delay variables two times. The previous is bit dampened due to output of the lag length criteria (Akaike information criterion, Schwarz information criterion). Then we made several tests for VAR residuals. These are Portmaneau Autocorrelation Test, Autocorrelation LM Test, Normality tests and White Heteroscedasticity Tests. These tests were made according to procedure described in the Eviews User´s Guide.

Finally, we conclude about the lag length of VAR to the max level of two months. The residuals are then normal and auto correlated but there is a significant heteroscedasticity.

Impulse – Response diagnosis refers about that the shock to the variable is through the dynamic lag system transformed to the other endogenous variables (current and future values). We provide this output as the Fig. 1, at which we see that our VAR model is suitable in lag level of two. Anyway, there is the two month delayed in the FOREX market variables. Variance decomposition separates the relative importance of each component in the VAR model. Both the FOREX market variables behave due to own innovation, no due one another.

Fig. 1: Impulse – Response diagnosis VAR (1,2) model of the spot exchange and forward rate



Source: Eviews

(Vector) Error Correction (EC) models are used for nonstationary time series, at which we know they are cointegrated. EC models restrict the long run behaviour of the endogenous variables to be limited and converged according to cointegration relationship. Unlike previous explanation, the short run dynamics is allowed and it is being observed. In the other words Error Correction models provides as a first step the cointegration equation (7) which is corrected with the VAR of correction term (8)

$$y_{2,t} = \beta y_{1,t} \tag{7}$$

$$\begin{aligned} \Delta y_{1,t} &= \alpha_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{1,t} \\ \Delta y_{2,t} &= \alpha_2 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{2,t} \end{aligned} \tag{8}$$

In an empirical analysis, we follow the conclusion about one cointegration vector according to Johansen Cointegration Test. Then we need to decide which lag level to choose in the correction term. In our empirical analysis of the relationship between spot exchange rate and the forward rate, we do not confirm the lag in the correction term. There is just correction according to original cointegration not lagged. This statement corresponds with the fact that financial

variables are usually not following the adaptive expectations but the rational expectations. The (V)EC output from the data sample is:

$$y_{2,t} = -1{,}01 y_{1,t} \tag{9}$$

$$\begin{aligned} \Delta y_{1,t} &= 0{,}828(y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{1,t} \\ \Delta y_{2,t} &= 0{,}872(y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{2,t} \end{aligned} \tag{10}$$

In this model, all the coefficients are statistically significant. They achieve low standard errors and relatively high t-statistics (the p-values confirm rejection of the null hypothesis about the coefficients to be zero). The potential constant has its own explanation with the existence of the transaction costs in the FOREX market.

Conclusion

The aim of this paper was to evaluate the Market Efficiency Hypothesis on the FOREX market in its weak form in the Czech Republic. This is about that the current prices fully reflect all the past information. The spot exchange dynamics is derived from the no arbitrary equilibrium between foreign and domestic investors. This is complexly described using the (un)covered interest rates parity conditions. These conditions lead to the so-called Fama´s equation about forward rate to be the unbiased predictor of the future spot exchange rate.

On the data sample of 2014 observations from the 2001 to 2019 we run few statistical tests to confirm/reject the hypothesis. We are not able to use the standard linear regression approach because the solution did not fit the standard Gauss - Markov Assumption. More we run ARMA (1,1) and VAR models, which confirm that the spot exchange rate and forward rate are more dependent on its own lagged values than on themselves.

All conclusion made are reasoned on the fact that the FOREX market variables are nonstationary. So we must finally exploit the times series analysis for the nonstationary time series. These are the cointegration approach and the Vector Error Correction Method. These two methods confirm stochastically stable equilibrium between spot exchange and lagged forward rate. Nevertheless, there is not lagged correction term. In the end, we have to reject the Fama´s equation (Interest rates parity condition) in its original view (even the weak form) but there is strong long run relationship between analysed variables. In the short run, there is a significant influence of random effects. More there is a difference, in which it is explained the effect of transaction costs or the FOREX risk premium. The problem is technically solvable

thank to nonlinear equilibrium adjustments. The main idea of this paper is that the exchange rate dynamics of the CZK/EUR follows the martingale evolution. It means that the best estimation of the future value of the exchange rate is the current value. It is better not to create any model for pricing, but to trade at the current value or to use the technical analysis.

Moreover we theoretically described explanation of the puzzle thank to representative agent model C-CAPM. By product of this paper is conclusion about fundamental analysis being useless in the FOREX trading in the short run (more probably even long run) in contrary with the technical analysis trying to avoid stochastic trends as a basis for trading.

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