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The Forecasting of Spot Exchange Rates Based on the Forward Exchange Rates

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Abstract

Radim Gottwald: **The Forecasting of Spot Exchange Rates Based on the Forward Exchange Rates**

The forecasting power of forward exchange rates for future spot exchange rates has been investigated by many researchers. In this paper, the author focuses on this topical economic theme too, and investigates the extent, to which the future spot exchange rates could be forecasted based on the current forward exchange rates. The paper aims at an assessment of the forecasting of spot USD/EUR exchange rates based on the forward exchange rates in the period from 2005 to 2013. Graphical and regression analyses are used to investigate the relationship between daily closing spot and forward rates, namely between 3 month rates and 6 month rates. The ordinary least squares method is used in order to forecast the chosen parameters. Hypotheses related to these parameters are tested at a significance level of 5%. By means of the augmented Dickey-Fuller test for a unit root in a time series sample, the author investigates whether the time series of the parameters is stationary. Afterwards, the time series is detrended in order to guarantee stationarity. Transformation into a non-linear econometric model with integrated autoregressive process AR(1) is used in order to reduce high positive autocorrelation in the residuals of the model. Thereafter, forecasts of the detrended model are made. Results revealed the following findings. According to the graphical analysis, the current forward exchange rates probably cannot be considered sufficiently reliable forecasters of the future spot exchange rates. According to the regression analysis, the forward forecasts even systematically undervalue the future spot exchange rates. Summarized, the current forward exchange rates cannot be considered sufficiently reliable forecasters of the future spot exchange rates. The above-mentioned findings are important for financial analysts working in financial companies or enterprises, which import or export some products, thus trading with foreign business partners using foreign currencies. Speculators on foreign exchange markets could make use of the presented findings as well.

Key words

Forward exchange rate, spot exchange rate, rational expectations theory, currency pair, FOREX

JEL: C53, F31, O24

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Introduction

The making of exchange rate forecasts is one of interesting economic topics. Economy of each country is influenced by the development of exchange rates between domestic and foreign currencies. A number of financial analysts make forecasts in order to profit from a possible trend of exchange rates in the future. Several methods can be used to make forecasts. The use of forward exchange rates is considered one of such methods. In general, the forward exchange rate is such an exchange rate at which e.g. a bank agrees to exchange one currency for another at a future date when it enters into some forward contract with an investor. The forward exchange rate is based on the spot exchange rate and refers to the rate that will be used to deliver a currency at some time in the future. In other words, forward rates appear in a contract for currency exchange in the future. The paper aims at an assessment of the forecasting of chosen spot exchange rates based on forward exchange rates over the chosen period. The author investigates an extent, to which the future spot exchange rates can be forecasted by this way. The paper follows a number of empirical studies focused on exchange rate forecasts. Some of these studies are quoted in the paper.

The remaining part of this paper is organized as follows: the chapter "Literary Survey" describes the relationship between spot rate and forward rate in detail. Efforts of many researchers to investigate the forecasting power of forward rates for future spot rates are clear from this chapter. Some empirical studies focused on the mentioned investigations are quoted. The choice of used currencies and analysed period are specified in the chapter "Methodology", in which the author presents the method of forecasting the spot rates. The chapter "Results" contains a graphical analysis and a regression analysis of the relationship between the spot and forward rates. The author investigates in it, whether the exchange rate time series is or is not stationary. This series is detrended and the author makes a forecast of the detrended model. In the chapter "Discussion", the author suggests how the research can continue in the future. Finally, the chapter "Conclusion" summarizes important findings related to this paper.

1 Literary Survey

In the past five decades, the relationship between the forward and spot exchange rates became a subject of interest for many researchers. Numerous studies investigated whether the forward rates are reliable forecasters of the future spot rates. However, researchers obtained conflicting results. In addition, methods that are even more sophisticated were used because of developing information technologies. It is often believed that the forward rates must be unbiased forecasters of the future

spot rates, otherwise speculators and investors could profit from the bias by taking a certain position on the spot exchange market and an opposite position on the forward exchange market. On the other hand, for example Kang (1992) states that the forward rates can be good forecasters of the future spot rates when the level of future spot rates is regressed on the level of forward rates. He also points out some new evidence about the role of interest rate differentials in the determination of exchange rates.

A number of interesting empirical studies focused on forecasting spot rates based on forward rates have been published recently. Some researchers use USD and just one other currency. Wesso (1999) tries to find out, whether the forward rates are optimal forecasters of the future spot rates in case of ZAR/USD rates over the period from 1987 to 1998. His empirical evidence indicates that both current forward rates and current spot rates are significant in forecasting the future spot rates. However, the current forward rates provide worse forecasting of the future spot rates than do the current spot rates. Furthermore, it is clear that estimated coefficients for the spot rates and the forward rates fall below one, rejecting the unbiased forecaster hypothesis. This difficultness of forecasting the future spot rates by means of the forward rates is in the centre of attention of Wang (2008). Using the example of USD/DEM rates over the period from 1974 to 1991, he points out that the exchange rate forecastability improves with the time horizon. Topbas (2014) focuses on expectations of market participants on foreign exchange market in Turkey. He uses USD/TRL rates over the period from 2002 to 2006. His results reject the test of forward exchange rate unbiasedness in forecasting the spot exchange rate. The forward premium also contains additional information for exchange rate forecasts. Moreover, variation in the forward discount for the forecast horizons reflects such a degree of variation in the risk premium, which is statistically significant. According to Nath (2013), the forward-bias puzzle is based on assumptions that the forward exchange rates equal the expected future spot rates and that these expectations are rational. He tests the forward exchange rate bias in INR/USD exchange rates over the period from 2003 to 2013. His results show that forecast errors have information content leading to assumed presence of risk premium. Bonga-Bonga (2009) assesses the relationship between ZAR and USD forward and future spot exchange rates over the period from 1994 to 2008. He establishes that the use of a linear model in testing the Forward Rate Unbiasedness Hypothesis can lead to a misspecification problem if really there is a nonlinear adjustment between the spot and forward exchange rates. His results show that the smooth transition regression forecasting method outperforms the random walk and ordinary least square methods in forecasting the future spot exchange rate.

Some researchers use USD and more than one other currency. The question whether the forward rates are rational forecasts of the future spot rates inspired Aggarwal, Lin and Mohanty (2008) to analyse USD, GBP, JPY, CHF, DEM and CAD rates over the period from 1973 to 1998. Their results show that USD forward rates for horizons rating from 1 to 12 months for other currencies excluding CAD are generally neither efficient nor rational forecasts of future spot rates. On the other hand, the rationality and efficiency for the USD forward rates for CAD is not rejected. Dominguez and Novales (1999) investigate, how to improve the future spot rate forecasting on the basis of the forward rates. They analyse USD, JPY, DEM, GBP, ESP, FRF, ITL and CHF rates from 1978 to 1998 and show that forward rates mostly produce better forecasts of spot rates than univariate autoregressions for a number of currencies.

Polito (2001) points out an empirical finding that the forward rates are useful indicators of the future rates. She tests the validity of the unbiased forward rate hypothesis using exchange rates of CAD, FRF, GBP, JPY and DEM from 1991 to 1999. Spot and forward rates are measured as units of currency per USD. The results do not fully support the unbiased forward rate hypothesis. The constant term is significantly different from zero after correcting for serial correlation, for all of the currencies, except CAD. Thus, the constant term is capturing information that the forward rates do not fully reflect all information available to economic agents.

Similarly, Sanchez (2013) tries to find whether the forward exchange rate can be considered a true unbiased forecaster of the future spot exchange rate. He uses USD/JPY and USD/GBP exchange rates over the period from 1990 to 2013. He mentions the Forward Rate Unbiasedness Hypothesis, which argues that the forward rate fully reflects the information concerning exchange rate expectations and thus, forward premiums forecast the direction change in the future spot rates. His results show that forward exchange rates have only little effect as forecasts of the future spot exchange rates since the Forward Rate Unbiasedness Hypothesis is rejected. In economic theory, the forward exchange rate should be an unbiased forecast of the future spot rate, as Aggarwal and Zong (2008) mention. They make forecasts of exchange rates using the following currencies: CAD, GBP, BEF, FRF, DEM, ITL, NGL, CHF and JPY, always against USD over the period from 1981 to 1994. They conclude that forward rate forecasts of the future spot exchange rate reflect systematic pessimism and under-reaction to new information. Moreover, the non-rational behaviour of changes in forward exchange rates is consistent with similar behavioural biases, which can be observed in other asset markets. Bashir, Shakir, Ashfaq and Hassan (2014) examine the relationship between spot and forward exchange rate efficiency and efficiency of foreign exchange market in Pakistan. Analysing AUD/PKR, CHF/PKR, EUR/PKR, JPY/PKR and USD/PKR exchange rates over the period from 2006 to 2013 they

find that the forward exchange rate closely forecasts the future spot exchange rate; however, the forward exchange rate does not fully reflect all the available information.

Some researchers use currency or currencies different from USD. Afanasenko, Gischer and Reichling (2011) focus on the forecasting power of the forward rates for the future spot rates. They analyse the German swap rates for the period from 1995 to 2007. Based on results, supportive evidence in favour of the forward rates as tools useful for forecasting is not suggested. The presence of cointegration in the term structure of interest rates is found out. They also use maximum likelihood estimates of the cointegration equation obtained with the used sample to construct forecasts for the next 12 month. GBP, DEM and JPY rates are used by Wolff (2000) in an effort to find out, whether the knowledge of the time series properties of the premium in the pricing of forward foreign exchange rates can be used to forecast the future spot rates. For a wide range of parameter values, he finds out the adjustment of the forward rate for a premium term leads to one-step-ahead forecast errors. Results show that 9-16% of the variance in these errors is due to variation in premiums.

Some researchers have described and applied other ways to forecast spot rates without using forward rates. Bianco, Camacho and Perez-Quiros (2012) propose econometric model for changes in exchange rate with the feature of mixing economic variables quoted at different frequencies. The model is applied with EUR/USD exchange rates over the period from 1999 to 2010. Tauser and Buryan (2011) forecast JPY/USD exchange rates over the period from 1980 to 2006. They propose a specific model to exchange rate forecasting. A no-arbitrage model is used by Rios (2012) in order to forecast exchange rates USD/GBP and USD/CAD over the period from 1976 to 2004. He shows that profits from using a vector autoregression model over a random walk model are negligible. The success of these approaches supports the assumption that foreign exchange markets are efficient. Corte and Tsiakas (2011) analyse 10 most liquid currencies in the world including USD over the period from 1976 to 2010 in order to provide a comprehensive review of economic and statistical methods used for assessing out-of-sample exchange rate predictability. Their results show that models based on purchasing power parity, uncovered interest parity and asymmetric Taylor rule perform better than the random walk in out-of sample forecasting.

In connection with the quoted recently published research studies, the contribution of this paper in relation to them can be determined. The author's approach differs from approaches used in the other research studies, and is beneficial in using two most tradable currencies, in the exact application of regression analysis and other econometric methods including testing of the hypotheses. Specifically, only Bianco, Camacho and Perez-Quiros (2012) use USD and EUR; however,

they do not use forward rates to forecast future spot rates. Thus, the results presented in this paper fill the gap in systematic research related to exchange rate forecasting.

2 Methodology

The aim of the paper is to assess the forecasting of USD/EUR spot exchange rates on the basis of the forward exchange rates over the period from 1 January 2005 to 31 December 2013, i.e. to investigate the extent to which future spot rates can be forecasted on the basis of current forward rates. In other words, the author wants to find out, whether the current forward rates can be considered reliable forecasters of the future spot rates. The choice of USD and EUR currencies is clear from Table 1, which presents the currency distribution of global foreign exchange market turnover in 2013.

Table 1: Currency Distribution

Rank	Currency	Share
1	USD	87.0%
2	EUR	33.4%
3	JPY	23.0%
4	GBP	11.8%
5	AUD	8.6%

Source: Bank for International Settlements (2013) and own calculations

Because two currencies are involved in each transaction, the sum of the percentage shares of individual currencies should total 200% instead of 100%. The dominant positions of USD and EUR are evident.

The covered interest rate parity could be used to explain the determination of the forward exchange rates. This parity relates to such a situation when the no-arbitrage condition is satisfied by means of using a forward contract. In general, the forward contract is a non-standardized contract between two parties to sell or to buy a financial asset at a specified time in the future at a price agreed upon today. This contract is used as hedge against the exposure to exchange rate risk. The covered interest rate parity can be represented as follows:

$$\frac{1+IR_{D,t}^{t+n}}{1+IR_{F,t}^{t+n}} SR_t = FR_t^{t+n}$$

whereas $IR^{t+n}{}_{D,t}$ is domestic interest rate at time t for period $t+n$, $IR^{t+n}{}_{F,t}$ is foreign interest rate at time t for period $t+n$, SR_t is spot exchange rate at time t and $FR^{t+n}{}_t$ is forward exchange rate at time t for period $t+n$. This equation is known as a covered interest parity equation and relates to the interest rate parity. The covered interest rate parity is found to hold when there are limited capital controls

and open capital mobility and this finding is valid for all currencies freely traded today in general. However, while this parity generally holds, it does not hold with precision due to the presence of political risks, transaction costs and differences in the liquidity of foreign versus domestic assets. The following equation expresses the assertion, which states that the forward exchange rates are unbiased forecasters of the future spot exchange rates:

$$FR_t^{t+n} = E_t\left(SR_{t+n}\right)$$

whereas $E_t(SR_{t+n})$ is expected spot exchange rate at time t for period $t+n$. Daily closing spot and forward exchange rates are used. Maturities of forward rates are 3 months and 6 months. To obtain all necessary data, the database of Reuters (2015) is used as a data source. By contrast to spot rates, forward rates are announced as forward points. Forward point is a number of basis points subtracted from or added to the current spot rate to determine the forward rates. It is the product of 1000 and the difference between the spot rates and forward rates. For example, if the USD/EUR spot exchange rate is 1.400 and the 3-month forward exchange rate is 5 forward points, the forward points are divided by 1000 and added to the spot exchange rate. Thus, the forward exchange rate is 1.405 USD/EUR.

Graphical analysis and regression analysis of the relationship between the spot rates, 3-month forward rates and 6-month forward rates are implemented at the beginning of the empirical analysis. Chosen parameters are forecasted by the ordinary least squares method. Calculated indicators are t-statistic, p-value, adjusted R-squared and Durbin-Watson statistic. Based on the values of indicators, hypotheses are tested relating to the parameters. Significance level of all tests in this paper is 5%, because it is a usual significance level. Stationarity of the USD/EUR spot rates and forward rates is investigated. Phillips (1986) states that the use of non-stationary data can give rise to apparent regression, because conventional significance tests can identify the existence of the relationship between parameters even though no such a relationship exists in reality. The augmented Dickey-Fuller test for a unit root in a time series sample is used to investigate this stationarity. As Dickey and Fuller (1979) state, the ADF statistic is a negative number and the more negative this number is, the stronger is the rejection of the hypothesis that there is a unit root at some level of confidence. The first differences of the USD/EUR spot rates, 3-month forward rates and 6-month forward rates are illustrated. The time series is detrended in order to guarantee time series stationarity. P-values of the ADF tests are calculated, too. Forecasts of the detrended model are made. The above-mentioned indicators are calculated as well, and based on their values, the author tests the hypotheses. High positive autocorrelation is found in the residuals of the model. Transformation into non-linear econometric model with integrated autoregressive process AR(1) is used in order to reduce this

autocorrelation. The author again calculates the indicators and tests the hypotheses. Based on the results, he assesses at the end of the empirical analysis the extent to which it is possible to forecast the future spot rates on the basis of the current forward rates.

3 Results

3.1 Graphical Analysis

At first, the relationship between the USD/EUR spot rates and 3-month forward rates is shown in Figure 1.

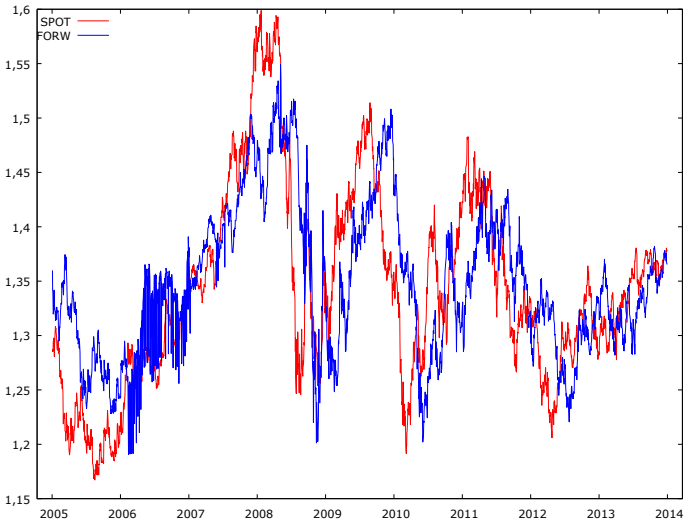

Figure 1: The Relationship Between the USD/EUR Spot Rates and 3-month Forward Rates (Source: Reuters (2015) and own calculations)

The relationship between the USD/EUR spot rates and 6-month forward rates is shown in Figure 2.

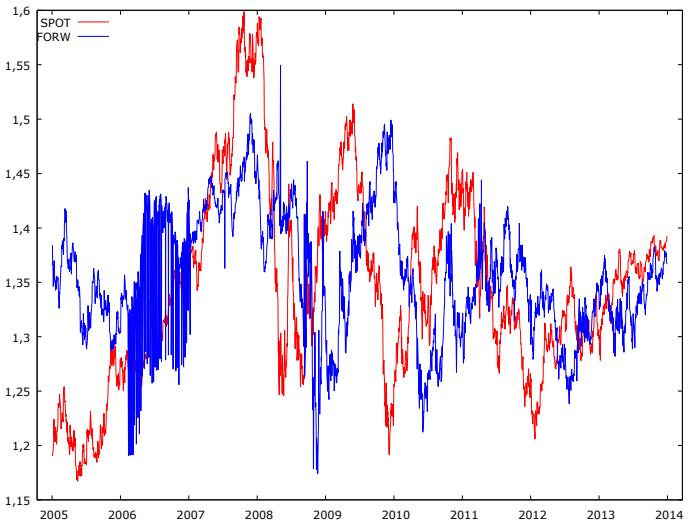

Figure 2: The Relationship Between the USD/EUR Spot Rates and 6-month Forward Rates (Source: Reuters (2015) and own calculations)

The range from about 1.15 to 1.60 of the 3-month and 6-month forward rates is clear from Figure 1 and Figure 2. Furthermore, the extent to which the forecasts are exact is evident. The spot rate curve would be the same as the forward rate curve only in the case of 100% accurate forecasting. However, expected values differ from real values relatively enough in Figure 1 and Figure 2. The spot rates exceed the forward rates during some periods but an opposite situation can be seen during other periods. Thus, the current forward rates probably cannot be considered sufficiently reliable forecasters of the future spot rates.

3.2 Regression Analysis

The relationship between the USD/EUR spot rates and forward rates is investigated by the regression analysis. The ordinary least squares method is used to forecast regression parameters. The following equation is analysed:

$$SR_{t+n} = a_0 + a_1 FR_t^{t+n} + u_{t+n}$$

whereas SR_{t+n} is spot rate at time $t+n$, a_0 and a_1 are regression parameters and u_{t+n} is residual of the model. The rise of the forward rate by one unit implies, ceteris paribus, the rise of the spot rate by a_1. The hypotheses related to regression parameters are tested. Table 2 presents indicators of the USD/EUR rates.

Table 2: Indicators of the USD/EUR Rates

Parameter	Coefficient	T-statistic	P-value	Adjusted R-squared	Durbin-Watson statistic
a_0 (3 months)	0.163549	6.10	1.23e-09	0.452730	0.055457
a_1 (3 months)	0.874264	44.06	<0.0001		
a_0 (6 months)	0.837029	20.23	4.96e-084	0.060448	0.022185
a_1 (6 months)	0.375433	12.32	7.38e-034		

Source: Reuters (2015) and own calculations

Regression parameter a_0 would be 0 and regression parameter a_1 would be 1 only in the case of 100% accurate forecasting. Based on this fact, following hypotheses are formulated.

Hypotheses related to a_0: null hypothesis H_0: $a_0=0$ alternative hypothesis H_1: $a_0\neq0$

Hypotheses related to a_1: null hypothesis H_0: $a_1=1$ alternative hypothesis H_1: $a_1\neq1$

Based on the calculations, the hypotheses should be rejected or failed to be rejected. The author uses the significance level, which is a probability of incorrectly rejecting the null hypothesis. The testing of statistical hypotheses is evaluated by the calculation of p-value and t-statistic. While p-value is probability, assuming the null hypothesis is true, of observing a result at least as extreme as the test statistic, t-statistic can be expressed as a ratio of the departure of an estimated parameter from its hypothetical value and its standard error. Adjusted R-squared measures the model suitability, in other words what percentage of the data can be explained by the chosen model.

In this case, t-statistic expresses the difference between forecasted value a_0=0.163549 and value a_0=0 (similarly a_1=0.874264 and a_1=1) which is divided by the standard error of the estimator.

The 3-month forward rates are analysed first. As for the a_0-related hypotheses, assuming validity of the null hypothesis, the T-ratio value of 6.10 occurs with a probability of p-value $1.23 \cdot 10^{-9}$. This probability is lower than the significance level of 5%. Thus, the null hypothesis is rejected at the 5% significance level. 5% or lower p-value is usually considered to be statistically significant. As for the a_1-related hypotheses, assuming validity of the null hypothesis, the T-ratio value of 44.06 occurs with a probability of p-value, which is lower than 0.0001. This probability is again lower than 5% significance level. Thus, the null hypothesis is rejected again at the 5% significance level. Analysing the 6-month forward rates, the null hypotheses are rejected analogously.

The results of the regression analysis can be summarized. Regression parameters statistically significantly differ from 0 values for regression parameter a_0 and 1 for regression parameter a_1. The forward forecasts systematically undervalue the future spot rates because of positive regression parameters a_0. These parameters are higher in the 6-month forward rates than in the 3-month forward rates. Potential reason could be risk premium since the longer the time horizon is, the higher uncertainty predominates on the foreign exchange market. The investor usually gets a certain risk premium; however, he accepts a higher risk only when the risk premium is higher too.

3.3 The Investigation of the Stationarity

The time series of the first differences is set from the initial time series. The augmented Dickey-Fuller test is used to investigate stationarity of the USD/EUR spot rates and forward rates. There are two pieces of information to be found in order to set this test correctly. The first information is whether the time series of the first differences contains a constant value, around which the values oscillate. The second information is whether such time series contains a trend. Figure 3 illustrates the first differences of the USD/EUR spot rates.

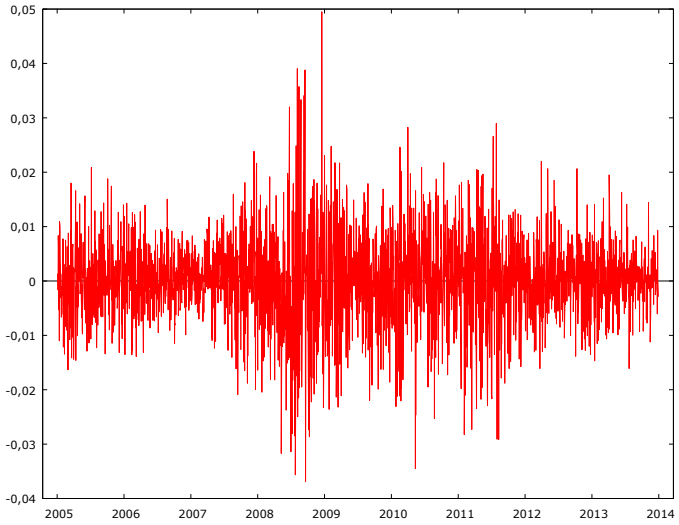

Figure 3: The First Differences of the USD/EUR Spot Rates (Source: Reuters (2015) and own calculations)

Figure 4 shows the first differences of the 3-month USD/EUR forward rates.

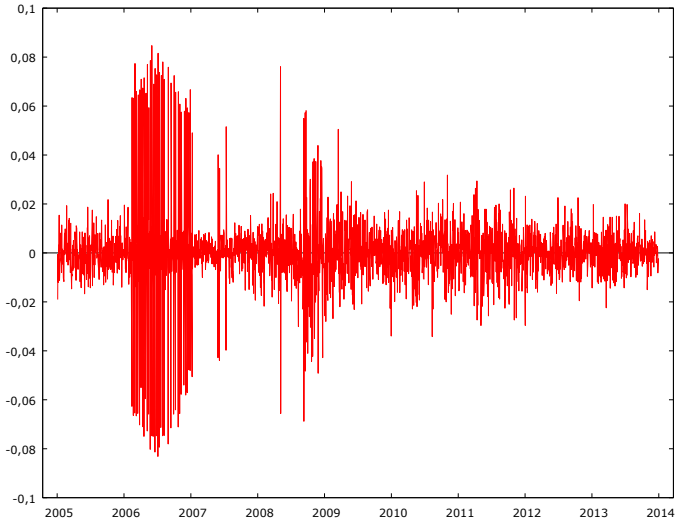

Figure 4: The First Differences of the 3-month USD/EUR Forward Rates (Source: Reuters (2015) and own calculations)

Finally, Figure 5 illustrates the first differences of the 6-month USD/EUR forward rates.

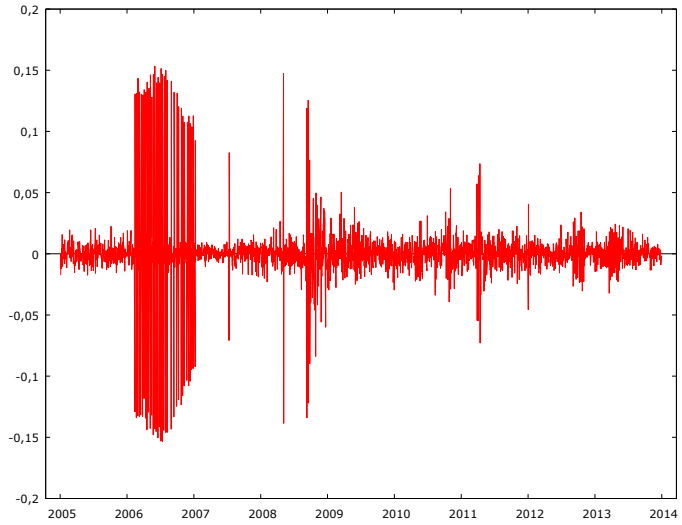

Figure 5: The First Differences of the 6-month USD/EUR Forward Rates (Source: Reuters (2015) and own calculations)

Figures 3, 4 and 5 show that the values oscillate around zero and that no trend is obvious. Thus, the ADF test is set as a "test without a constant" and "test without a trend". The first differences are expected to be stationary; however, the ADF test will definitively confirm or disprove the expectation. Table 3 presents p-values of the ADF test for a unit root in a time series of the USD/EUR spot rates and forward rates.

Table 3: P-values of the ADF Test for a Unit Root in a Time Series of the USD/EUR Spot Rates and Forward Rates

Exchange rate	P-value
Spot rate (3 months)	0.7024
Forward rate (3 months)	0.6969
Spot rate (6 months)	0.7541
Forward rate (6 months)	0.6740

Source: Reuters (2015) and own calculations

P-values presented in Table 3 express minimum significance level for rejection of the null hypothesis for a unit root. With respect to the significance level of 5%, all time series are found to be non-stationary. In other words, they contain a unit root. The test shows that all time series are differentiated by level 1, i.e. the time series of their first differences are already stationary.

3.4 Detrending

Potential non-stationarity of the time series implies a necessity to detrend this time series in order to guarantee stationarity. The time series is detrended according to the following formula:

$$SR_{t+n} - SR_t = a_0 + a_1\left(FR_t^{t+n} - SR_t\right) + x_{t+n}$$

Left side expresses the change in the spot exchange rate from the rate at time *t* to the rate at time *t+n*, while $FR_t^{t+n} - SR_t$ is forward premium. Similarly, regression parameter a_0 would be 0 and regression parameter a_1 would be 1 only in the case of 100% accurate forecasting. x_{t+n} is residual of the model. Stationarity is investigated again of the time series $SR_{t+n} - SR_t$ and $FR_t^{t+n} - SR_t$. Table 4 presents p-values of the ADF test for a unit root in a time series of USD/EUR rate differences.

Table 4: P-values of the ADF Test for a Unit Root in a Time Series of USD/EUR Rate Differences

Exchange rate	P-value
SR_{t+3} - SR_t	0.5232
SR_{t+6} - SR_t	0.5579
FR_{t+3} - SR_t	0.6109
FR_{t+6} - SR_t	0.6102

Source: Reuters (2015) and own calculations

Similarly, p-values presented in Table 4 express minimum significance level for rejection of the null hypothesis for a unit root. However, with respect to the significance level of 5%, all time series are found to be stationary. In other words, they do not contain a unit root.

3.5 The Forecasts of the Detrended Model

The time series of the 3-month USD/EUR forward rates is analysed according to the following formula:

$$SR_{t+3} - SR_t = a_0 + a_1\left(FR_t^{t+3} - SR_t\right) + x_{t+3}$$

The respective formula for 6-month USD/EUR forward rates is as follows:

$$SR_{t+6} - SR_t = a_0 + a_1\left(FR_t^{t+6} - SR_t\right) + x_{t+6}$$

Table 5 presents indicators of the USD/EUR rates for the detrended model.

Table 5: Indicators of the USD/EUR Rates for the Detrended Model

Parameter	Coefficient	T-statistic	P-value	Adjusted R-squared	Durbin-Watson statistic
a_0 (3 months)	-7.38277e-05	-0.041	0.9673	0.865214	0.085621
a_1 (3 months)	0.941521	122.7	<0.0001		
a_0 (6 months)	0.005053	1.798	0.0724	0.840344	0.079389
a_1 (6 months)	0.956240	111.1	<0.0001		

Source: Reuters (2015) and own calculations

The hypotheses related to regression parameters are tested again. In both cases, p-value related to a_0 is higher than the 5% significance level. Thus, the null hypothesis fails to be rejected at the 5% significance level. P-value related to a_1 is lower than the 5% significance level in both cases. Thus, the null hypothesis is rejected at the 5% significance level.

Adjusted R-squared is relatively high in both cases. Durbin-Watson statistic is near zero. Thus, a high positive autocorrelation in the model residuals is detected. Transformation into non-linear econometric model with integrated autoregressive process AR(1) is used in order to reduce this autocorrelation. The process AR(1) is defined as follows:

$$y_t = c + \varphi_1 y_{t-1} + \varepsilon_t$$

whereas c is constant which is not statistically significant from 0, ε_t is white noise and φ_1 is parameter which must satisfy $| \varphi_1 | < 1$, otherwise the process would not be stationary. Table 6 presents indicators of the USD/EUR rates for the non-linear model.

Table 6: Indicators of the USD/EUR Rates for the Non-linear Model

Parameter	Coefficient	T-statistic	P-value	Adjusted R-squared	Durbin-Watson statistic
a_0 (3 months)	-0.028456	-0.8223	0.4110	0.991397	2.233638
a_1 (3 months)	0.601050	48.66	<0.0001		
a_0 (6 months)	-0.142975	-0.9912	0.3217	0.993940	2.220770
a_1 (6 months)	0.375077	32.52	8.80e-192		

Source: Reuters (2015) and own calculations

Similarly as in the previous cases, the hypotheses are tested, which relate to regression parameters. Based on the comparison of the 5% significance level and p-values related to a_0 respectively a_1, the null hypothesis related to a_0 fails to be rejected at the 5% significance level, while the null hypothesis related to a_1 is rejected at the 5% significance level. The used formulas could be interpreted so that changes in rate at time *t* and *t+3*, alternatively at time *t* and *t+6* are caused by the discount.

In the USD/EUR exchange rates related to 3 months and 6 months, the adjusted R-squared and Durbin-Watson statistic increased after the transformation into a non-linear econometric model with the integrated autoregressive process AR(1). It is clear that the autocorrelation in the residuals of the model is really reduced. Durbin-Watson statistic is found in the zone of no autocorrelation.

The results can be summarized. The current forward exchange rates cannot be considered sufficiently reliable forecasters of the future spot exchange rates. While the indicator values are

similar to the expected ones in some cases, there are other cases when the values differ from the expected ones.

4 Discussion

The contribution of this paper consists in finding the extent to which the forecasting chosen future spot exchange rates based on the current forward exchange rates can be considered reliable. Forecasting the exchange rates on foreign exchange markets remains one of hot economic themes. Findings about the forecasting power of the forward exchange rates for the future spot exchange rates can be considered important for speculators on foreign exchange markets and for financial analysts working in financial companies and international trading companies in import/export business. The use of forward rates in forecasting spot rates is expedient because of several reasons. The forward rates are usually available on the Internet, really easy, quick and cheap to find. They could be also available in the databases of financial institutions. The forward rates adapt to new market information with a minimum delay.

The more reliable the forecasters are the higher profit the speculators can realize on foreign exchange markets. Theoretically, knowing the forward rates allows forecast the future spot rates exactly while the forward rates reflect exactly the expectations of market participants. However, even if the market participants take into consideration all available necessary information, 3 months and 6 months will be a too long time. The reason is clear. New information, in other words expected and unexpected events happen on foreign exchange markets many times a day. Future spot rates differ from their real values because of unexpected events. Thus, the choice of maturities expressed in months is vitally important. The shorter the maturity is the higher the adjusted R-squared is likely to be.

Currently, certain levels of differences are measured between the forecasted rates and the real rates. The levels are supposed to be probably lower in the future. Due to the continual development of information technologies, econometrics and statistics, models that are more sophisticated will emerge. Forecasts made by using these models will be probably less different from real values. The author believes that more research is needed. Research in this economic field can continue by several ways. Researchers could choose other exchange rates, maturities, time periods, statistical indicators and other models to forecast the spot rates.

Conclusions

The author followed a number of empirical studies focused on the exchange rate forecasting. Several recently published studies are quoted in the paper. The forecasting was assessed of the USD/EUR spot exchange rates on the basis of the forward exchange rates over the period from 2005 to 2013. Specifically, the relationship between the rates was assessed by graphical and regression analyses. The author applied econometric methods to investigate stationarity, to reduce autocorrelation and to test hypotheses. While the values of indicators were similar to the expected ones in some cases, other values differed from the expected ones. A crucial summarized finding was deducted. The present forward exchange rates were not found to be sufficiently reliable forecasters of the future spot exchange rates. This finding partially corresponds to the results of some empirical studies quoted in the paper, especially those published by Aggarwal, Lin and Mohanty (2008), Polito (2001) and Afanasenko, Gischer and Reichling (2011).

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