RADIM GOTTWALD*

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The Prediction of the USD/EUR Spot Exchange Rate on the Basis of the Forward Exchange Rates

Introduction

The making of exchange rate predictions is one of the interesting economic topics. The economics of each country is influenced by the development of the exchange rates between domestic and foreign currencies. Financial analysts make predictions in order to profit from the possible trend of exchange rates in the future. Several methods can be used to make predictions. The using of forward exchange rates is considered to be one of such methods. The aim of the paper is the assessment of the prediction of chosen spot exchange rates on the basis of the forward exchange rates over the chosen period. The extent to which the future spot exchange rates can be predicted by this way is examined by the author. The paper follows a number of empirical studies focused on the exchange rate predictions. Some of these studies are quoted in the paper.

The remainder of this paper is organized as follows. Section "Literature" describes the relationship between the spot rate and the forward rate in the light of the literature, showing the effort of many researchers to examine the predictive power of forward rates for future spot rates. Some empirical studies on the subject are also quoted. The choice of currencies and analysed time period are specified in the section "Methodology", along with the description of methods and procedures used. Section "Results" contains graphical analysis and regression analysis of the relationship between the spot and forward rates. The author makes the predictions on the detrended model. The contribution of the paper is emphasized in the section "Discussion". "Conclusion" summarizes important findings.

1. Literature

In the past five decades, the relationship between the forward and spot exchange rates has become the subject of interest of many researchers. Numerous studies have examined

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whether the forward rates are reliable predictors of the future spot rates. However, re-searchers have obtained conflicting results. Moreover, more sophisticated methods have been used because of the development of the information technologies. There is often the belief that the forward rates must be unbiased predictors of the future spot rates, otherwise speculators and investors could profit from the bias by taking certain position in the spot exchange market and the opposite position in the forward exchange market. Kang (1992) states that the forward rates can be good predictors of the future spot rates when the level of the future spot rates is regressed on the level of forward rates. He also brings out some new evidence on the role of interest rate differentials in the determina-tion of the exchange rates.

A number of interesting empirical studies on the prediction of spot exchange rates on the basis of forward exchange rates have been published. Some researchers use USD and just one other currency. Wesso (1999) tried to find out whether the forward rates were optimal predictors of the future spot rates in case of the 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 predicting the future spot rates. However, the current forward rates provide worse predictions of the future spot rates than do the current spot rates. Furthermore, it is clear that estimated coefficients for the spot rates and the for-ward rates fall below one, rejecting the unbiased predictor hypothesis. The difficulty of predicting the future spot rates by means of the forward rates is at the centre of attention of Wang (2008). Using the USD/DEM rates over the period from 1974 to 1991, he points out that the exchange rate predictability improves with the time horizon.

Some researchers use USD and more than one other currency. The question whether the forward rates are rational predictions of the future spot rates inspired Aggarwal et al. (2008) to analyse USD, GBP, JPY, CHF, DEM and CAD rates over the period from 1973 to 1998. Their results show that the USD forward rates for horizons ranging from 1 to 12 months against other currencies excluding CAD are generally not efficient or rational predictions of future spot rates. On the other hand, the rationality and efficiency of the USD forward rates for CAD was not rejected. Dominguez and Novales (1999) examined, how to improve the future spot rate predictions on the basis of the forward rates. They analysed USD, JPY, DEM, GBP, ESP, FRF, ITL and CHF rates from 1978 to 1998 and showed that forward rates mostly produced better predictions of spot rates than univari-ate autoregressions for a number of currencies.

The question whether the forward rates are useful indicators of the future rates was also examined by Polito (2001). 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, meaning that the forward rates do not fully reflect all information available to economic agents.

Afanasenko et al. (2011) focus on the predictive power of the forward rates for the future spot rates by analysing the German swap rates for the period from 1995 to 2007. Their results give no evidence in favor of the forward rates as useful tools for predic-tions. They also use maximum likelihood estimates of the cointegration equation ob-tained with the used sample to construct predictions for the next 12 months. 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 rates can be used to predict future spot rates. He finds out for a wide range of parameter values that the

adjustment of the forward rate for a premium term leads to prediction errors. Results show that 9–16% of the variance in these errors is due to variation in premia.

2. Methodology

The aim of the paper is to assess the prediction of the spot exchange rates USD/EUR on the basis of the forward exchange rates over the period from January 1, 2005 to December 31, 2013. We examine the extent to which the future spot rates can be predicted on the basis of the present forward rates. In other words, the author wants to find out whether the present forward rates can be considered to be reliable predictors of the future spot rates. The choice of the currencies USD and EUR is clear from Table 1, which reports 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 the USD and EUR are evident.

The covered interest rate parity could be used to explain the determination of the forward exchange rates. This parity is related to such a situation when the no-arbitrage condition is satisfied by 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 to hedge against exposure to exchange rate risk.

The covered interest rate parity can be represented as follows:

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

where $IR_{D,t}^{t+n}$ is domestic interest rate at time t for period $t+n$, $IR_{F,t}^{t+n}$ is foreign interest rate at time t for period $t+n$, SR_t is spot exchange rate at time t and FR_t^{t+n} is forward exchange rate at time t for period $t+n$. This equation is known as the covered interest parity equation and it refers to the interest rate parity. The covered interest rate parity is found to hold when there is a limited capital control and open capital mobility; this finding is valid for all currencies freely traded in the present-day markets. 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 that forward exchange rates are unbiased predictors of the future spot exchange rates:

$$FR_t^{t+n} = E_t(SR_{t+n}),$$

where $E_t(SR_{t+n})$ is expected spot exchange rate at time t for period $t+n$.

In our analysis we use daily closing spot and forward exchange rates. The maturities of forward rates are 3 months and 6 months. The database of Reuters (2014) is used as the data source. The forward rates are announced as forward points, in contrast to the spot rates. The forward point is the 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 and forward rates. For example, if the spot exchange rate of the USD/EUR is 1.400 and the 3-month forward exchange rate is 5 forward points, forward points are divided by 1000 and added to the spot exchang rate. So, the forward exchange rate is 1.405 USD/EUR.

Graphical analysis and regression analysis of the relationship between the spot, 3-month forward and 6-month forward rates are implemented at the beginning of the empirical analysis. The regression parameters are estimated by the ordinary least squares method, with t-statistic, p-value, adjusted R^2 and Durbin-Watson statistic being calculated. Based on the values of these indicators, the hypotheses related to the significance of the parameters are tested (the significance level of all tests in this paper is 5%).

The next step is the examination of the stationarity of the spot and forward exchange rates. Phillips (1986) states that the using of non-stationary data can give rise to apparent regression. We use the augmented Dickey-Fuller test (1979) for a unit root to examine the stationarity. The first differences of the spot, 3-month forward and 6-month forward rates USD/EUR are illustrated. The time series is then detrended in order to guarantee stationarity. P-values of the ADF statistics are calculated, too.

The last step of the examination includes the predictions of the detrended model. The indicators mentioned above are also calculated and, based on their values, the author tests the significance of the parameters. Because of a high positive autocorrelation in the residuals, the transformation into non-linear econometric model with integrated autoregressive process AR(1) is used in order to eliminate this autocorrelation. The author again calculates all the respective indicators and tests the hypotheses.

Based on the results, the extent to which it is possible to predict the future spot rates on the basis of the present forward rates is assessed at the end of the empirical analysis.

3. Results
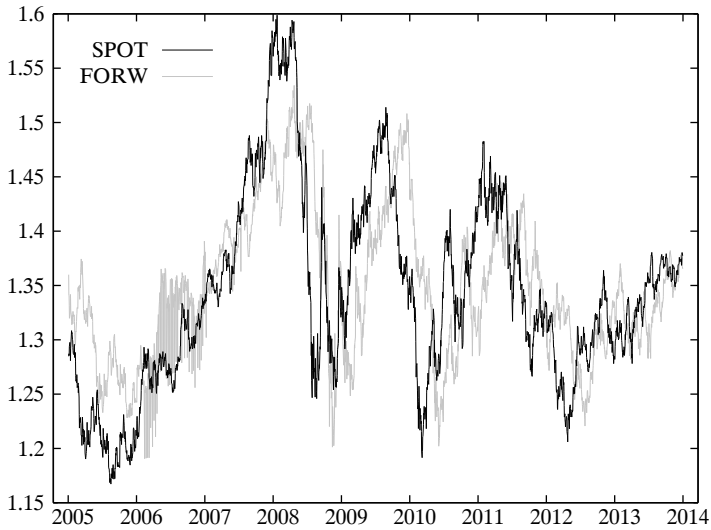
3.1. Graphical Analysis

The relationship between the spot and 3-month forward rates USD/EUR is illustrated in Figure 1, and the relationship between the spot and 6-month forward rates USD/EUR is illustrated in Figure 2.

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 predictions may be exact is evident. The spot rate curve would be the same as the forward rate curve only in the case of 100% accurate prediction. However, expected values differ from real

values relatively much. The spot rates exceed the forward rates during some periods but the opposite situation can be seen during other periods. Thus, the present forward rates probably cannot be considered to be sufficiently reliable predictors of the future spot rates.
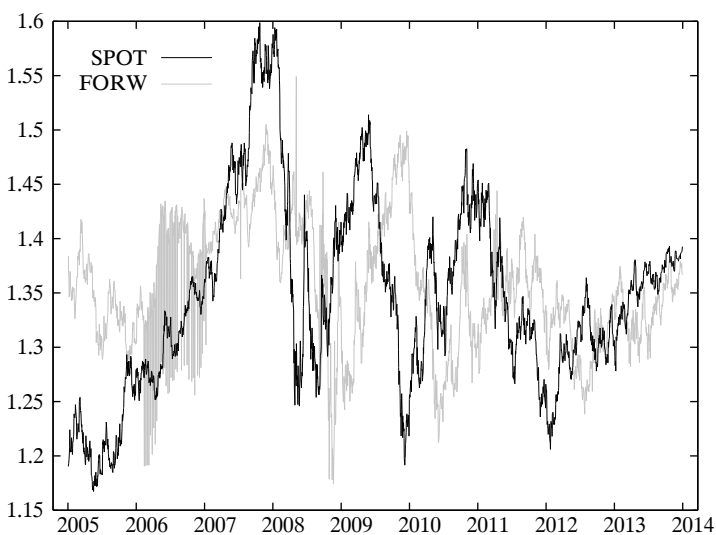
Figure 1

The relationship between the spot and 3-month forward rates USD/EUR

Source: Reuters (2014) and own calculations.

Figure 2

The relationship between the spot and 6-month forward rates USD/EUR

Source: Reuters (2014) and own calculations.

Miscellanea

3.2. Regression Analysis

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

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

where SR_{t+n} is spot rate at time $t+n$, a_0 and a_1 are regression parameters, FR_t^{t+n} is the forward rate at time t for period $t+n$, 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. Table 2 reports the results of the regression.

Table 2
Regression results

Parameter	Coefficient	t-statistic	p-value	Adjusted R^2	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 (2014) 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 prediction. Based on this fact, the following hypotheses are formulated:

Hypotheses related to a_0:
null hypothesis H_0: $a_0 = 0$;
alternative hypothesis H_1: $a_0 \neq 0$.

Hypotheses related to a_1:
null hypothesis H_0: $a_1 = 1$;
alternative hypothesis H_1: $a_0 \neq 1$.

At first, the 3-month forward rates are analysed. As for the hypotheses related to a_0, assuming the validity of the null hypothesis, the probability of $t = 6.10$ is $p = 1.23 \cdot 10^{-9}$. This probability is lower than 5% significance level; thus, the null hypothesis is rejected. As for the hypotheses related to a_1, assuming the validity of the null hypothesis, the probability of $t = 44.06$ is p-value lower than 0.0001. This probability is lower than 5% significance level; thus, the null hypothesis is again rejected. Analysing the 6-month forward rates, the null hypotheses are rejected analogously.

The results of the regression analysis can be summarized as follows. Regression parameters significantly differ from 0 for a_0 and 1 for a_1. The forward predictions systematically undervalue the future spot rates because of positive regression parameters a_0. These parameters are higher in the case of the 6-month forward rates than for the 3-month forward rates. Risk premium could be the potential reason, because the longer the time horizon is, the higher the uncertainty in the foreign exchange market. Investor usually gets certain risk premium, however he accepts higher risk only when the risk premium is also higher.

3.3. Testing of the stationarity

Time series of the first differences is set from initial time series. The augmented Dick-
ey-Fuller test is used to investigate stationarity of the spot and forward rates USD/EUR.
Two informations must be found in order to correctly make this test. 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 spot rates USD/EUR. Figure 4 illustrates
the first differences of the 3-month forward rates USD/EUR. Finally, Figure 5 illustrates
the first differences of the 6-month forward rates USD/EUR.
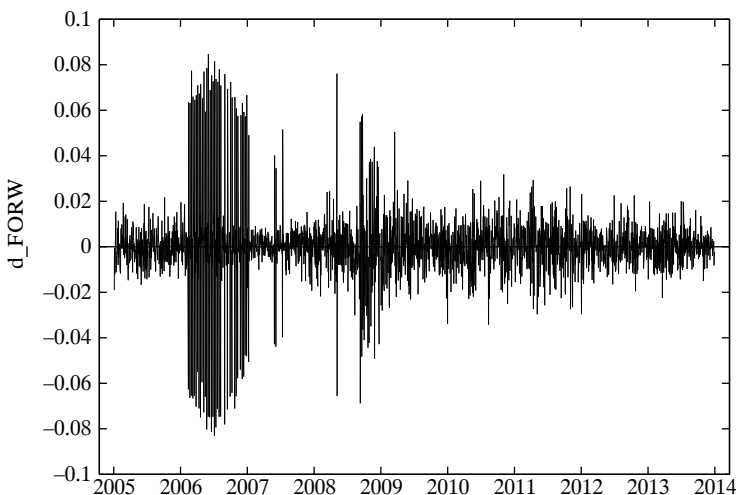
F i g u r e 3

The first differences of the spot rates
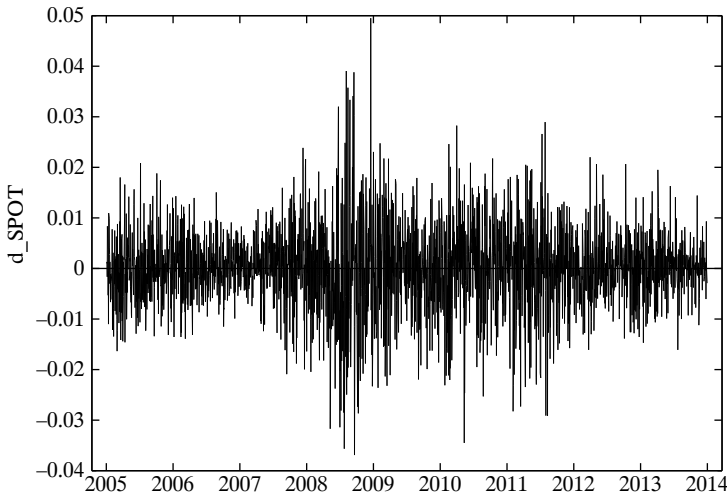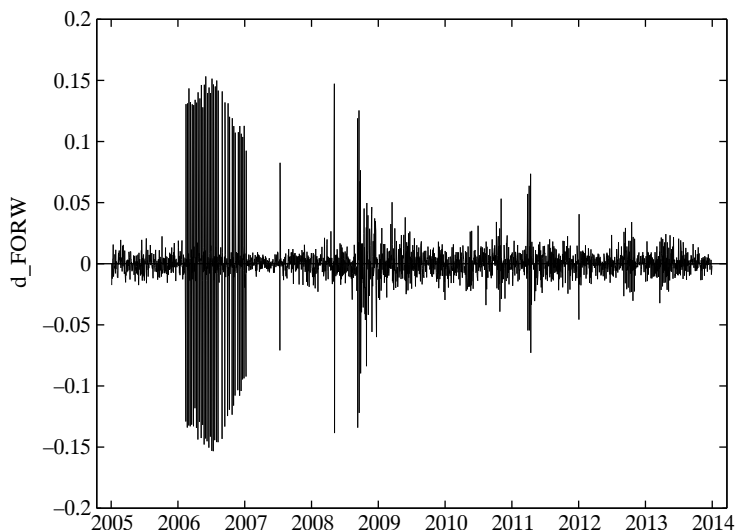

Source: Reuters (2014) and own calculations.

F i g u r e 4

The first differences of the 3-month forward rates

Source: Reuters (2014) and own calculations.

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F i g u r e 5

The first differences of the 6-month forward rates

Source: Reuters (2014) and own calculations.

Figures 3, 4 and 5 show that the values oscillate around 0 and that no trend is visible. Thus, the ADF test is set as "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 it. Table 3 reports *p*-values for the ADF test for a unit root in the time series of the spot and forward rates USD/EUR.

T a b l e 3

**P-values for the ADF test for a unit root
in the time series of spot and forward exchange 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 (2014) 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 5% significance level, all time series are found out to be non-stationary. In other words, they contain unit root. At the same time, the time series of their first differences are stationary.

3.4. Detrending

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

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

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

Table 4

**P-values for the ADF test for a unit root in the time series
of the differences of the exchange rates**

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 (2014) and own calculations.

Similarly to the previous case, p-values presented in Table 4 express minimum significance level for rejection of the null hypothesis for a unit root. With respect to 5% significance level, all time series are found out to be stationary.

3.5. The predictions of the detrended model

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

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

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

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

Table 5 reports the regression results for the detrended model.

Table 5

Regression results for the detrended model

Parameter	Coefficient	t-statistic	p-value	Adjusted R^2	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 (2014) and own calculations

The hypotheses related to regression parameters are again tested. P-value related to a_0 is higher than 5% significance level in both cases. Thus, the null hypothesis cannot be rejected at the 5% significance level. P-value related to a_1 is lower than 5% significance level in both cases. Thus, the null hypothesis is rejected at the 5% significance level.

Adjusted R^2 is relatively high in both cases. Durbin-Watson statistic is close to 0. Thus, there is a high positive autocorrelation in the residuals of the model. The transformation into non-linear econometric model with integrated autoregressive process AR(1) is used in order to eliminate this autocorrelation. The process AR(1) is defined as follows:

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

where c is constant, which is not significantly different from O, ε_t is white noise, and φ_1 is parameter which must satisfy $|\varphi_1| < 1$; otherwise the process is not stationary. Table 6 reports the regression results for the non-linear model.

Table 6

Regression results for the non-linear model

Parameter	Coefficient	t-statistic	p-value	Adjusted R^2	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 (2014) and own calculations

Similarly to previous cases, the hypotheses related to regression parameters are tested. Based on the p-values, the null hypothesis related to a_0 is not rejected at the 5% significance level, while the null hypothesis related to a_1 is rejected at the 5% significance level. The adjusted R^2 and Durbin-Watson statistic have increased after the transformation into non-linear econometric model with integrated autoregressive process AR(1). The autocorrelation in the residuals of the model has been really eliminated. Durbin-Watson statistic is in the zone of no autocorrelation.

The results of the estimation can be summarized as follows. The present forward exchange rates cannot be considered to be sufficiently reliable predictors of the future spot exchange rates. The values of indicators are similar to the expected in some cases, but there are also some cases when the values are different from expected.

4. Discussion

The contribution of this paper consists in assessing the extent to which the predictions of future spot exchange rates on the basis of the present forward exchange rates can be reliable. Making the predictions of exchange rates in the foreign exchange markets is still one of the topical economic themes. The findings about the predictive power of the forward exchange rates for the future spot exchange rates can be important for speculators in the foreign exchange markets and for financial analysts working in financial companies and international trading companies dealing in import/export business. The using of the forward rates for the purpose of predicting spot rates is advantageous because of

several reasons. The forward rates are usually available on the Internet, they are 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 are the predictions of the future exchange rates, the higher profits can be realized by speculators in the foreign exchange markets. Theoretically, the knowledge of the forward rates allows to predict the future spot rates exactly while the forward rates reflect exactly the expectations of market participants. However, even if market participants take into consideration all available neccesary information, 3 months and 6 months will be too long time. The reason is clear. New information, in other words expected and unexpected events, appear in the foreign exchange markets really many times in a day. The future spot rates differ from their real values because of unexpected events. Thus, the choice of maturities expressed in months is really important. The shorter maturity is, the higher adjusted R^2 probably is.

Nowadays the predicted exchange rates differ from the actual rates, but the forecasting errors will be probably lower in the future thanks to the continuous development of information technologies, econometrics and statistics, and more sophisticated models. The author is sure that the research on the subject should continue. The researchers could choose other exchange rates, maturities, time periods, statistical indicators and other models to predict the spot rates.

Conclusion

The paper followed in a number of empirical studies focused on the exchange rate predictions. Several recently published studies were quoted in the paper. The prediction of the spot exchange rates USD/EUR on the basis of the forward exchange rates over the period from 2005 to 2013 was assessed. The relationship between the rates was assessed by graphical analysis and regression analysis. The author applied econometric methods in order to examine stationarity, eliminate autocorrelation and test the significance of the results. The present forward exchange rates were not found out to be sufficiently reliable predictors of the future spot exchange rates. This finding partially corresponds with the results of some other empirical studies quoted in the paper, especially written by Aggarwal et al. (2008), Polito (2001) and Afanasenko et al. (2011).

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PROGNOZOWANIE KURSU WALUTOWEGO USD/EUR NA PODSTAWIE JEGO NOTOWAŃ W TRANSKACJACH TERMINOWYCH

Streszczenie

Celem artykułu jest ocena możliwości prognozowania rzeczywistych kursów walutowych na podstawie ich notowań w transakcjach terminowych. Analiza dotyczy prognozowania kursu rynkowego USD/EUR na podstawie notowań w transakcjach terminowych w okresie od 2005 r. do 2013 r. Relacja między dziennym kursem zamknięcia i kursem notowanym w transakcjach terminowych 3- i 6-miesięcznych została zilustrowana graficznie i przeanalizowana za pomocą regresji. Autor bada stacjonarność szeregu czasowego i dokonuje jego detrendyzacji dla zapewnienia stacjonarności oraz przekształca równanie do formy nieliniowej w celu usunięcia silnej autokorelacji reszt. Prognozy kursu są wykonywane na modelu zdetrendyzowanym. Wyniki analizy pokazują, że bieżące notowania kursu w transakcjach terminowych nie są dostatecznie wiarygodnymi wskaźnikami przyszłego kształtowania się kursu rynkowego. Informacja ta jest ważna dla analityków finansowych prognozujących kursy walutowe na użytek instytucji finansowych i przedsiębiorstw uczestniczących w obrocie międzynarodowym oraz dla graczy spekulujących na rynkach walutowych.

Słowa kluczowe: kurs walutowy, USD/EUR, prognozy, modele ekonometryczne

THE PREDICTION OF THE USD/EUR SPOT EXCHANGE RATE ON THE BASIS OF THE FORWARD EXCHANGE RATES

Abstract

The aim of the paper is to assess the extent to which the future spot exchange rates can be predicted on the basis of the present forward exchange rates. The analysis refers to the prediction of the spot exchange rate USD/EUR on the basis of the forward exchange rates over the period from 2005 to 2013. Both graphical and regression analyses are used to examine the relationship between daily closing spot and forward rates, specifically 3-month rates and 6-month rates. The regression equation is estimated by the ordinary least squares method, and the hypotheses related to the parameters are tested at the 5% significance level. The author examines whether the time series is stationary. Subsequently, the time series is detrended in order to guarantee stationarity. The transformation into non-linear econometric model is used in order to eliminate high positive autocorrelation in the residuals of the model. Then the predictions of the detrended model are

made. The results of the analysis show that the present forward exchange rates are not sufficiently reliable predictors of the future spot exchange rates. These findings are important for financial analysts working in financial companies or enterprises participating in international turnovers, as well as for speculators acting in the foreign exchange markets.

Key words: exchange rate, USD/EUR, prediction, econometric models

ПРОГНОЗИРОВАНИЕ ВАЛЮТНОГО КУРСА USD/EUR НА ОСНОВАНИИ ЕГО КОТИРОВОК ПО СРОЧНЫМ СДЕЛКАМ

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Целью статьи является оценка возможности прогнозирования реальных валютных курсов на основании их котировок по срочным сделкам. Анализ касается прогнозирования рыночного курса USD/EUR на основании его котировок по срочным сделкам за период с 2005 по 2013 год. Соотношение между дневным курсом закрытия и курсом, обозначенным в 2-х и 6-ти месячных сделках, было представлено графически и проанализировано с помощью регрессии. Автор исследует стационарность временного ряда и делает его бестрендовым с целью обеспечения стационарности, а также преобразовывает уравнение в нелинейную форму в целях устранения сильной автокорректировки остатков. Прогнозы курса делаются на бестрендовой модели. Результаты анализа показывают, что текущие котировки курса в срочных сделках не являются достаточно достоверными показателями будущего формирования рыночного курса. Эта информация важна для финансовых аналитиков, прогнозирующих валютные курсы по заказу финансовых институтов и предприятий, участвующих в международном обороте, а также для игроков, занимающихся спекуляцией на валютных рынках.

Ключевые слова: валютный курс, USD/EUR, прогнозы, эконометрические модели