Covered Interest Rate Parity: The Case of the Czech Republic

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COVERED INTEREST RATE PARITY: THE CASE OF THE CZECH REPUBLIC

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Abstrakt
Tento příspěvek se zabývá teorií kryté úrokové parity a snaží se zjistit, zda tato teorie platila pro devizový kurz CZK/EUR v období od května 2001 do listopadu 2007. Byla použita běžná OLS regrese doplněná MA(1) procesem reziduí a ARCH(6) modelem rozptylu reziduí[1]. Výsledky ukazují, že teorie kryté úrokové parity v daném období neplatila, nicméně zdá se, že hlavními faktory pro formování tříměsíčního forwardového kurzu CZK/EUR byl úrokový diferenciál a nominální spot kurz, což je plně v souladu s touto teorií.

Klíčová slova
Krytá úroková parita, devizový kurz, úroková míra, měnové trhy.

Abstract
This paper tries to find out, whether the Covered Interest Rate Parity (CIRP) theory was valid for exchange rate CZK/EUR during the period ranging from May 2001 to November 2007. As a main tool, a common OLS regression was chosen. It was augmented by MA(1) process of residuals and by ARCH (6) model of residuals' variance. The results show, that the CIRP theory was not valid during selected period. However, it seems apparent, that the main factors for 3-month forward exchange rate CZK/EUR determination were an interest rate differential and a nominal spot exchange rate. This is fully consistent with the CIRP theory.

Key words
Covered interest parity, exchange rate, interest rate, foreign exchange markets.

1 Introduction

The Covered Interest Rate Parity theory (CIRP) is one of many theories, which try to formulate equilibrium conditions of foreign exchange markets. Its' principles are simple. This theory posits that domestic assets' interest rate should be equal to foreign assets' interest rate plus expected percentual change of exchange rate. This is in fact the simple form of Uncovered Interest Rate Parity (UIRP). But, if we substitute expected future exchange rate with known future exchange rate (i.e. forward exchange rate), we get CIRP.

The validity of CIRP in the Czech republic was tested, for example, by Komárková (2006), or by Komárek – Komárková (2008). She found out, that CIRP was valid in the Czech republic during examined period. However, Komárková (2006) uses OLS regression to test functional form of CIRP as it is given by equation (2). In this paper, we tests CIRP in slightly different way, using the equations (9) and (10). Nonetheless, our results also show that CIRP is valid,

[1] A similar approach to account for autocorrelation of residuals is used in Stančík (2007). Although he uses AR(p) process, the principle is the same.

but in terms of determining the forward exchange rate by spot exchange rate and interest rates' differential.

The aim of this paper is to test empirically, whether the CIRP holds for the nominal exchange rate CZK/EUR or not. We use daily data from May 2001 to November 2007. The econometric testing incorporates OLS regression augmented by MA(1) process of residuals and by ARCH(6) model of residuals' variance.

The paper is divided into following sections. The first section defines CIRP, regressions', MA(1) and ARCH(6) functions used for econometric testing. Also we display some graphs of data, brief description and some conclusion arising from them. In the second section we present the results of econometric regression. The third section concludes.

2 Creating the model of the Covered Interest Rate Parity

2.1 The Covered Interest Rate Parity

The CIRP model can be derived as follows.

First, we have to specify the UIRP. The equation (1) defines the UIRP as equality between domestic and foreign assets' interest rates ratio and ratio of future expected exchange rate and current exchange rate. Assuming that the future value of foreign assets includes a risk premium, we can write[2]:

$$\frac{E_{t+1}}{E_t} = \frac{(1+i)}{(1+i^*)} * (1+\sigma), \tag{1}$$

where E_{t+1} is the future expected exchange rate, E_t is the current exchange rate, i is the domestic assets' interest rate, i^* is the foreign assets' interest rate and σ is the risk premium of foreign assets held by domestic agents due to exchange rate uncertainty.

Assuming that foreign exchange markets are effective and therefore F_t is the best prediction of E_{t+1}, we may substitute E_{t+1} with F_t, which is the known future exchange rate, i.e. the forward exchange rate and we get the equation of CIRP:

$$\frac{F_t}{E_t} = \frac{(1+i)}{(1+i^*)}, \tag{2}$$

where F_t is forward exchange rate, E_t is current (spot) exchange rate, i and i^* are domestic and foreign assets' interest rates. Note that risk premium has been removed. It is simply because the uncertainty adherent to the possible expected exchange rate change has gone. When the equation (2) holds, the foreign exchange market of domestic and foreign currency is in the equilibrium state.

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[2] Or in another form: $(1+i) = \frac{(1+i^*)}{(1+\sigma)} * \frac{E_{t+1}}{E_t}$

2.2 Creating the OLS regression function

If we want to apply the OLS regression on equation (2), we have to take the logarithms of selected equation. By doing this operation and after moving the logarithm of E_t to the right side of the equation we get:

$$\ln(F_t) = \ln(1+i) - \ln(1+i^*) + \ln(E_t) + \varepsilon_t\,, \tag{3}$$

or:

$$LF_t = \alpha_1 + \beta_1 * LID_t + \beta_2 * LIF_t + \beta_3 * LS_t + \varepsilon_t\,, \tag{4}$$

where LF_t is natural logarithm of forward exchange rate, LID_t and LIF_t are natural logarithms of domestic and foreign assets' interest rates. LS_t is natural logarithm of spot nominal exchange rate CZK/EUR and ε_t is the error term. α_1 is constant and β_1, β_2, β_3 are parameters, where β_2 is assumed to be negative and β_1 and β_3 to be positive. Since testing for common unit root (Levin, Li, Chu; Breitung; and Hadri tests) shows that time series are integrated by order 1, we have to use first differences.

This yields in equation (5):

$$DLF_t = \alpha_1 + \beta_1 * DLID_t + \beta_2 * DLIF_t + \beta_3 * DLS_t + \varepsilon_t\,. \tag{5}$$

This equation can be used for standard OLS regression.

2.3 Defining MA(1) process of residuals

Since OLS regression of equation (5) suffers from autocorrelation of residuals, to account for this undesirable effect we implement MA(1) process, which form is defined by equation (6):

$$\varepsilon_t = \phi_1 \gamma_{t-1} + \upsilon_t\,, \tag{6}$$

where ε_t is value of residuals in time t, γ_{t-1} is value of forecast error in time $t-1$ and υ_t is error term of equation (6).

Thus, so far our regression equation has the following form:

$$DLF_t = \alpha_1 + \beta_1 * DLID_t + \beta_2 * DLIF_t + \beta_3 * DLS_t + \phi_1 \gamma_{t-1} + \upsilon_t\,. \tag{7}$$

2.4 Defining ARCH(6) models of residuals

Since ARCH LM test of equation (7) shows that autoregressive conditional heteroskedasticity (ARCH) is present, we have to incorporate into our regression function a model of ARCH to capture this effect on variance of error term υ_t. Presence of ARCH effect means that variance of residuals is not constant, which violates one of the conditions of valid OLS (including MA(1)) regression[3]. We use ARCH(6) model, as it is specified below[4].

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[3] Implementation of ARCH model is also justified by the presence of volatility clustering in differenced time series data of spot and forward exchange rate. See Fig. 1.

2.4.1 ARCH(6)

This model captures unstable variance of residuals by using following approach[5]:

$$\sigma^2{}_t = \omega_t + \sum_{n=1}^{6} \alpha_n * \upsilon_{t-n}^2 , \tag{8}$$

where σ^2_t is a variance of residuals υ_t, υ^2_{t-n} is a squared value of residual in time t-n.

2.5 Final model for OLS estimation

Our model which was used for OLS regression and which captures the effect of autocorrelation and ARCH on residuals is presented by equations (9) and (10):

$$DLF_t = \alpha_1 + \beta_1 * DLID_t + \beta_2 * DLIF_t + \beta_3 * DLS_t + \phi_1 \gamma_{t-1} + \upsilon_t , \tag{9}$$

$$\sigma^2{}_t = \omega_t + \sum_{n=1}^{6} \alpha_n * \upsilon_{t-n}^2 . \tag{10}$$

Residuals υ are assumed to follow NID(μ,σ^2), where $\mu = 0$ and $\sigma^2 = 1$. μ and σ^2 are supposed to remain constant during whole period, i.e. residuals are homoskedastic.

2.6 Data

For econometric testing of CIRP, daily data from May 2001 to November 2007 were used. For known future exchange rate (F_t) we use 3-month forward exchange rate of CZK/EUR, for current exchange rate (E_t) we use spot exchange rate of CZK/EUR. As proxies of domestic and foreign interest rate (i and i^*), PRIBOR 3M and LIBOR 3M were chosen.

Fig. 1 shows leveled and differenced logarithmic values of all used variables.

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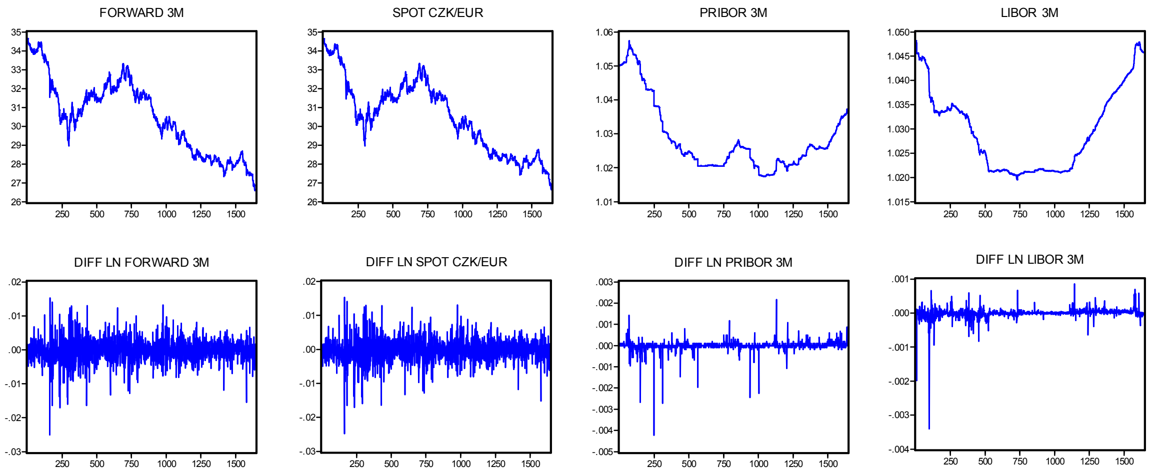
[4] The ARCH (6) was chosen as the most suitable one after conducting several tests, which were aimed to pick the best model of ARCH effect of residuals. The candidates were ARCH, GARCH, PARCH, TARCH, EGARCH and Component ARCH models. The OLS regression which included MA(1) and ARCH(6) displayed the best results in terms of presence of no autocorrelation and of no remaining ARCH effect.

[5] See Arlt, J., Arltová, M. (2003, p. 166) or Arlt, J., Arltová, M. (2006, p. 128).

Fig. 1 Development of leveled and differenced variables

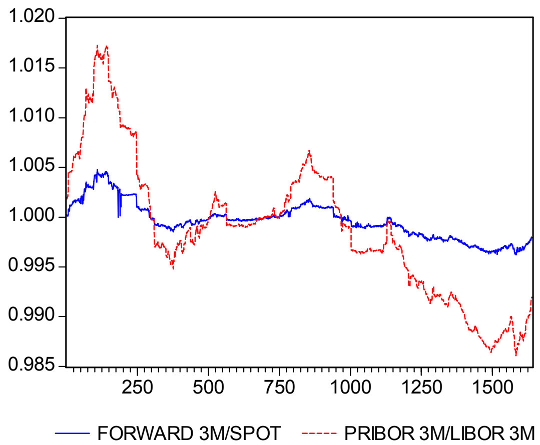


Source: CNB, BBA, own calculations

Note: The X axis is not time-labeled, since there were some unmatched gaps in time series.
To be able to match selected time series, some data have to be removed.
Hence, displayed data do not cover all days of selected period of time.

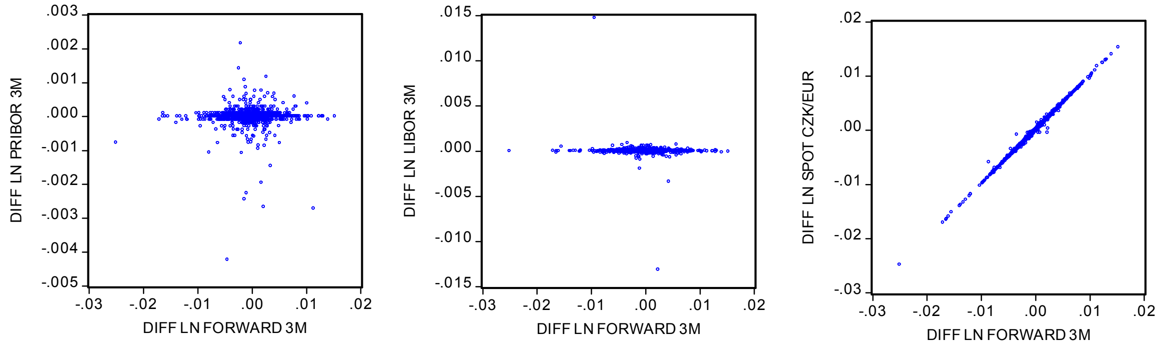
We may see that SPOT CZK/EUR and FORWARD 3M development (in leveled or differenced form) is in fact almost the same. That is, of course, not surprising, because the forward exchange rate usually follows the same pattern as spot exchange rate does. Value of forward exchange rate differs from spot by value given by interest rate differential. Also from differenced forms of forward and spot exchange rates we may see a typical pattern of volatility clustering which justifies ARCH(6) implementation.

Fig. 2 Comparison of Forward 3M/spot ratio and PRIBOR 3M/LIBOR 3M ratio



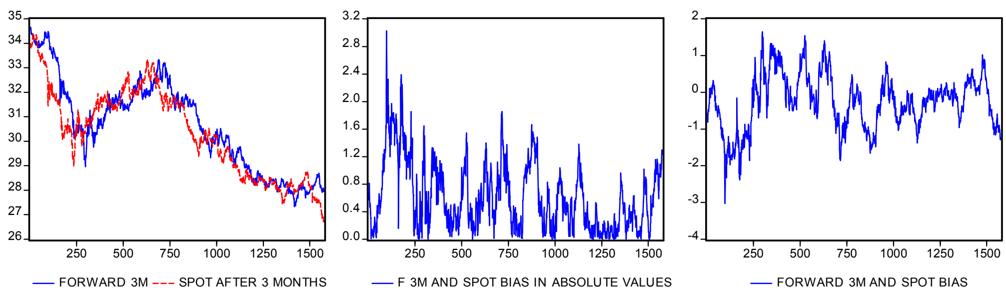
Given the equation (2), when CIRP holds, the values of these two ratios should be the same. Thus, seeing Fig. 2, we could conclude, that (strict) CIRP theory did not hold for CZK/EUR exchange rate. However, as we will see in the 2nd section, the econometric testing of equations (9) and (10) shows us, that interest rate differential and spot exchange rate are the main components in determining known future exchange rate.

Fig. 3 Relationships between regressand and regressors



In Fig. 3 we can see that, there is clear linear relationship namely between forward and spot rate. That is, of course, not surprising, as it is apparent from Fig. 1.

Fig. 4 Comparison of predicted spot rate by Forward 3M and real spot rate



Source: CNB, own calculations

Looking at Fig. 4, we see that foreign exchange markets were not successful in predicting future spot exchange rate by forward 3M. We can see that during almost the whole examined period, the CZK/EUR rate was predicted by exchange markets to be weaker than it actually happened to be. Also we may notice that the bias of predicted and real spot rate was developing in cyclical pattern with decreasing range except for the end of examined period.

3 Results of econometric testing of CIRP validity

The model we test has form given by equations (9) and (10), i.e.:

$$DLF_t = \alpha_1 + \beta_1 * DLID_t + \beta_2 * DLIF_t + \beta_3 * DLS_t + \phi_1 \gamma_{t-1} + \upsilon_t , \tag{9}$$

$$\sigma^2{}_t = \omega_t + \sum_{n=1}^{6} \alpha_n * \upsilon_{t-n}^2 . \tag{10}$$

We test whether the 3-month forward exchange rate is determined by the 3-month domestic and foreign interest rate differential and by the spot exchange rate or not. The results are presented in Tab. 1.

Tab. 1 Regression results*

Dependent Variable	DLF
Independent Variables:	
Constant	0.0000 (0.7289)
DLID	0.2447 (0.0000)
DLIF	-0.2599 (0.0000)
DLS	1.0047 (0.0000)
MA(1)	-0.5107 (0.0000)
ARCH (6):	
Dependent Variable	σ^2_t
Independent Variables:	
ω_t	0.0000 (0.0000)
υ^2_{t-1}	0.1578 (0.0002)
υ^2_{t-2}	0.2194 (0.0000)
υ^2_{t-3}	0.8639 (0.0000)
υ^2_{t-4}	-0.0754 (0.0005)
υ^2_{t-5}	0.1264 (0.0000)
υ^2_{t-6}	0.0926 (0.0000)
R^2	0.9982
Adj. R^2	0.9982
F-stat.	0.0000
Autocorrelation:	
Correlogram	no autocorrelation
Q-stat.	possible autocorrelation up to 24th lag.
Normality:	
JB-test	not normal distribution (0.0000)
No. of observations	1639

* - probability values in parentheses. Results of tests of model's validity are available upon request.

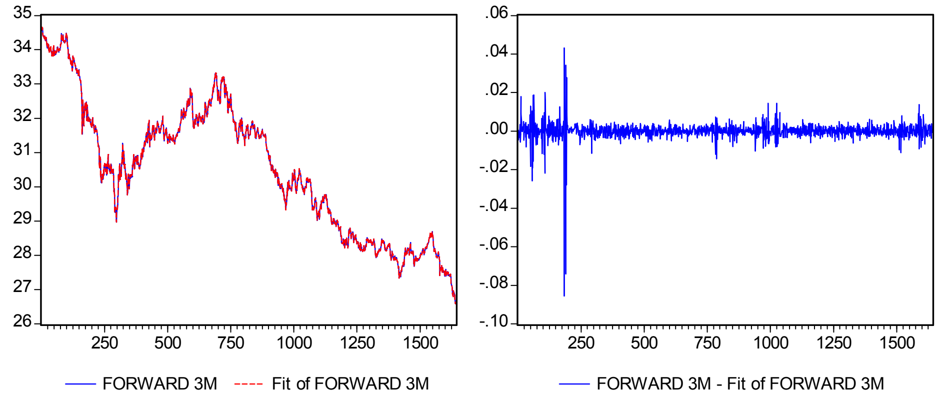
From regression results we are able to clearly see, that interest rate differential and spot rate were crucial factors for forming forward exchange rates.

The results of autocorrelation tests are mixed. A correlogram suggests that there is no autocorrelation in residuals. However, Q-statistics suggests that the autocorrelation is present up to 24th lag. By implementing ARCH(6) model we were able to capture ARCH effect and volatility clustering of exchange rate time series.

All parameters of variables (except for both constants) are highly statistically significant, and whole model is highly statistically significant as well. High value of R^2 indicates that fitted values of forward exchange rate almost totally fit the real values, as it can be seen from Fig. 5.

However, there is one serious drawback of the selected model. Residuals clearly do not follow NID (0,1) distribution, namely because of an excessive kurtosis (and therefore JB test for normality is highly statistically significant). Since residuals' distribution is not normal, the chosen model is not suitable for prediction.

Fig. 5 Comparison of fitted and real values of forward exchange rate



Source: CNB, own calculations

4 Conclusion

In this paper, we tried to find out, whether Covered Interest Rate Parity holds for CZK/EUR exchange rate.

We have found that: (i) the simple comparison of exchange rates' and interest rates' ratios does not confirm the validity of CIRP, as it is given by equation (2), (ii) the comparison of predicted spot rate and real spot rate indicates that foreign exchange markets were not effective, which violates important assumption of CIRP, i.e. possibility of substituting the E_{t+1} by F_t, (iii) the OLS regression augmented by MA(1) process of residuals and by ARCH(6) model of residuals' variance shows, that the interest rates' differential and the spot exchange rate were dominant factors of determining the forward (known future) exchange rate. Thus, in this sense, the CIRP was valid in the Czech republic during selected period.

However, the chosen model is not suitable for forward exchange rate prediction, since the distribution of residuals is not normal.

The challenge for future research may be implementing more sophisticated model, such as Markow-switching model, to be able to make the task of doing some valid predictions of the forward exchange rate development less difficult.

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