

## ESTIMATION OF THE TIME-VARYING RISK PREMIUM IN THE CZECH FOREIGN EXCHANGE MARKET

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### Abstract:

The paper presents both the theoretical account of the issue of foreign exchange risk premium and the actual estimates of the time-varying risk premium for the cases of the Czech koruna to euro and US dollar. The risk premium is modelled within a state space framework and estimated using the Kalman filtering procedure. Some financial market fundamentals are used to estimate the risk premium, and thus not only do the estimates give insight into the foreign exchange market behaviour but also into some linkages between the various segments of the financial market as a whole.

**Keywords:** financial market, foreign exchange risk premium, interest rate parity, Kalman filter

**JEL Classification:** E44, E47, F31

### 1. Introduction

The models of exchange rate behaviour, both more and less sophisticated, as well as macroeconomic models usually exploit the condition of interest rate parity. There is a large number of empirical studies investigating how this condition stands when confronted with empirical data with various partial conclusions. However, most of them hold the view that the time needed for the accommodation of the exchange rate to interest rate differential is longer than one would expect in financial markets. This implies the existence of periods of excess returns; a violation of the interest rate parity condition. One of possible explanation of this phenomenon is the existence of risk premium.

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The paper presents an empirical investigation into the issue of a time-varying foreign exchange risk premium in the Czech foreign exchange market. More precisely, it is focused on the estimation of the risk premium in cases of the bilateral exchange rates of the Czech koruna to euro and US dollar.

Both pure statistical and structural models have been applied in the literature to estimate foreign exchange risk premium with the emphasis on general equilibrium approach in the recent years. Both advantages and risks of those modelling strategies will be briefly discussed below. For reasons to be put forward in due time, this paper applies the rather statistical approach to the estimation of the risk premium. However, it also exploits some fundamental variables to explain the evolution of the risk premium which in the end interlinks the behaviour of the Czech foreign exchange market with some other segments of the Czech financial market. In this respect it brings some new insight into the behaviour of the Czech financial market.

It is necessary for the estimation of the risk premium and the exposition of the issue as a whole to make clear what exactly is meant by the risk premium and how exactly the risk premium relates to other variables. Thus the first part of the paper presents the exposition of the basic theoretical relationships and also gives a brief survey of the key approaches to the issue as well as the key approaches to the foreign exchange risk premium modelling. The second part presents the methodology of the analysis. It exposes the idea of the modelling strategy taken in this paper and also it provides a step-by-step account of how the risk premium was actually modelled. The third part presents the analysis of the data which enter the empirical part of the paper and some preliminary estimates. The fourth part gives the actual results of the model application to the EUR/CZK and USD/CZK exchange rates. Then it gives an analysis of the estimated risk premium and points out the linkages between the various segments of the financial market. The last part of the paper summarizes the main conclusions.

## **Theoretical Background**

The research into these issues was spurred by the behaviour of US dollar in the years 1981 and 1982. There was a strong appreciation of dollar to yen while it was traded with forward discount in future foreign exchange market. Applying the covered interest rate parity line of reasoning, a forward discount means a positive interest rate differential (difference between US and Japanese interest rate). However, from the point of view of the uncovered interest rate parity, a positive interest rate differential implies a depreciation of American dollar. This, in turn, is in contrast with the actual behaviour of US dollar in the early 1980s. One of the possible explanation of this inconsistency between the covered and uncovered interest rate parity view is the existence of risk premium.

Now the basic theoretical relationships will be formulated. The way of how the relationships will be put forward is close to the one presented by Lewis (1994). Together with the presentation of the main theoretical conclusions, the Fama result, given by Fama (1984), which later became known as one of the foreign exchange puzzles, see for example Froot and Thaler (1990), will also be given.

After the basic relationships are recovered, a brief account of the key approaches to this issue will be given as well as the modelling strategies applied in risk premium modelling.

First, uncovered and covered interest rate parity conditions will be recalled. Uncovered interest rate parity captures the relationship between the expected change in the exchange rate and the differential in the returns on domestic and foreign assets:

$$\frac{E_t(S_{t+k}) - S_t}{S_t} = \frac{1 + i_t^D}{1 + i_t^F}, \quad (1)$$

where  $S$  denotes spot exchange rate between domestic (D) and foreign (F) currency, number of units of D *per* unit of F, operator  $E$  denotes expectations and  $i$  means interest rate. Taking logarithms of both sides of equation (1), an approximative version of uncovered interest rate parity may be applied:

$$E_t(s_{t+k}) - s_t = i^D - i^F, \quad (2)$$

where  $s$  denotes logarithm of  $S$ .

Covered interest rate parity condition may be expressed in much the same manner as equation (1) with the substantial difference, which is the substitution of the expected spot exchange rate by forward exchange rate  $F$ . Taking logarithms of both sides of such an equation, the condition may be stated as:

$$f_{t+k} - s_t = i_t^D - i_t^F, \quad (3)$$

where  $f$  denotes logarithm of  $F$ .

Regarding equations (2) and (3), the equilibrium of the foreign exchange market (alternatively, the efficiency of the foreign exchange market) implies the fact that the forward rate is an unbiased predictor of the future spot exchange rate for the given maturity of the forward contract ( $k$ ):

$$f_{t+k} = E_t(s_{t+k}) + \varepsilon_t, \quad (4)$$

where  $\varepsilon$  denotes the forecasting error, which should have normal distribution and should be serially uncorrelated (iid).

If the condition as expressed by equation (2) does not hold then it is possible to express *ex post* excessive return (*er*). The *ex post* excessive return may be expressed as follows:

$$er_{t+k} = s_{t+k} - s_t + i_t^F - i_t^D. \quad (5)$$

Now it is possible to substitute from equation (3) into equation (5):

$$er_{t+k} = s_{t+k} - f_{t+k}, \quad (6)$$

To compare with equation (4) which says that *ex ante* excessive return has a mean zero and is iid, equation (6) expresses the actual, *ex post*, excessive return. This expression may be reformulated by adding and subtracting the current spot exchange rate from both sides of equation (6):

$$er_{t+k} = \Delta s_{t+k} - (f_{t+k} - s_t). \quad (7)$$

The difference between forward and spot exchange rate (for a given maturity of the forward contract) is referred to as forward premium. The *ex post* excessive return is thus dependent on forward premium and the realized change in the spot exchange rate. Now applying expectations to (7), it is possible to express the so-called predicted excessive return (*per*):

$$E_t(er_{t+k}) \equiv per_t = E_t \Delta s_{t+k} - (f_{t+k} - s_t), \quad (8)$$

where *per* denotes predicted excessive return. Substituting from equation (6) into equation (8), the excessive return may be expressed as follows:

$$er_{t+k} = per_t + \eta_t, \quad (9)$$

where  $\eta$  is the forecast error.

This much constitutes the basics needed for the exposition of the idea used to estimate the time-varying risk premium later in the paper. To complete the theoretical elements, the so-called Fama result will be exposed further.

It is based on Fama testing the implications of foreign exchange market efficiency as given above:

$$\Delta s_{t+k} = a_0 + a_1 (f_{t+k} - s_t) + u_t, \quad (10)$$

where  $u_t$  denotes the residuals of the regression (10). The regression equation (10) just tests the relationship given by the interest parity conditions and one can clearly see that under foreign exchange market efficiency the estimate  $a_0$  should be 0 and that for  $a_1$  should equal 1. However, Fama (1984) found out that not only were the estimates for  $a_1$  less than one, but also they were negative in many cases. The magnitude of the estimated coefficients of regression (10) has an interesting implication for the magnitude of volatility of the possible risk premium.

To see this, it is useful to express the probability limit of the coefficient  $a_1$  of the regression equation (10):

$$a_1 = \frac{\text{cov}(\Delta s_{t+k}, f_{t+k} - s_t)}{\text{var}(f_{t+k} - s_t)}, \quad (11)$$

where *cov* denotes covariance and *var* denotes variance. Exploiting the fact that differences between expected and realized changes in spot exchange rate are given by the error term in (10), this expression for the estimate of  $a_1$  may be further reformulated as:

$$a_1 = \frac{\text{cov}(E_t \Delta s_{t+k}, f_{t+k} - s_t) + \text{cov}(u_t, f_{t+k} - s_t)}{\text{var}(f_{t+k} - s_t)} = \frac{\text{cov}(E_t \Delta s_{t+k}, f_{t+k} - s_t)}{\text{var}(f_{t+k} - s_t)}. \quad (11a)$$

This rests on the assumptions of the least squares method; the second covariance in the numerator of the first fraction must be zero.

The risk premium  $rp$  is defined as the difference between the forward rate and the expected spot rate for the given maturity of the forward contract:

$$rp_{t+k} = f_{t+k} - E_t(s_{t+k}). \quad (12)$$

It follows that the excessive return (6) and the predicted excessive return (8) may be looked upon as the opposite value of the *ex post* or *ex ante* risk premium. Now using (12) the forward premium may be expressed as:

$$f_{t+k} - s_t = rp_{t+k} + E_t \Delta s_{t+k}. \quad (13)$$

The variance of the risk premium (13) is:

$$\text{var}(rp_{t+k}) = \text{var}(f_{t+k} - s_t) + \text{var}(E_t \Delta s_{t+k}) - 2\text{cov}(f_{t+k} - s_t, E_t \Delta s_{t+k}). \quad (14)$$

Now substitute into equation for the probability limit of  $a_1$  (11a) from equation (14) and rearrange to obtain the final result:

$$a_1 = \frac{1}{2} + \frac{\text{var}(E_t \Delta s_{t+k}) - \text{var}(rp_{t+k})}{2\text{var}(f_{t+k} - s_t)}. \quad (15)$$

One can clearly see from equation (15) that if the estimated coefficient of the regression (10) is just equal 0.5, the variance of the risk premium is equal to the variance of the expected change in spot exchange rate. If the estimated coefficient is less than 0.5 or even negative, the variance of the risk premium exceeds the variance of the expected change in spot exchange rate.

This result is difficult to examine in the case of the Czech economy because the variables entering regression (10) are not stationary therefore it is not possible to use the same approach as was used by Fama.

Before moving further to review the basic approaches to risk premium modelling, take account of equation (13). From this one sees that it does not have to be the risk premium which is the driving force of the possible misalignment of the parity conditions. The key factor may be the wrong (not rational) expectations.

This approach has been challenged by both theoretical and empirical work. There are two explanations for this issue. The first one relies on irrational expectations and was proposed and tested by Froot and Frankel (1989) who used data on business expectations of exchange rate behaviour to show the existence of systematic expected errors. They thus conclude that the forward premium bias is by no means fully attributable to risk premium.

The second explanation does not regard the expectations as irrational but examine the issue of market expectations formation under the condition of infrequent changes in the

distribution of shocks hitting the economy. The result of this investigation leads to the incorporation of learning about past and future changes into the process of expectation formation. The so-called rational systematic forecast errors which result from this cause the forward premium bias not through the presence of serial correlation in the forecast error. Again, it is not the risk premium which causes the misalignment, nor is it that the market participants be irrational. The key work in this field is due to Lewis (1989).

In a recent work Chinn (2006) shows the data give a little more credit to UIP condition than it is usually acknowledged. It is pointed out that especially in the short horizon the assumption of a mean zero forecast error seems problematic.

The fact is that the risk premium strand has remained dominant. The second fact with respect to the Czech financial market is that the data do not enable one to apply such an investigation as is exploited by the “forecast error” strand of work.

One of the early empirical studies which finds the existence of the risk premium key for the explanation of the biasedness of the forward premium is Canova and Ito (1983). Their view is supported by Hodrick and Srivastava (1984). Both studies focus on the behaviour of US dollar.

Besides more or less statistical approaches to risk premium modelling, more and more studies have been exploiting some economic models to estimate the risk premium. In the early work this was usually done within the international CAPM while later on the intertemporal CAPM model have been used. Though the intertemporal CAPM follows in the up-to-date general equilibrium approach and is superior to the static versions of CAPM, they are both unable to provide a satisfactory estimates of the returns and their risks at the same time. For the exposition of the issue and estimation of time-varying risk premium with the general equilibrium models see Engel (1992) and Bekaert (1994). Usually a satisfactory variance of the risk premium is achieved by an implausibly high risk aversion parameter. This was noted by Mehra and Prescott (1985) and further by Weil (1989). Though some advance has been made by using other than time-separable utility functions, see Epstein and Zin (1989) and introducing habit formation into the utility function, see Backus *et al.* (1993), Cochrane and Campbell (1999) and for a more recent study Smith and Wickens (2002). Nice overview of this issue is given by Cochrane (2005). Usually more general, semi-structural approach is taken under the banner of stochastic discount factor (SDF) modelling. A comprehensive review is given by Smith and Wickens (2002). Bansal (1997) applies term structure models to explain forward premium within SDF approach.

A statistical approach to the risk premium modelling will be used in this paper with regard to some additional fundamentals.

## 2. Methodology

Fama and French (1988, 1992) and Chen (1991) presented analyses of the common risk factors of the behaviour of the returns in the financial market, especially stocks and bonds. They used several fundamentals to explain the behaviour of stocks and bonds, but three common factors appeared in those studies and were later used to explain the

behaviour of future basis in the commodity markets by Bailey and Chan (1993). These are dividend yield of the stock market, term premium and default premium.

Baum and Barkoulas (1996) exploit these findings to discuss the relationship between forward premium in the exchange rate market and those fundamentals. Using the expression (13) they test the dependence of the forward premium and the forecast error on those fundamentals. While they found the forward premium dependent on these fundamentals, the error is found to be independent of them. Thus they arrived at the conclusion that there was a relationship between the forward premium and the fundamentals which was transmitted via the risk premium. However, they did not go as far as to estimate the time-varying risk premium using the fundamentals.

This paper makes use of this idea, however, the test used in Baum and Barkoulas (1996) is just a preliminary analysis to the actual estimation of the risk premium and the discussion of the dependence of the risk premium on the fundamentals.

In this paper only two of the three fundamentals will be used: dividend yield (DY) and term premium (P) as the data to construct the default premium, which should express the difference between corporate bonds yield and government bonds yield, are not sufficient. In addition, net foreign assets (NFA) as a traditional variable used for modelling foreign exchange premium is used.

The preliminary analysis may be summarized as follows:

$$FP = \alpha_1 DY + \alpha_2 P + \alpha_3 NFA + \sum_{i=4}^m \alpha_i AR + \sum_{j=m+1}^n \alpha_j MA + \varepsilon_t, \quad (16)$$

$$FE = \beta_1 DY + \beta_2 P + \beta_3 NFA + \sum_{i=4}^m \beta_i AR + \sum_{j=m+1}^n \beta_j MA + \eta_t, \quad (17)$$

where  $FP$  denotes forward premium,  $FE$  forecast error,  $DY$  dividend yield,  $P$  term premium,  $NFA$  net foreign assets,  $AR$  is an autoregressive and  $MA$  moving average element and  $\varepsilon$  and  $\eta$  are residuals with mean zero and no serial correlation.

The ARMA terms are added to achieve nice behaviour of the residuals. To sum up, if the fundamentals (DY, P, NFA) are significant in the regression (16) and insignificant in (17) it can be viewed as an argument for the existence of the risk premium in foreign exchange market.

The time-varying risk premium is recovered within a state-space model:

$$\begin{aligned} S_{yoy,t} &= IRD_t + RP_t + v_t \\ RP_t &= \gamma RP_{t-1} + \phi DY_t + \varphi P_t + \psi NFA_t + v_t \\ v &\sim N(0, \sigma_v^2) \\ v &\sim N(0, \sigma_v^2) \end{aligned} \quad (18)$$

where  $S_{yoy}$  denotes yearly relative changes in spot exchange rate,  $IRD$  denotes interest rate differential,  $RP$  denotes risk premium and  $v$  and  $v$  are residuals with mean zero and respective variance. The risk premium in (18) is the excessive return in (5).

The variance of the residual of the signal equation (equation for yearly relative changes in spot rate) is set to the variance of the relative changes in spot rate for the given sample. The variance of the state equation (equation for risk premium) is estimated. The covariance of the respective residuals is set to zero. The coefficient of the interest rate differential is set to one according to theory. All variables (except year-on-year changes in spot rate) enter in first differences. The model is estimated by maximum likelihood method.

Next part of the paper first examines the data which enter the analysis and then presents estimates of the preliminary analysis according to regressions (16) and (17).

### 3. Data and Some Preliminary Estimates

The risk premium will be estimated for two exchange rates: EUR/CZK and USD/CZK, units of CZK *per* unit of EUR and USD respectively. The spot rates and forward points for maturity of three months were retrieved from CNB (Czech National Bank). The data on forward points are published on daily basis and were transformed into monthly data by averaging.

The data on interest rates to calculate interest rate differentials were taken from Eurostat; three-month money market rates for the Czech, euro area and US economies were used.

Dividend yield was retrieved from the yearly reviews of the Prague stock exchange and the term premium was calculated in four variants as the difference between: the yield on government bonds with the maturity of five or ten years and three-month Pribor (P1 and P2) and the yield on government bonds with the maturity of five or ten years and those with the maturity of one year (P3 and P4). The variable of net foreign assets was computed as a cumulated current account deficit relative to GDP starting in 2000. The accumulation was carried out on quarterly basis. The quarterly series was then transformed into monthly series using quadratic polynomial (to transform the quarterly series into monthly series, quadratic polynomial is fit for a each set of three consecutive points from the quarterly series and then used to fill in the missing points in the monthly series for that period so that the average of the interpolated high frequency points matches the actual low frequency values).

It is necessary to assess the stationarity of the variables which enter the estimation procedure. Therefore Table 1 presents the unit root test (ADF) for forward premium, calculated as the difference of logarithms of forward and spot exchange, logarithm of spot exchange rate, interest rate differentials, dividend yield, term premiums and net foreign assets.

The estimation sample is significantly limited by the availability of forward points on EUR/CZK exchange rate. It starts in May 2001 and goes up to May 2009. Accounting for the fact that yearly relative changes in the spot rate will be used, the sample actually starts in May 2002.

All the entering series but the first measure of term premium (P1) may be considered nonstationary and will be used first differenced in the modelling procedure.

Next the estimation of the regressions (16) and (17) will be presented. The information is given by Table 2 for both the exchange rates EUR/CZK and USD/CZK.

Table 1

**Unit Root Test: left column shows t-statistic for ADF on levels while right columns shows t-statistic for ADF on 1st differenced series**

| Variable               | Level<br>t-statistic | 1 <sup>st</sup> difference<br>t-statistic |
|------------------------|----------------------|---|
| FD <sub>CZK/EUR</sub>  | -2,200400            | -6,304706***                              |
| FD <sub>CZK/USD</sub>  | -1,509227            | -7,023854***                              |
| S <sub>CZK/EUR</sub>   | -0,849710            | -7,496906***                              |
| S <sub>CZK/USD</sub>   | -1,402146            | -7,232834***                              |
| IRD <sub>CZK/EUR</sub> | -2,149320            | -5,518115***                              |
| IRD <sub>CZK/USD</sub> | -1,349171            | -7,076034***                              |
| DY                     | -2,090389            | -9,343759***                              |
| P1                     | -2,928751**          | -6,030490***                              |
| P2                     | -2,428180            | -5,521827***                              |
| P3                     | -2,659213*           | -5,762756***                              |
| P4                     | -2,187143            | -5,499693***                              |
| NFA                    | -2,865396*           | -5,110517***                              |

Note: \*\*\*, \*\*, \* denotes rejection of the null at 1%, 5%, 10% level of significance, respectively

Table 2

**Regression Analysis of the Behaviour of Forward Premiums and Forecast Errors with Respect to the Fundamentals**

| Regression for forward premium CZK/EUR |           |              | Regression for forward premium CZK/USD |           |             |
|--|-----------|--------------|--|-----------|-------------|
| Variable                               | estimate  | t-statistic  | Variable                               | estimate  | t-statistic |
| DY (-1)                                | 0,011156  | 2,390835**   | DY (-1)                                | 0,016092  | 2,135419**  |
| P2                                     | -0,045098 | -2,114212**  | P2                                     | -0,088090 | -1,840553*  |
| NFA                                    | -0,004199 | -1,694577*   | NFA                                    | 0,005682  | 1,282484    |
|  |           |              | MA (-1)                                | 0,262893  | 2,781295*** |
| MA (-1)                                | 0,382200  | 4,048612***  | MA (-2)                                | 0,324135  | 3,411175*** |
| Adj. R2                                | 0,22837   |              | Adj. R2                                | 0,173158  |             |
| Log likelihood                         | 655,8642  |              | Log likelihood                         | 612,0198  |             |
| DW                                     | 1,926579  |              | DW                                     | 1,986968  |             |
| Regression for forecast error CZK/EUR  |           |              | Regression for forecast error CZK/USD  |           |             |
| Variable                               | estimate  | t-statistic  | Variable                               | estimate  | t-statistic |
| DY (-1)                                | -0,244587 | -1,439257    | DY (-1)                                | -0,182603 | -0,520190   |
| P2                                     | 1,108052  | 1,714594*    | P2                                     | 4,404564  | 2,041349**  |
| NFA                                    | -0,404046 | -2,379540**  | NFA                                    | -0,143495 | -0,810632   |
| AR (-1)                                | 0,974001  | 86,05882***  |  |           |             |
| MA (-1)                                | -0,982224 | -58,27145*** | MA (-1)                                | 0,284357  | 2,856398*** |
| Adj. R2                                | 0,219118  |              | Adj. R2                                | 0,089625  |             |
| Log likelihood                         | 297,6158  |              | Log likelihood                         | 217,8911  |             |
| DW                                     | 2,019234  |              | DW                                     | 1,942068  |             |

Note: \*\*\*, \*\*, \* denotes rejection of the null at the 1%, 5% or 10% level of significance, respectively

The regression output shows that both forward premiums are dependent on dividend yields and term premium, the significance ranging between 5% and 10%. The forward premium for US dollar is not dependent on net foreign assets. The MA elements were added to achieve no statistically significant serial correlation among the residuals. The model explains almost 23% of the variance of the forward premium in the case of EUR/CZK and about 17% in the case of USD/CZK. The serial correlation was tested by Ljung-Box Q-statistic up to order 12. This output is not presented in the paper; Durbin-Watson statistic is given instead.

The second part of the output in Table 2 shows that generally the financial fundamentals are less significant in the regressions for forecast errors. The relatively high percentage of explained variability of the forecast errors is given mainly by the inclusion of AR and MA terms to achieve no statistically significant serial correlation in the residuals so that the estimates of the regressions are valid. Dividend yield lost its significance in both cases. The significance of term premium is lower in the case of the forecast error for EUR/CZK but it is higher in the other case. Net foreign assets gained some significance in the case of the forecast error for EUR/CZK. The results of the analysis are thus somewhat ambiguous. The variables draw less significance in the regressions for forecast errors but they do not lose it. According to the Baum-Barkoulas interpretation (1996) the role of systematic expected errors cannot be fully discarded.

#### 4. Estimates of Time-Varying Risk Premium

The time-varying risk premium was estimated within the model (18). The results of the estimated models are given in Table 3.

Table 3

**Models for Risk Premium**

| Model for CZK/EUR |           |             |
|-------------------|-----------|-------------|
| Variable          | estimate  | t-statistic |
| RP                | 0,999193  | 82,88229*** |
| DY                | 1,467078  | 2,771874*** |
| P2                | 4,062335  | 1,707189*   |
| NFA               | 0,094987  | 1,626401    |
| Log likelihood    | 142,2106  |             |
| AIC               | -3,004578 |             |
| Model for CZK/USD |           |             |
| Variable          | estimate  | t-statistic |
| RP                | 0,981834  | 81,87510*** |
| DY                | 1,686882  | 1,657825    |
| P2                | 5,601334  | 1,590821    |
| NFA               | 0,373984  | 1,974402**  |
| Log likelihood    | 62,34111  |             |
| AIC               | -1,268285 |             |

Note: \*\*\*, \*\*, \* denotes rejection of the null at 1%, 5%, 10% level of significance, respectively

The first part of the table gives the results for the estimates of the coefficients related to the respective variables listed in the first column of Table 3. In the interpretation of the estimates it is important to bear in mind that it is the excess return as in (5) which is directly estimated by the model. In the tables and figures further below the sign is changed so that the results can be interpreted directly as a risk premium. In the case of the model for the exchange rate EUR/CZK, it is worth noting the following: the estimated risk premium follows an autoregressive process with the autoregressive coefficient close to one. This means that the series shows a great deal of persistence. The dividend yield enters significantly and there is a negative relationship between the dividend yield and the risk premium. The same holds for the term premium but the significance is lower. The significance of the estimated coefficient for net foreign assets just exceeds the 10% level (by about 0.2). NFA is negative throughout the sample, thus increase in the deficit of the current account increases the risk premium. Regarding the lower significance, the magnitude of the estimated coefficient is also low. The variance of the residual in the signal equation (UIP condition) was set at app. 0.003, which corresponds to the actual variance of the yearly relative changes in the spot rate. The variance of the residual in the state equation was estimated at app.  $5 \cdot 10^{-7}$ . The model explains app. 36% of the variability of the yearly changes in the spot rate.

The estimated risk premium shows a similar persistence in the model for the exchange rate USD/CZK. The significance of the estimated coefficients for dividend yield and term premium just exceeds the 10% level (by 0.1 and 0.2 respectively). Net foreign assets enter significantly. The variance of the residual in the signal equation was set at app. 0.02 and the variance of the residual in the state equation was estimated at app.  $5 \cdot 10^{-5}$ . However, the model as a whole is much less significant as indicated by the value of the likelihood function and also the fact that it explains just about 5% of the variability of the yearly changes in the spot rate.

Figure 1  
Forecasts of Year-on-Year Changes in Spot Rates; EUR/CZK (lhs), USD/CZK (rhs)

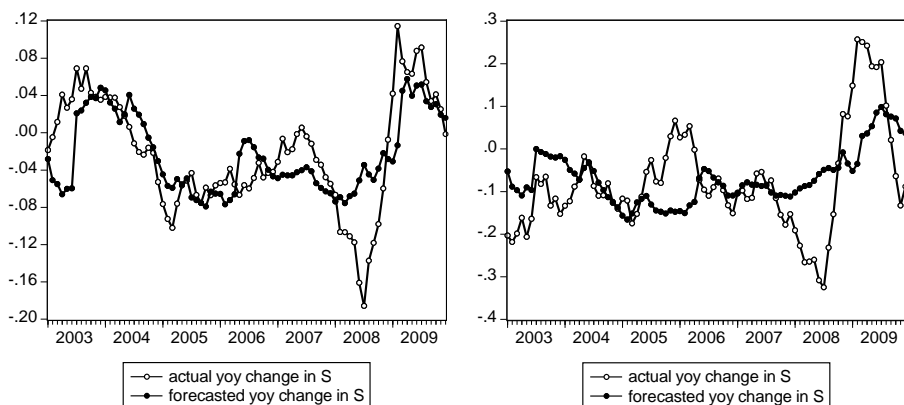
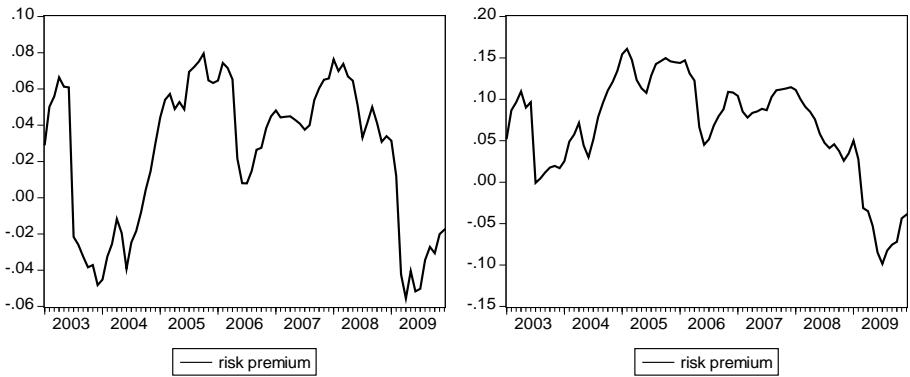


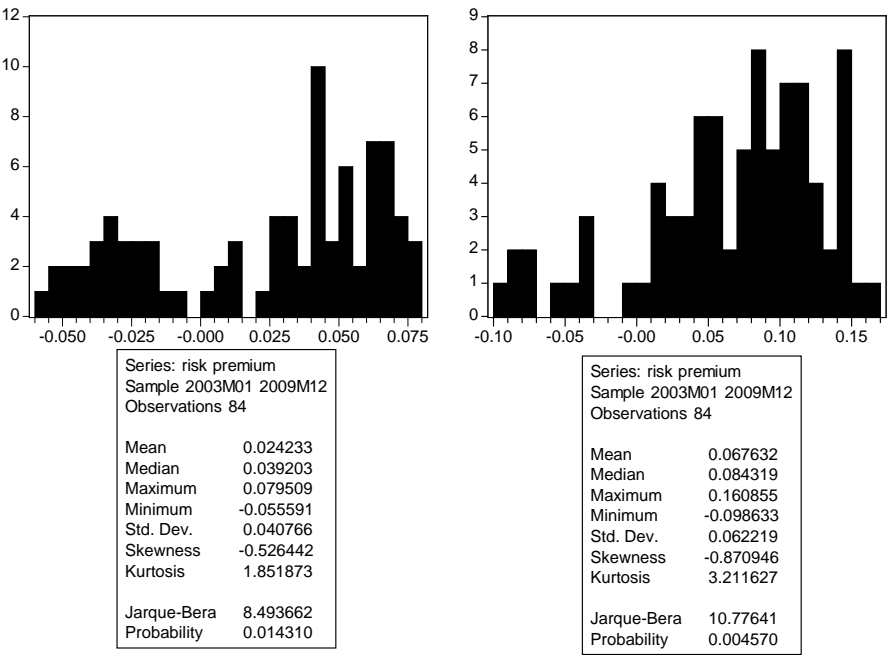
Figure 1 gives the result of the two models for the forecasted yearly changes in EUR/CZK and USD/CZK which are compared with the actual behaviour of the spot rate. Figure 2 presents the estimates of the risk premium for the two spot rates and Table 4 gives their basic characteristics.

Figure 2  
Estimates of Risk Premia; EUR/CZK (lhs), USD/CZK (rhs)



Note: \*\*\*, \*\*, \* denotes rejection of the null at 1%, 5%, 10% level of significance, respectively

Table 4  
Basic Characteristics of Risk Premia; EUR/CZK (lhs), USD/CZK (rhs)



The average values of the estimated risk premia is positive; app. 2.5% in the case of the exchange rate EUR/CZK. In the context of the model this means that on average the foreign investors required 2.5% higher return compared to similar foreign (euro) investments. The variance of the estimated risk premia is lower than the variance of the yearly changes in spot exchange rates which is at odds with the traditional Fama result. The variance of the risk premium in the case of EUR/CZK is app. 0.002 and in the case of USD/CZK it is app. 0.004. In fact the variance of the estimated risk premium in the case of USD/CZK is much lower than the variance of the year-on-year changes in the spot rate, which is app. 0.02. Much higher variance of the exchange rate of Czech koruna to US dollar is obviously the reason why the results of the model came out as poor. The difference between the variances of the risk premium and exchange rate in the case of EUR/CZK is much less significant.

The sharp appreciation of Czech koruna in 2008 (year-on-year appreciation of koruna to euro reached over 10% from February to September) was accompanied by a decrease in the risk premia and it even reached negative values. This was subsequently corrected. Loosely, the decrease in risk premia may be explained by a run from the dollar denominated assets at that time. This is also shown in the estimated risk premia for USD/CZK, however, I stress that this model showed much less significance. From the point of view of the model, the decrease was supported especially by increases in dividend yield and increase in term premium. The impact of NFA was negligible.

Boubakri and Guillaumin (2010) estimate foreign exchange risk premium for CEEC economies primarily to assess the rate of financial integration. From the point of view of my paper it is worth noting the statistical relevance of term premium and dividend yields which among other variables they use as instruments in the estimation procedure. In their analysis these factors were not found significant in the case of the Czech economy. They estimate highly variable and on average positive risk premium (slightly over 2%) for the Czech economy.

Kočenda and Poghosyan (2010) use multivariate GARCH in mean model to estimate a variable foreign exchange risk premium based on SDF approach. On average the risk premium is app. 4% without the impact of macroeconomic variables. This relatively higher estimate may be influenced by the sample, which in their case is from 1994 to 2006. They find the risk premium is significantly influenced by inflation and growth of money supply; the impact of growth of industrial production as a proxy for consumption growth is much less significant.

## 5. Conclusions

The paper presented two models for the estimation of time-varying risk premium in the foreign exchange market for the exchange rates of Czech koruna to euro and US dollar. The models build on uncovered interest rate parity condition and, assuming the existence of time-varying risk premium, the premium is filtered out using the Kalman filtering procedure. The premium is shown to be dependent on some fundamental

variables related to other segments of the financial market. Among the variables there are dividend yield of the capital market index, term premium and net foreign assets. These relations are directly built within the models.

The model for the exchange rate of Czech koruna to euro shows some explanatory power with regard to the behaviour of the spot exchange rate. The estimated risk premium is dependent on all of the selected variables although the statistical significance of its dependence on net foreign assets slightly exceeds the 10% level. The series of the risk premium follows a highly persistent autoregressive process and its mean value is positive which corresponds with the economic intuition. The qualitative aspect of the dependence of the estimated risk premium on the fundamental variables is in accordance with economic reasoning. The series reaches negative values twice: first time it can be attributed to the EU entrance and second time it is connected with the period of financial turbulences and sharp temporary appreciation.

The model for the exchange rate of Czech koruna to US dollar gives a broadly similar picture of the estimate of the time-varying risk premium. However, the model as a whole shows a substantially lower statistical significance. Probably the much higher variability of the exchange rate of Czech koruna to US dollar as compared with the previous case would be the key factor why the qualitatively same model failed in several aspects.

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