Testing the Expectations Hypothesis of the Czech term structure of interest rates

Testování hypotézy očekávání časové struktury úrokových sazeb v ČR

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Abstract

In the paper we test the Expectations Hypothesis for the Czech interbank market in 2000 to 2011. The study is a continuation of the similar analysis performed on the Czech market by Viktor Kotlan in late 1990's that proved the EH for about 50% of the interbank rates. We expected that the development of the Czech interbank market will contribute that our analyses will prove the EH for most of the tested rates. To our surprise the results indicate a rejection of the EH at the Czech market during the tested period. The same results were achieved even when assuming a shorter time series up to the year 2007 excluding the data for the financial crises.

Key words

Expectations hypothesis, Term structure, Czech interbank market

JEL Classification: E37, E43

1. Introduction

The expectations hypothesis of the term structure of interest rates is the proposition that the long term rates are determined by the market's expectation for the short term rates plus a risk premium. Analysing the term structure enables to identify expectations of the market participants about the future interest rates which play an important role for macroeconomic modelling, monetary policy and its transmission mechanism. We might also find the practical implication on the level of microeconomics, for example when we decide whether to take the loan now or some time later.

There is number of studies examining the term structure for different economies worldwide. The studies mostly find evidence supporting the EH but the results seem to be country specific.

Campbell and Shiller (1991) studied US market and formulated so called Campbell-Shiller paradox when they found that the slope of the term structure almost always gives a forecast in the wrong direction for the short-term change in the yield on the longer bond, but gives a forecast in the right direction for long-term changes in short rates. However, Jondeau and Ricart (1999) showed that the Cambell-Shiller puzzle doe not arise in the cases of French and UK short-term rates.

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Gerlach and Smets (1995) tested short end (less than one year) of the maturity spectrum of EURO-rates for 17 countries using between 10 to 30 years of data. They conclude that despite the presence of the time varying term premium, for many countries the EH is broadly compatible with the data.

Domínguez and Novales (2000) analyzed the long-term relationships among interest rates at different maturities of Eurodeposits and found strong evidence in favor of the EH as an adequate representation of the term structure. However, they also provide evidence that past rates contain information additional to that in forward rates to predict future short-term rates, against the rational expectations version of the EH and market efficiency.

Bataa (2005) examines the term structure for UK and shows that although the EH does not hold for UK interest rate at the short end of the maturity spectrum, there is robust support for this theory at interim maturities. On the other hand, Thorton (2004) analyses the EH for Japan and concludes that the EH appears not to fare well in Japan, but still he finds some evidence supporting EH for the shorter maturities.

There is also a study for Czech Republic. Viktor Kotlán (1999) examined the term structure of the Czech interbank market in 1993-1998 for the maturities from one month up to one year. The results showed that the expectations hypothesis in its pure form was valid for some maturities, though not for all. The validity of the EH was proven mostly for longer maturities (from three months to one year) and rejected for shorter maturities (below three months). Kotlan however points out that the findings should be treated with caution since relatively short time series of interest rates were used. Also we shall bear in mind that the year 1993 is the year when the Czech interbank market opened and that it took several volatile periods until the Czech market stabilized. And second, the year 1997 was the year of the Czech monetary crisis. Both facts could have an effect on Kotlan's results.

We have decided to update the Kotlan's study using the up-to-date data in period 1998-2010. The aim of our study is to examine whether the development of the Czech economy had some impact on conclusions formulated by Kotlan. The Czech market in 1998-2010 inevitably showed less volatile and more predictable development than the market in 1993-1998. Our hypotheses are two. First we expect that our study will prove the EH for maturities where Kotlan identified its existence. Second, we expect that the development of the Czech market will enable us to identify the EH for some new maturities for which the EH was rejected by Kotlan.

The rest of the paper is organized as follows. The chapter 2 provides a brief insight into the term structure of interest rate and describes the methodology of our testing. The chapter 3 describes our data and is leading us to chapter 4 that summarize the performed analysis of the EH. The concluding remarks can be found in the last chapter 5.

2. Testing of the Expectations hypothesis

The term structure of the interest rates is the relationship between the interest rate and the time to maturity of some financial asset which typically is a bond. There are different types of quotation of the interest rates. In this paper we denote:

- $i_{n,t}$ to be the spot interest rate with maturity at time n quoted in period t
- $f_{n,n+m,t}$ to be a forward rate starting at time n with maturity at time $n+m$ quoted in period t

All rates assumed within this paper are assumed to bear a simple interest. That means that the interest is calculated only from the principal of the lent / borrowed amount. Under the simple interest method, the following relationship holds between the spot and the forward rates:

$$f_{n,n+m,t} = E_t i_{m,t+n} = \frac{(n+m)\cdot i_{n+m,t} - n \cdot i_{n,t}}{m} \quad (1)$$

The pure expectations hypothesis theory believes that a long term interest rate equals the average of the current and future short term rates over the life of the long term interest rates (Baata 2005):

$$i_{n,t} = \frac{1}{k}\sum_{i=0}^{k-1} E_t i_{m,t+i} \quad (2)$$

The pure expectation hypothesis implies that holding the long term interest rates should bear the same pay-off as a strategy of rolling over several fixed short term interest rates over the same period. On the other hand the investors might require certain premium when entering into the longer term contracts compared to the roll over strategy. The pure expectations hypothesis cannot consider any kind of premium.

In order to capture the risk premium in the term structure of interest rate there has been formed the second famous theory, the **liquidity preference theory** that allows considering a constant term premium *c*:

$$i_{n,t} = \frac{1}{k}\sum_{i=0}^{k-1} E_t i_{m,t+i} + c \quad (3)$$

The above relationships are rarely tested directly since it is often prove that the tested series are not stationary. On the other hand it is often proved that the series are stationary in their first differences, i.e. that they are integrated by order one. Later we will show that our data exactly meet this general experience.

The rationality requires that: $$i_{m,t+n} = E_t i_{m,t+n} + \varepsilon_{t+n} = f_{n,n+m,t} + \varepsilon_{t+n} \quad (4)$$

where ε_{t+n} has a zero mean and is orthogonal to the information available at time *t* (Baata 2005). Subtracting the current spot rates from both sides of the equation lead us to the most tested equation of the expectation hypothesis:

$$(i_{m,t+n} - i_{m,t}) = \alpha + \beta \cdot (f_{n,n+m,t} - i_{m,t}) + \varepsilon_{t+n} \quad (5)$$

The relationship (5) states that the spread between the expected forward rate and the real future spot rate predicts the spread between the current and the future short term rates. Under the pure expectations hypothesis the parameter alpha is zero and beta equals to one.

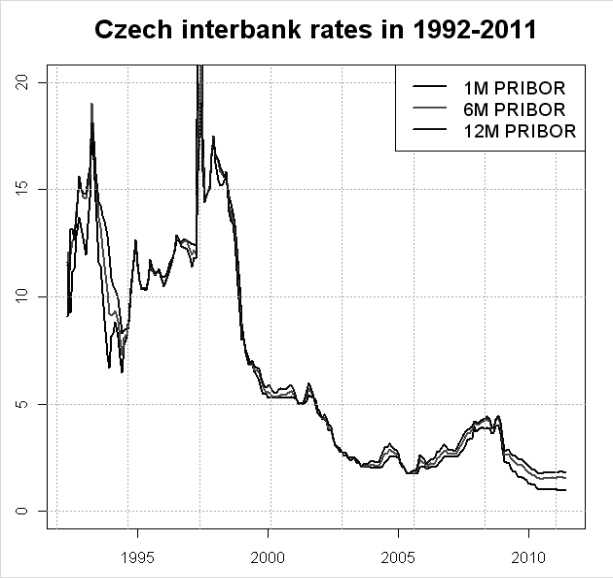
All analyses presented in the following chapters were carried out using the statistical software R, ver.2.13.1.

3. Data from the Czech interbank market

Our dataset comes from the public database of Czech national bank that on daily basis publishes representative interest rate data for the Czech interbank market. The rates known as PRIBID and PRIBOR are available at maturities of 1, 2, 3, 6, 9 and 12 months. We use the ask rates PRIBOR that are in our opinion more representative of the true situation on the market, particular in time of lower liquidity on the market. The data sample selected for our analysis covers the period from January 2000 to June 2011 and similarly as in Kotlan study are aggregated for each calendar month. The final sample includes 138 observations.

The Czech interbank market has changed its characteristics over the time. The figure 1 presents a development of the selected Czech interbank rates (i_1, i_6, i_{12}) over the history of the Czech interbank market from 1992 to 2011.

Figure 1: Czech interbank rates in 1992-2011, CNB 04/1992-07/2011



The detail description of the rates is provided in the Table 1. The rates are aggregated in 5 time frames. The rates have peaked in 1997 during the Czech monetary crisis and after that have steadily decreased. In 2011 the rates are at historical lows. Looking at relative variation of the interest rates, we might see a different path. The relative variation is here presented via coefficient of variation, e.g. the ratio of standard deviation and the mean of the rates.

For short tenors the variation coefficient bottomed in 2008 and after that started to increase. On the other hand for longer tenors the variation coefficient continued decreasing even after 2008. Therefore, the current short term rates are at historical lows but have relative higher variability than in the period before 2008. On the other hand the longer term rates are also at historical lows but in addition show historical low variability. We expect that the low relative variance of the long tenors will contribute to proving the EH also for this rates.

Table 1: Descriptive statistics of Czech interbank rates in April 1992 to June 2011, statistics: mean, standard deviation (parenthesis), variation coefficient (italics)

	1992-1994	**1995-1999**	**2000-2004**	**2005-2008**	**2009-2011**
Count	33	60	60	48	30
$\mathbf{i_1}$	10.73	12.26	3.72	2.74	1.40
	(2.91)	(4.64)	(1.37)	(0.78)	(0.51)
	27.14%	*37.83%*	*36.86%*	*28.39%*	*36.66%*
$\mathbf{i_2}$	4.80	12.12	3.72	2.80	1.52
	(4.69)	(4.12)	(1.37)	(0.82)	(0.53)
	97.67%	*34.00%*	*36.84%*	*29.24%*	*34.98%*
$\mathbf{i_3}$	11.50	12.01	3.74	2.86	1.64
	(2.93)	(3.79)	(1.37)	(0.85)	(0.53)
	25.46%	*31.53%*	*36.73%*	*29.81%*	*32.36%*
$\mathbf{i_6}$	12.07	11.82	3.79	2.95	1.91
	(2.97)	(3.40)	(1.39)	(0.86)	(0.47)
	24.59%	*28.73%*	*36.53%*	*29.18%*	*24.38%*
$\mathbf{i_9}$	5.45	11.71	3.86	3.03	2.05
	(5.38)	(3.26)	(1.41)	(0.86)	(0.45)
	98.77%	*27.82%*	*36.42%*	*28.41%*	*22.19%*
$\mathbf{i_{12}}$	12.62	11.69	3.93	3.10	2.16
	(2.70)	(3.21)	(1.43)	(0.86)	(0.45)
	21.37%	*27.48%*	*36.35%*	*27.79%*	*20.70%*

4. The expectations hypothesis test for the Czech interbank market

The Czech interbank market is quoted in 1, 2, 3, 6, 9 and 12 months tenors which enable to define several different forward rates. For the rest of the paper we focus on forward rates with 1 month, 3 months and 6 months tenors which we believe are most widely applied at the market (apart from a one year tenor which cannot be tested with our data). The concrete tested rates are the following: $f_{1,2}$, $f_{2,3}$, $f_{3,6}$, $f_{6,9}$, $f_{9,12}$, $f_{3,9}$, $f_{6,12}$.

Many studies showed that the interest rate time series are often stationary and cannot be tested directly by the OLS method. On the other hand, it is also often proven that the series are stationary in their first differences (e.g. are integrated by the order one). To test the stationarity we applied two standard methods for unit root tests which are the Augmented Dickey-Fuller test and the Phillips-Perron test. The null hypothesis of non-stationarity can be rejected at 99% (***), 95% (**) or 90% (*). The same labelling is used also in the next analyses.

The results summarized in the Table 2 show that none of the rates is stationary in levels while all rates are stationary in their first differences which was somehow expected with respect to results of other studies mentioned above. The proper way of testing the EH will therefore be the relationship (5) from the chapter 2.

Table 2: Augmented Dickey-Fuller and Phillips-Perron unit root test, data: CNB 01/2000-07/2011

Interest rate	**ADF** (levels)	**PP** (levels)	**ADF** (first diff.)	**PP** (first diff.)
i_1	-2.13	-4.05	-3.21*	-89.92***
i_2	-2.20	-4.02	-3.27*	-72.39***
i_3	-2.19	-4.08	-3.23*	-65.40***
i_6	-2.00	-4.45	-3.53**	-61.29***
i_9	-1.95	-4.74	-3.78**	-63.58***
i_{12}	-1.96	-5.01	-4.00**	-63.11***
$f_{1,2}$	-2.14	-4.13	-3.30*	-72.06***
$f_{2,3}$	-2.03	-4.57	-3.38*	-65.28***
$f_{3,6}$	-1.69	-5.25	-3.90**	-63.37***
$f_{6,9}$	-1.66	-5.67	-4.36***	-70.14***
$f_{9,12}$	-1.98	-5.32	-4.80***	-66.06***
$f_{3,9}$	-1.66	-5.32	-4.13***	-65.97***
$f_{6,12}$	-1.73	-5.77	-4.52***	-64.48***

As a next step we performed the regression model (5). In order to achieve maximally comparable results with Kotlan (1999) we applied the same analysis as him. Each regression is accompanied with the Durbin-Watson test for autocorrelation of error terms and the Wald test for testing the null hypothesis of zero alpha and unit beta in the model. Rejecting of this null hypothesis would mean also rejecting the EH for the particular rates.

The results are described in the Table 3 and at the first glance are not very satisfactory concerning our expectations of proving EH for most of the rates. All regressions of the original model (5) show extremely low coefficients of determination which would indicate almost no relationship between the tested parameters. The Durbin-Watson tests show the strong autocorrelation of error terms. The value of the test statistic might lie between values of 0 to 4. The value of 2 indicates no autocorrelation while deviation from 2 indicates positive / negative autocorrelation. Our tested series show strong positive autocorrelation which have negative effect of the regression quality. Under such evidence there see no value in interpreting the estimated parameters. To summarize all information we add that the standard errors are calculated with Newey-West method robust to the autocorrelation of error terms and to the heteroscedasticity.

In order to cope with the autocorrelation we changed the regression model into regression model with ARMA errors. For the $f_{1,2}$ rate the most suitable model was identified as the

ARMA(1,0) or AR(1) model. For all other rates we applied ARMA(1,1) model. The quality of the regressions improved significantly as the Durbin-Watson test statistics are closed to the value 2. The coefficient of determination also significantly increased and apart from $f_{1,2}$ rate indicates a strong relationship between the tested variables. What is still not satisfactory are the estimated parameters that are only rarely significant and the value of Wald test that indicates a rejection of the EH for all of the tested rates.

The results surprised us since our initial hypothesis was that we would prove the EH at least in the extent as Kotlan. Our conclusion is that during the period 01/2000-07/2011 we reject the existence of EH for the Czech interbank market for all tested rates. In a reaction to this finding we tested also a shorter time series from 01/2000 to 12/2007 omitting the years of the financial crisis but the results were very similar and also the main conclusion of rejecting the EH was the same (the detail analysis is not described in the paper).

Table 3: Regression analysis $\left(i_{m,t+n} - i_{m,t}\right) = \alpha + \beta \cdot \left(f_{n,n+m,t} - i_{m,t}\right) + \varepsilon_{t+n}$ *, data: CNB 01/2000-07/2011*

		Alpha		**Beta**		**AR1**		**MA1**		**R2**	**D-W**	**Wald test**	
		Par	s.e.	Par	s.e.	Par	s.e.	Par	s.e.	est.	est.	a=0,b=1	Pr>|t|
$f_{1,2}$	simple	-0.05**	0.02	0.18	0.23					2.0%	1.20	>10	0.00
	ARMA	-0.08***	0.03	0.46***	0.17	0.46	0.09	-	-	19.3%	2.06	>10	0.00
$f_{2,3}$	simple	-0.09	0.06	0.11	0.26					1.0%	0.57	>10	0.00
	ARMA	-0.06	0.04	-0.01	0.03	0.36	0.08	1.00	0.02	68.4%	2.05	>10	0.00
$f_{3,6}$	simple	-0.16	0.11	0.29	0.21					2.5%	0.35	>10	0.00
	ARMA	-0.14	0.09	0.14	0.19	0.74	0.06	0.48	0.06	76.7%	1.77	>10	0.00
$f_{6,9}$	simple	-0.38	0.30	0.49	0.43					4.2%	0.14	3.04	0.22
	ARMA	-0.23	0.24	-0.10	0.14	0.91	0.04	0.40	0.09	90.6%	1.92	>10	0.00
$f_{9,12}$	simple	-0.66	0.53	0.68	0.53					7.5%	0.10	1.90	0.39
	ARMA	-0.40	0.37	-0.06	0.13	0.94	0.03	0.47	0.08	93.8%	1.93	>10	0.00
$f_{3,9}$	simple	-0.16	0.12	0.38	0.36					1.7%	0.39	4.66	0.10
	ARMA	-0.01	0.11	-0.52*	0.31	0.75	0.06	0.49	0.06	76.1%	1.73	>10	0.00
$f_{6,12}$	simple	-0.36	0.39	0.50	0.58					2.8%	0.16	1.61	0.45
	ARMA	-0.09	0.23	-0.46**	0.19	0.90	0.04	0.55	0.10	90.9%	1.96	>10	0.00

At last we analysed the cointegration of the tested time series. We again followed the Kotlan paper. The simplest method of the cointegration tests is to test the stationarity of error terms for the regression equition (4). The stationarity was examined again with the methods of the Augemented Dickey-Fuller test and of the Phillips-Perron test. The results in the Table 4 show that a null hypothesis of non-stationarity might be rejected for all rates except the $f_{9,12}$ rate.

Table 4: Cointegration analysis $i_{m,t+n} = f_{n,n+m,t} + \varepsilon_{t+n}$,
null-hypothesis: non-cointegration, data: CNB 01/2000-07/2011

Interest rate	ADF	PP
$f_{1,2}$	-3.499**	-61.502***
$f_{2,3}$	-3.462**	-34.136***
$f_{3,6}$	-3.138	-28.716***
$f_{6,9}$	-3.606**	-20.360***
$f_{9,12}$	-2.785	-12.991
$f_{3,9}$	-3.500**	-32.211***
$f_{6,12}$	-3.925**	-21.967**

5. Concluding remarks

We have tested the EH on the Czech interbank market in 01/2000 to 07/2011. The study is a continuation of the similar study made by Kotlan (1999) on data from 04/1992 to 07/1998 that proved the EH for about half of the Czech interbank rates. We have expected that the development of the Czech market will contribute to proving EH for most of the interbank rates. However our factual results were very different. The performed analyses rejected the existence of the EH for all tested interbank rates.

The results were surprising to us and we next tested the EH also for shorter time series omitting the years of financial crisis. However, the tests on series from 01/2000 to 12/2007 have led to same results. We again rejected the EH for all tested rates.

We have not analysed the detail economic reasons behind our conclusions which we consider as interesting area for the further investigation.

References

[1] Bataa, E., Kim, D. H., Osborn, D. R. (2005): Testing the Expectations Hypothesis for the UK Term Structure, *The University of Manchaster, Available at: http://economics.soc.uoc.gr/macro/10conf/docs/Paper16a.pdf*

[2] Bekaert, G., Hodrick, R. J. (2001): Expectations Hypotheses Tests, *The Journal of Finance, vol. LVI, no. 4, pp.1357-1394*

[3] Campbell, J. Y., Shiller, R. J. (1991): Yield Spreads and Interest Rate Movements: A Bird's Eye View, *Review of Economic Studies 58, 495-514*

[4] Campbell, J. Y. (1995): Some Lessons from the Yield Curve, *Journal of Economic Perspectives, vol. 9, num. 3, pp.129-152*

[5] Domínguez, E., Novales, A. (2000): Testing the Expectations Hypothesis in Eurodeposits, *Journal of International Money and Finance, vol.19, pp. 713-736*

[6] Gerlach, S., Smets, F. (1995): The Term Structure of Euro-rates: some evidence in support of the expectations hypothesis, *Bank for International Settlements, Working paper No.28*

[7] Jondeau, E., Ricart, R. (1996): The Expectations Hypothesis of the Term Structure: Tests on US, German, French and UK Euro-rates, *Banque de France Working Paper No. 35*

[8] Kotlán, V. (1999): The Yield Curve in Theory and in Practice of the Czech Interbank Market, *Finance a úvěr 7/1999, vol. 49, Charles University, Prague*

[9] Thornton, D. L. (2004): Testing the Expectations Hypothesis: Some New Evidence for Japan, *Federal Reserve Bank of St. Louis Review, 86(5), pp. 21-39*

Summary

Článek se zabývá testováním teorie očekávání na českém mezibankovním trhu v letech 2000 až 2011. Naše studie volně navazuje na podobnou analýzu provedenou na českém trhu v druhé polovině devadesátých let Viktorem Kotlánem. Kotlánova studie prokázala existenci teorie očekávání pro zhruba 50% mezibankovních sazeb. Předpokladem, který jsme si pro náš výzkum stanovili, bylo, že vývoj na českém mezibankovním trhu vedl ke zlepšení podmínek na trhu a přispěl k prokázání teorie efektivních trhů pro většinu testovaných sazeb. Do určité míry překvapení jsme však tento předpoklad neprokázali. Naopak se zdá, že v letech 2000 až 2011 většina českých mezibankovních sazeb teorii efektivních trhů neodpovídala. Zvolené časové období zahrnuje nástup finanční krize, což může výsledky ovlivňovat. Otestovali jsme proto následně také kratší období v letech 2000 až 2007. Výsledky nicméně zůstaly velmi podobné. Naším závěrem proto je, že v první dekádě nového tisíciletí na českém mezibankovním trhu teorie efektivních trhů nebyla prokázána.