EFFICIENCY OF THE SECONDARY T-BILL MARKET

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Abstract:
The article analyzes efficiency of the Czech treasury T-bill market and the interbank deposit market over period 1993 to 1999. An efficient market-expectation hypothesis and alternative preferred habitat hypothesis were selected to compare both the markets and to determine the extent to which they are affected by macroeconomic fundamentals. The results reveal that the treasury T-bill market is more effective compared to the interbank deposit market. This founding has strong implication in the sence that only the treasury market over the given period is appropriate to be empirically investigated.

Keywords: treasury bill, interbank deposit market, efficiency, term structure hypotheses

JEL Classification: C22, G14, E43, E44

1. Introduction

An important topic in the context of financial markets is the efficiency issue. The efficiency of financial markets is subject to detailed research in the literature, and a lot of articles focused on this topic have been published. Most often, capital markets, and especially stock markets, are studied in terms of efficiency. A less but still considerable amount of literature deals with the efficiency of the individual segments of the money market. The following study proposes the efficiency test for two parts of the Czech money market, the short-term securities market and the interbank deposit market. Before this issue is addressed, the basic institutional concept of efficiency should be introduced. For the market to be efficient, some fundamental requirements are assumed. Efficiency implies a reasonably large number of investors who seek out profit opportunities from mispriced securities. The competitive nature makes it hard to earn extra profit, and the actions of investors are thus important to drive the market towards efficiency. Efficiency also implies that consistent prediction of price or interest rate change in the future is not possible. In other words, new information is freely accessible to all participants, and no inside information is available. In addition to the above, investors should decide on their risk preferences and try to minimise transaction costs and taxes. The institutional survey of the Czech money market enables us to evaluate the degree in which the basic

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efficiency requirements are satisfied. From the preliminary view, fast development of the money market and its institutional background remarkably contributed to the money market's efficient functioning. Lack of liquidity through certain periods, changes in tax legislation and unexpected monetary development over some periods have been proven, on the other hand, to be factors that discourage investors. The extent to which these particular effects influenced the individual segments of the money market is a subject of the following paper.

2. Test of the Efficient Market-expectation Hypothesis

To apply the short-term bill rates in mathematical applications, information about the efficiency of this market is fundamental. The efficiency test, proposed here, combines approaches of Modigliani and Sutch (1967), Modigliani and Shiller (1973), and Pesando (1978). Because the tests of market efficiency are usually tests of joint hypotheses, the expectation hypothesis of the term structure is also briefly discussed in this context.

The theory of rational expectations states that prices of securities should reflect all available information. Market efficiency is appealing in this content because it assumes that no unexploited profit opportunities exist in the financial markets. At current price (yield), market participants cannot expect to earn a higher than normal rate of return by investing in any particular security. This means that when investors perceive unexploited profit opportunities, they buy or sell securities to the point where the efficient-market condition holds. In essence, market efficiency implies an arbitrage condition.

The pure expectation hypothesis of the term structure states that the long-term interest rate will equal an average of short-term interest rates that is expected to occur throughout the life of the long-term bond.[1)] The important point of this theory is that a bond with no maturity is preferred over time. Bonds are thus supposed to be perfect substitutes, and the expected returns on these bonds must be equal. Unlike the pure expectation hypothesis, the (constant-term premium) expectation hypothesis is less restrictive, and the presence of time-invariant term premiums is permitted. The proposition of efficiency under the expectation hypothesis is referred to as the efficient market-expectation hypothesis (EME) (see e.g. Cargill, 1975; Pesando, 1978). The testable version of the efficient market-expectation hypothesis implies that the long-term bill rate follows approximately a martingale sequence. Then, the current change in the long-term bill rate is a random variable, uncorrelated with all the information contained in the past series of data. Thus, under EME, the joint hypothesis to be tested is that the market for treasury bills is efficient, and variation in yields is attributable only to expectation effects.

In order to give this theory empirical content, a model of the equilibrium return for treasury bills must be specified. Under the hypothesis of efficient market-expectations, the yield on an n-period bill $R_{n,t}$ can be expressed by means of a one-period spot rate $R_{1,t}$ and the series of one-period forward rates ${}_{t+i}\mathrm{f}_{1,t}$

$$R_{n,t} = [\,(1 + R_{1,t})\,(1 + {}_{t+1}\mathrm{f}_{1,t})\,\ldots\ldots\,(1 + {}_{t+n-1}\mathrm{f}_{1,t})]\;1/\,n - 1 \qquad (1)$$

1) Most literature anticipates long-term bonds of maturities higher than one year. Because this study deals with maturities less than one year, the six-month *T*-bill rate stands for long maturity.

Let φ_t represents the information available to the market in period *t*. Setting the non-overlapping one-period rates to zero in the formula for the first difference $R_{n,t} - R_{n,t-1}$, we obtain (approximately) a martingale sequence of the spot rate on an *n*-period bill

$$E(R_{n,t} \mid \varphi_{t-1}) \cong R_{n,t-1} \tag{2}$$

Formula (2) permits the existence of constant-term premia. If such premia exist and the market is efficient, the variation in the long-term interest rate is solely due to the receipt of new information. Under EME, a change in the *n*-period bond rates ε_t is a random variable uncorrelated with all of the information at the beginning of the period

$$E(\varepsilon_t \mid \varphi_{t-1}) = 0 \tag{3}$$

Table 1
Term Structure Hypotheses: A Review

Pure Expectation Hypothesis. The term premium is zero for all maturities. Expected excess return is zero.
Expectation Hypothesis. The term premium is constant and the same for all maturities. Expected excess return equals a constant which is the same for all maturities.
Liquidity Preference Hypothesis. The term premium increases with maturity. Expected excess return on a bond is constant but the value of the constant is larger the longer the period to maturity.
Time Varying Risk. The term premium depends on the maturity and varies over time. Expected excess return on a bond varies both with time to maturity and over time.
Market Segmentation Hypothesis. The term premium depends in part on the outstanding stock of bonds of different maturities. Excess returns are influenced in part by the outstanding stock of bonds of different maturities.
Preferred Habitat Hypothesis. Bonds that mature at dates which are close together are close substitutes and have similar term premia.

There is an unlimited number of information sets that can be employed to test the validity of the EME. Naturally, a number of alternative macroeconomic models have succeeded in isolating the determinants of the time-varying term premiums. In view of the liquidity effect, additional research has made use of an efficient market-expectations framework in which the effect of monetary growth on interest rates is analyzed. In the presented study, Modigliani and Sutch and Modigliani and Shiller's preferred habitat models of the term structure are used in contrast to the efficient market hypothesis. Under the preferred habitat proposition, the long-term interest rate will equal an average of the short-term interest rate expected to persist throughout the life of the bond plus a term premium which represents the supply and demand conditions for that bond. The theory takes the view that the expected return on one bond influences the expected return on a bond of different maturity (and bonds of different maturities are substitutes), but investors are allowed to prefer one bond maturity over another. The preferred habitat theory combines the features of the expectation theory and the segmented markets theory which consider the determination of interest rates for each maturity as the outcome of the supply and demand in that market only. The alternative testable versions of the equation (3) are thus the preferred habitat specifications of Modigliani and Sutch:

$$R_{n,t} - R_{n,t-1} = c + a_0\left(R_{1,t} - R_{1,t-1}\right) + \sum_{i=1}^{n} a_i\left(R_{1,t-i} - R_{1,t-i-1}\right) + \varepsilon_t \tag{4}$$

and Modigliani and Shiller:

$$R_{n,t} - R_{n,t-1} = c + a_0\left(R_{1,t} - R_{1,t-1}\right) + \sum_{i=1}^{n} a_i\left(R_{1,t-i} - R_{1,t-i-1}\right) + \\ + b_0\left(\pi_{1,t} - \pi_{1,t-1}\right) + \sum_{i=1}^{n} b_i\left(\pi_{1,t-i} - \pi_{1,t-i-1}\right) + \varepsilon_t \tag{5}$$

where π_t denotes the level of inflation and R_t the yield on treasury bills. We further suppose that random disturbances ε_t have normal distribution. Since the Modigliani and Sutch model explains the current change in the dependent variable by means of the lagged short-term rate only, the Modigliani and Shiller model also employs an effect of the price-expectations components.

The difference between the EME hypothesis and the preferred habitat theory is more evident from above. Under EME, the condition of market efficiency requires the long-term rate uncorrelated with all distributed lag terms (not taking into account the current change in the short-term rate – the first difference of the explanatory variable). As it will be demonstrated further, the EME hypothesis is an important criterion for distinguishing the different interest rate regimes and maps the behaviour of different money market segments.

This econometric study deals with the secondary market of treasury bills and the interbank deposit market. Both play an important role in the short interest rate determination, and the results on the efficiency of these markets are informative for conducting further research insofar as they explain the structural behaviour of the whole money market. Following this approach, the results were obtained for a six-month (long-rate) and one-month (short-rate) *T*-bill and the interbank deposit time series observed in the period from September 1993 to December 1999. The data set includes 76 observations, sampled monthly. The mean values are similar for treasury yields, however, the mean values for interbank rates decrease with maturity. This evidence is consistent with the preferred habitat hypothesis that permits the presence of negative term premia. The same conclusion holds for three-month interbank rates as well, although the statistics are not presented here. Because of the increased sensitivity to exogenous conditions, the standard deviation of the one-month interbank rate exceeds the similar statistics reported for the rest of the interest rates. The extremely large maximum PRIBOR values are related to the short period in mid-1997. Note that the data are sampled as a monthly average and that the short-term interbank O/N rate far exceeded 50 % in May 1997. The skewness and kurtosis reveal symmetric central distributions with a small bias for the one-month interbank rate.

Table 2
Treasury Yields and Interbank Deposit Rates: Statistical Evidence on Monthly Data

	Mean	St. Dev.	Minimum	Maximum	Skewness	Kurtosis
T-bill 1M rate	9.124	2.906	5.460	15.260	0.768	-0.402
T-bill 6M rate	9.236	2.759	5.350	15.160	0.765	-0.308
PRIBOR 1M	11.516	4.412	5.560	31.540	2.138	8.028
PRIBOR 6M	11.378	3.193	5.640	21.240	0.430	0.135
Inflation	8.414	3.176	1.037	13.446	- 0.945	0.334

Table 2 provides summary statistics of data applied in a test of the efficient expectation-market hypothesis. The table contains data for one- and six-month nomi-

nal treasury rates, interbank deposit rates, and inflation. The treasury rates are offer quotes on CNB-bills and government *T*-bills. The interbank money market rate is the nominal PRIBOR. The sample period is September 1993 to December 1999, and the set of data contains 76 monthly observations.

With both sets of data, equations (4) and (5) were estimated using OLS. The results of estimation for the secondary market with short-term securities are presented in Table 3. For the Modigliani and Sutch and the Modigliani and Shiller specifications, we have two columns of coefficients. Firstly, the results suggest that the current values of one-month *T*-bill differences are highly significant as new information strongly contributes to the immediate realization of interest rates. This is given by coefficients a_0 with *t*-statistics of 10.84 and 9.85 for the Modigliani and Sutch and the Modigliani-Shiller specifications, respectively. It says, however, nothing about violation of the efficiency proposition. Second, the results suggest that the lags in the short-term rate do not contribute to the explanatory power of equations (4) and (5)**.** Third, marginally significant coefficients of the inflation rate do not convey a great deal of new information. This is proved by the results of the *F*-tests for both specifications that were found highly below the critical values.[2)] The result that none of the estimated lagged coefficients is significant at a 5% level for both specifications supports the efficient market hypothesis. In other words, the information that the current change in the long-term rate is uncorrelated with distributed lag terms for both the Modigliani and Sutch and the Modigliani and Shiller models reveals that the efficient market-expectation hypothesis cannot be rejected. In addition, the evidence suggests that the secondary market for treasury bills does not behave in accordance with the preferred habitat hypothesis.

Table 4 contains estimates of the parameters given by equations (4) and (5) for the interbank deposit rates (PRIBOR). The results suggest that the expectation hypothesis does not hold anymore as the dependent long-term rate does not follow the martingale process. *F*-statistics, obtained similarly as in Table 3, were found significant on 5% level for both models. From the standpoint of the expectation hypothesis, the market is not efficient because the lagged values of the short-term rate and inflation convey past information to contemporary realization of the long-term rate. Contrary to the treasury market, the data on interbank rates generate an excess of serial autocorrelation, and estimates of the standard errors can be biased. This is evident for the Modigliani and Sutch model. Based on this evidence, the efficient market-expectation hypothesis for the interbank deposit market can be rejected. An empirical explanation why the treasury market is efficient and the interbank market is not, rests in structure of data. Special treatment with the data set after May 1997 was required because a part of the data observed from mid-1997 was not appropriate for econometric investigation.[3)] In particular, data on the interbank deposit market react more flexibly to any exogenous changes in macroeconomic con-

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2) *F*-statistics were computed as a difference between unrestricted and the restricted specifications, the restricted specification contained only the current values of one-month interest rate differences. The critical values for the Modigliani and Sutch and the Modigliani and Shiller specifications are $F_{7.55} = 5.84$ and $F_{14.55} = 3.20$ on 1% significance level. The critical values for the Modigliani and Sutch and the Modigliani and Shiller specifications are $F_{7.55} = 3.32$ and $F_{14.55} = 2.24$ on 5% significance level.

3) The most influential change in the interest rate structure occurred in mid-May 1997 when sharp depreciation of the koruna led to destabilization of the entire money market. The one-day PRIBOR reached more than a hundred per cent, the one-week PRIBOR rose to 90 % and long-term rates fluctuated above 20 %. On a smaller scale, a similar increase in the interest rate level occurred at the end of the year under the influence of the crisis in Southeast Asia. The interbank rates have been steadily declining from the beginning of 1998.

ditions, and since the yields on treasury bills through the period of monetary turbulence remained stable, the deposit market was hit more strongly. In order to avoid the effects of irregular trading, excess volatility and frequent outliers, monthly data were used instead of daily (or weekly) observations. By using monthly data, the whole structure of yields is homogeneous, and the test of efficiency still gives consistent results. It is also worth mentioning that by using monthly data, a larger range of maturities is allowed to be empirically investigated. However, monthly data differ from daily observations from the standpoint of term premia. Using monthly data, interbank rates have almost identical structure (except for period of instability in 1997) for maturities from one month to six months. Difference in long maturity can be thus explained using lagged differences in short maturity and because of predictability, the interbank market is inneficient. In opposite, this does not hold for treasury bill market where monthly data for different maturities differ as well.

The results have a strong implication for the empirical study of interest rates by means of one-factor econometric models. The requirement of efficiency allows only data on treasury bills to be applied. In other words, since the efficiency implies the nonarbitrage condition, treasury bill data allow the one-factor interest rate models to be estimated consistently.

Table 3
Efficiency of the Secondary Market with Short-term Bills – the Results

Modigliani and Sutch			Modigliani and Shiller		
c	- 0.0149	(- 0.19)	c	0.0561	(0.71)
a_0	0.6315	(10.84)**	a_0	0.5957	(9.85)**
a_1	0.0466	(0.82)	a_1	- 0.0263	(- 0.38)
a_2	0.0121	(0.21)	a_2	- 0.0223	(- 0.30)
a_3	- 0.0561	(- 0.98)	a_3	- 0.1080	(- 1.54)
a_4	- 0.0643	(- 1.13)	a_4	- 0.1387	(- 1.95)
a_5	0.0057	(0.10)	a_5	- 0.0641	(- 0.92)
a_6	- 0.0056	(- 0.09)	a_6	- 0.0761	(- 1.10)
			b_0	0.0630	(0.53)
			b_1	- 0.0029	(- 0.02)
			b_2	0.0825	(0.72)
			b_3	0.1963	(1.71)
			b_4	0.0823	(0.72)
			b_5	0.1668	(1.49)
			b_6	- 0.0800	(- 0.77)
adj. R^2	0.6684		adj. R^2	0.6731	
SEE	0.6124		SEE	0.5835	
F-stat.	0.4508		F-stat.	0.6725	
D-W	2.0907		D-W	2.1837	

The results for the six-month bill rate as a dependent variable and the one-month lagged rate are presented for the models of Modigliani and Sutch and Modigliani and Shiller in Table 3. The observed period was September 1993 to December 1999, 76 monthly yields in total. The current values of *T*-bill rates are highly significant as new information strongly contributes to the intermediate realization of interest rates. Because *t*-statistics of the distributed lagged coefficients are not significant at a 5% level, the efficient market hypothesis cannot be rejected. Furthermore, the *F*-test statistics and nonsignificant coefficients on inflation suggest that both the models can be nested. ** denotes significance at 1% level.

Table 4
Efficiency of the Interbank Deposit Market – the Results

Modigliani and Sutch			Modigliani and Shiller		
c	- 0.0253	(- 0.45)	c	0.0081	(0.16)
a_0	0.3359	(14.45)**	a_0	0.3437	(16.55)**
a_1	0.1789	(7.64)**	a_1	0.1771	(8.43)**
a_2	- 0.0221	(- 0.79)	a_2	- 0.0454	(- 1.72)
a_3	0.0655	(2.47)*	a_3	0.0650	(2.52)*
a_5	0.0292	(1.24)	a_4	- 0.0203	(- 0.75)
a_6	0.0424	(1.83)	a_5	0.0202	(0.88)
			a_6	0.0235	(1.01)
			b_0	0.1828	(2.55)*
			b_1	0.0237	(0.33)
			b_2	0.0077	(0.11)
			b_3	0.0951	(1.38)
			b_4	0.1127	(1.61)
			b_5	0.0731	(1.06)
			b_6	- 0.1706	(- 2.51)*
adj. R^2	0.8698		adj. R^2	0.8921	
SEE	0.4484		SEE	0.3951	
F-stat.	4.3329**		F-stat.	2.6606**	
D-W	1.5203		D-W	1.9402	

Both the Modigliani and Sutch and the Modigliani and Shiller models were estimated using the first differences in six-month and one-month interbank rates, similarly as in Table 3. The period of observations is September 1993 to December 1999, 76 monthly yields in total. Because the past history of the short rate and the history of the short rate together with the history of the rate of inflation prove significant in both models, the efficient market-expectation hypothesis can be rejected. The results do not reject the Modigliani and Sutch and the Modigliani and Shiller version of the preferred habitat model of the term structure, however, the information set can contain other variables as well. ** and * denote significance at 1% and 5% level, respectively.

3. Conclusions

The efficient market hypothesis states that all currently available public information is rapidly reflected in security prices. Because the test of efficiency requires a proper definition of the relevant information and a model which shows the impact of this information upon prices, most tests of efficiency are joint tests of a pricing model and efficiency. As an empirical application, the efficient market-expectation hypothesis was chosen to test the efficiency of individual money market segments. Note that the theory of single-factor models of the interest rate employed in the following chapters was developed only under the condition that the market is efficient and that the expectation hypothesis holds true. The alternative preferred habitat hypothesis was represented by the specifications of Modigliani and Sutch and Modigliani and Shiller. Under the null hypothesis of zero lagged coefficients of both these models, the results conclude that the efficient market-expectation hypothesis cannot be rejected.

There were two parts of the money market tested for efficiency: the short-rate *T*-bill market and the interbank deposit market. Because of frequent gaps in daily data

on the secondary *T*-bill market (mostly in 1997 and 1998), the test of efficiency was proceeded for both markets using the data sampled monthly. It was found that the monthly data offset the overshooting effect in interest rates from 1997 and truly reflect the aggregated development of the term structure. Treasury bill rates on the secondary market for the period later than 1999 were not available. Due to small sample of data, estimation cannot be done on two separate intervals adjusting better time-series structural change.

There are two main results. First, despite the disadvantageous development of the interest rate structure in 1997 and 1998, the secondary *T*-bill market still remains efficient. Second, the interbank deposit market is inefficient, and this conclusion suggests that use of interbank rates for an empirical study of short-rate models is disputable. This result for the given period is not surprising. During periods of uncertainty, investors participating in the money market do not always appreciate term premia correctly. This is less evident for treasury bill market, and although the interbank deposit market is a well-developed part of the money market, a longer time horizon may allow arbitrage opportunities. The topic can be also alternatively explored by the concept of relative efficiency, i.e. efficiency in one market measured against another, which can be more useful than the traditional approach. From this standpoint the result is that the treasury bill market reveals to be more efficient compared to the deposit market. In all cases, the result concerning efficiency suggests that the treasury bill data is appropriate in any other empirical study.

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