OPEN MARKET OPERATIONS AND THE PRICE OF LIQUIDITY: THE CASE OF THE CZECH REPUBLIC BETWEEN 1998 AND 2004

Karel Bruna, University of Economics, Prague, Czech Republic

ABSTRACT

Effective monetary policy depends on the ability of central banks to stabilize fluctuations of overnight interest rates around their policy rate. The function of the stabilization mechanism involves balancing aggregate bank demand for reserves with the central bank's supply of reserves in the interbank market. This paper discusses the main sources of temporal gaps between the demand for and the supply of reserves and their impact on overnight interest rate volatility. A theoretical explanation of the role of intertemporal substitution in periods of fluctuating reserves demand is provided. Crucial features of central bank targeting of overnight interest rates are discussed. The behavior of overnight interest rates in the Czech interbank market (1998-2004) is empirically examined in the context of excess liquidity. Some relevant structural changes in the interbank market are identified. Specifically, we find undershooting of the non-stability of excess liquidity in the interbank market and a sharp decline of overnight interest rate volatility associated with the introduction of intraday credit.

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INTRODUCTION

Like the European Central Bank (ECB) and U.S. Federal Reserve System (Fed), the Czech National Bank (CNB) places a strong emphasis on the price of bank reserves traded within open market operations. In the case of CNB, the price of these highly-liquid resources is a fortnightly (bi-weekly) limit repo rate. This fortnightly repo rate acts as the upper limit of interest rates in banks bids for transient deposits of excess liquidity in daily CNB repo tenders.

Our previous study (see Brada, Bruna 2004) indicated that the actual level of the repo rate was, to a limited extent, a determinant of the dynamics of short-term interest rates in the Czech interbank market. The spread between the repo rate and interest rates may become relatively large while quantitatively significant deviations from the repo rate are a relatively long-term phenomenon. On the other hand, in ultra-short interest rates, overnight (O/N), seven day (7D) and fortnight (14D), the actual level of the repo rate seems to constitute a center of gravity that restricts fluctuations of these rates around the repo rate. This center of gravity limits potential deviations of ultra-short interest rates from the repo rate to be of transient character only.

The causes of different interest rate behaviors lie in the way CNB's involves itself in ultra-short maturity trading. CNB directly influences the price of the most liquid resources in the money market by announcing the explicit repo rate level. In addition, through repo tenders, CNB ensures an amount of liquidity for the banking sector that eliminates the existence of a longer-term deficits or excess bank reserves. Such deficits and excess could cause ultra-short interest rates to deviate significantly from the longer run repo rate.

The objective of this study is to examine the main aspects of a mechanism that efficiently stabilizes ultra-short interest rates in the proximity of the repo rate in the money market. Further, the relationship between errors in CNB liquidity prediction and development of O/N interest rates in the Czech interbank market is analyzed and tested. Stabilizing

BASIC RELATIONS BETWEEN INTEREST RATES IN THE MECHANISM STABILIZING ULTRA-SHORT INTEREST RATES

It is assumed that at a time t agents in the money market compare the actual size of the quoted n-day interest rate with the expected future development of O/N interest rates in the run of subsequent n days. In the longer contract maturity, market participants require an increasing reward in the form of a term premium. The resulting equilibrium in the money market can be expressed as the equilibrium of a speculator who, on the basis of available information (Ω_t), quotes actual n-day interest rate (IR_t^n) as the sum of the expected average level of O/N interest rates in the period t to $t+k$ ($IR_t^{O/N,e}$, $IR_{t+1}^{O/N,e}$, ..., $IR_{t+k}^{O/N,e}$) and term premium (ρ_t^n):

$$IR_t^n = \frac{1}{n}\sum_{k=0}^{n-1} IR_{t+k}^{O/N,e} \big| \Omega_t + \rho_t^n . \tag{1}$$

It is also assumed that the central bank uses the announced s-day interest rate ($REPO_t^s$) as the main monetary-policy interest rate when the maturity of this rate (the repo rate) equals at maximum, the maturity of ultra-short rates (i.e. $s \leq n$). In this case, the market O/N interest rate represents the repo rate. The announced level of the repo rate usually corresponds to the average effective O/N interest rate in the interbank market over several trade days. In case the market O/N interest rate represents the repo rate, the announced level of the repo rate usually corresponds to the average effective O/N interest rate in the interbank market over several trade days. On the contrary, if the repo rate is a specific interest rate, exclusively used in central bank monetary operations, then the announced level of the repo rate usually corresponds to the limit (minimum or maximum) level of the effective repo rates in periodic tenders for the supply or the withdrawal of liquidity.

The mechanism stabilizing ultra-short interest rates is understood to be a continuous process. This continuous process results in a situation where the average level of ultra-short interest rates copies the course of the repo rate. Quantitatively more significant deviations of these rates from the repo rate are of transient character only. This process occurs when agents in the money market are convinced that the average spread between expected O/N interest rates and the actual and expected level of the repo rate will approach zero in the run of future n days:

$$\frac{1}{n}\sum_{k=0}^{n-1} (IR_{t+k}^{O/N,e} - REPO_{t+k}^{s,e}) \big| \Omega_t = p , \; p \to 0 \tag{2}$$

With the existence of supplementary instruments of monetary policy in the form of deposit and lending facilities it is possible to identify lower and upper fluctuation limits of expected O/N interest rates. Moreover, it is possible to estimate a minimum volatility of the spread between expected O/N interest rates and the repo rate. Decreases in O/N interest rates should stop at the level of the O/N interest rate at deposit facilities. On the contrary, an increase in O/N interest rates should reach a maximum at the level of O/N interest rate from the lending facility.

O/N interest rates indicate the price of money in the interbank market and play a key role in the bank's liquidity position management. It is assumed that O/N interest rates will fluctuate more or less symmetrically around the repo rate. This fluctuation is in relation to day-to-day differences between the central bank's supply of reserves and aggregate demand of banks for reserves. It does not mean that volatility cannot assume high values. The supply of the central bank's reserves is based on a prediction of the volatile demand function. During the trading day, the money market is subject to liquidity shocks related to changes in the demand for reserves. These liquidity shocks can have a large influence on the actual volume of banking system reserves.

Nevertheless, it is assumed that the volatility of the spread between expected O/N interest rates and the repo rate will be lower in cases when the central bank carries out open market operations with daily frequency (like operations of the Fed or CNB). Day-to-day adjustments allow the bank to respond more quickly to changes in demand for reserves than less frequent adjustments. The volatility of the spread is expected to be lower if the central bank uses the one-day repo rate because it is possible to directly stabilize the O/N interest rate around the repo rate. By comparison, when the central bank operates with seven-day or fortnight repo rates, stabilization of O/N interest rate fluctuations is not the focus of its attention.

DETAILED SPECIFICATION OF STABILIZATION MECHANISM INVOLVED IN FUNCTIONS OF DEMAND FOR RESERVES AND SUPPLY OF RESERVES

Detailed specification of the ultra-short interest rate stabilization mechanism occurs because dynamics of O/N interest rates may be substantially influenced. This influence occurs from banks trading to meet minimum reserve requirements with the central bank (see e.g. Bindseil, Seitz, 2001; Prati, Bartolini, Bertola, 2002 or Gaspar, Quirós, Mendizábal, 2004). From the viewpoint of aggregate demand for reserves by banks, minimum reserve requirements determine the minimum average balance of reserves held with the central bank. In this context Hamilton (1996), Taylor (2001) and Bartolini, Bertola, Prati (2001 and 2002) discussed a simple model of demand for reserves in which banks carry out intertemporal substitution of demand for reserves aimed at minimizing the cost of holding reserves. The principle of this substitution is that banks limit the holding of reserves on days when the money market is characterized by relatively high demand for reserves and high prices. They hold excess reserves on days when excess liquidity is present in the market and reserves are cheaper. In this model agents in the money market speculate on expected changes in O/N interest rates on any two consecutive days. They change their actual demand for reserves in relation to an expected change in the O/N interest rate on the following day.

The result of this speculation is a change in the relationship between demand and supply in the money market. This change in demand is immediately reflected in variations in actual O/N interest rates. The expectation of a decrease (increase) in tomorrow's O/N interest rate leads to a decrease (increase) in the actual O/N interest rate. Under equilibrium in the money market, the actual level of the O/N interest rate corresponds exactly to the expected next day level of the O/N interest rate:

$$IR_t^{O/N} = IR_{t+1}^{O/N,\,e} \Big| \Omega_t \tag{3}$$

The above-mentioned conditions do not hold in all circumstances. The model noted above was derived from operations in the U.S money market where the price of reserves traded in open market operations corresponds to the actual level of the O/N interest rate. In situations where the central bank uses the repo rate with longer than O/N maturity as the main monetary-policy tool, both the absolute price of funds in the money market and the price of funds deposited with the central bank are important.

If the actual spread between the expected O/N interest rate and the repo rate is positive, banks may view resources in the money market to be expensive. On the contrary, if the spread is negative, reserves may seem cheap. An expected decrease in the spread between two trading days may therefore imply that banks will temporarily change the actual demand for reserves. An expected decrease in the positive (negative) spread between two trade days may therefore implies that banks will temporarily increase (decrease) the actual demand for reserves. They will try to decrease (increase) the balance of reserves below (above) the level corresponding to the minimum reserve requirement.

If banks expect a change in the repo rate along with a change in the spread, movements of the actual O/N interest rate are determined in parallel. First, changes in the spread between the expected O/N interest rate for the current day and the actual and expected next day repo rate affect the spread. Second the related expected change in the O/N interest rate between the actual and the next trade day affect the spread. This suggests that expected changes in the repo rate will be accompanied both by changes in the price at which the central bank will carry out its open market operations and in the price around which the level of future ultra-short interest rates will be stabilized effectively.

When this parallel situation occurs, equilibrium in the money market occurs at the point where the size of the expected spread between the O/N interest rate and the repo rate for the actual day corresponds to the size of the expected spread between both interest rates for the next day. When both spreads are equal, the average spread *p* is defined as:

$$(IR_t^{O/N,e} - REPO_t^s)\big|\Omega_t = (IR_{t+1}^{O/N,e} - REPO_{t+1}^{s,e})\big|\Omega_t = p \tag{4}$$

A number of authors have documented that variations in O/N interest rates are sometimes easy to predict (see e.g. Hamilton, 1996; ECB, 2002; Würtz, 2003; Gaspar, Quirós, Mendizábal, 2004; FRBNY 2004 and Prati, Bartolini, Bertola, 2002). This situation contradicts the above equilibrium condition. In fact, the intertemporal substitution of reserves is not strong enough to suppress systematic features in the behavior of O/N interest rates. Calendar effects are mentioned most frequently when O/N interest rates vary according to a certain day on which a specific trade day falls (e.g. the last or the first working day of the week, the last day of the month, quarter or year, etc.). In addition, a systematic increase in the size and variability of the spread between O/N interest rates and the repo rate can be seen on the last days of the maintenance period in some markets.

One reason predictable movements of the spread between O/N interest rates and the repo rate persist may be that the main motive of banks trading in the money market is not to minimize the costs of holding reserves but rather to continuously hold bank reserves. In the context of individual and aggregate liquidity shocks, such reserves enable the bank to cope with potential fluctuations in the need for reserve resources during the course of a trading day.

Individual liquidity shocks result because of the need to clear payments within the interbank payments system. Hence these shocks do not have an immediate impact on the level of aggregate demand for reserves. However, full dependence of banks on external liquidity resources may be too costly or risky because it makes banks trade in the money market even if conditions are not favorable. This risk may lead to the holding of standby reserves and reduce the need for day-to-day speculation in O/N interest rate movements. As indicated by Bindseil, Seitz, 2001; ECB, 2002; and FRBNY, 2004, variance between the expected and actual development of net government revenues within a day may be an important source of instability of O/N interest rates.

The maintenance period has two phases. In the first phase of the maintenance period the average balance in the account of reserves is often below the minimum level required. In the second phase of the maintenance period banks increase their demand for reserves (see e.g. ECB, 2002; FRBNY, 2004). Therefore, in the first phase of the maintenance period the size and volatility of the spread between O/N interest rates and the repo rate is very low. The volume of transactions in the interbank market is relatively low, and banks do not experience a liquidity deficit in the market (see e.g. Prati, Bartolini, Bertola, 2002).

In the second phase of the maintenance period, a deficit of liquidity frequently occurs in the banking system. Banks must accumulate larger volumes of reserves to meet minimum reserve requirements. It is no longer easy to counterbalance negative liquidity shocks by decreasing funds in the reserves account. In these instances, the bank may be fined for failure to meet minimum reserve requirements. For this reason, it is logical for banks to increase their reserve balance above the minimum reserve requirement to accommodate any negative aggregate liquidity shock. A high demand for reserves at the end of the maintenance period could cause the average size of the spread and volatility between O/N interest rates and the repo rate to increase.

The intensity of O/N interest rate movements is also dependent on the extent to which the central bank accommodates the supply of reserves in open market operations. Central banks usually have concerns about changing their supply of reserves according to movements in the demand for reserves (see e.g. CNB, 2004; ECB, 2004; FRBNY, 2004). The Central Banks goal is to prevent instability in the demand for reserves which could result in a quantitatively significant deficit or excess of liquidity in the money market. Such an excess or deficit in liquidity would destabilize movements of O/N interest rates.

Changes in the supply of reserves of central banks are based on predictions of bank demand for reserves for a specific time period. The length of the time period is influenced by the frequency of open market operations. The variability of reserve demand influences the way the central bank moves its supply of reserves to the money market. Changes in the demand for reserves in an ultra-short or short period are usually satisfied by transient changes in liquidity through repo operations with short-term maturity securities. Lasting changes in the demand for reserves may be satisfied by changing the standing supply of liquidity through spot purchases and sales of securities. Open market operations are commonly conducted once per day in the morning hours by means of a short tender between the central bank and selected commercial banks.

The supply of reserves is usually maintained with the goal of accommodating changes in the demand for reserves. These changes in the demand for reserves result from dynamics associated with satisfaction of minimum reserve requirements and from the influence of aggregate liquidity shocks. A critical issue for O/N interest rates is if central banks fully respond to the demand for excess reserves. Calendar effects and pressures for an increase in O/N interest rates at the end of the maintenance period suggest that central banks satisfy only a portion of the demand for excess reserves through open market operations. If this is the case, a relatively large portion of the demand for reserves may remain unsatisfied causing large errors in liquidity prediction. These prediction errors may be reflected in certain systematic movements of O/N interest rates.

SIMPLE ECONOMETRIC MODEL OF THE MECHANISM STABILISING THE SPREAD BETWEEN ULTRA-SHORT INTEREST RATES AND REPO RATES

The aggregate demand of banks for reserves (R_t^D) and supply of reserves of the central bank (R_t^S) can be modeled as follows, where the variables are defined in Table 1:

$$R_t^D = MRR_t^{D,e} + ER_t^{D,e} + AF_t^{D,e} + OMO_{t-k} + \alpha\left[(IR_t^{D,O/N,e} - REPO_t^s) - (IR_{t+1}^{D,O/N,e} - REPO_{t+1}^{D,s,e})\right] + u_t \quad (5)$$

$$R_t^S = MRR_t^{S,e} + ER_t^{S,e} + AF_t^{S,e} + OMO_{t-k} + \beta(IR_t^{S,O/N,e} - REPO_t^s - p) + v_t \quad (6)$$

Table 1: Definition of Variables

$MRR_t^{D,e}$ and $MRR_t^{S,e}$	express the expectations of banks and the central bank concerning the closing balance on the account of reserves for the purposes of satisfaction of minimum reserve requirement for a given trade day *t*,
$ER_t^{D,e}$ and $ER_t^{S,e}$	the expectations of banks and the central bank concerning the level of excess reserves.
$AF_t^{D,e}$ and $AF_t^{S,e}$	are the expectations of banks and the central bank concerning the influence of autonomous factors.
OMO_{t-k}	the volume of the open market operations with *k*-day maturity, which falls on actual day. α (α > 0) is the parameter for the sensitivity of demand for reserves to the change in the spread between O/N interest rates and the repo rate expected by banks.
$\left[(IR_t^{D,O/N,e} - REPO_t^s) - (IR_{t+1}^{D,O/N,e} - REPO_{t+1}^{D,s,e})\right]$	the product of both factors, expresses the significance of intertemporal substitution of banks for the demand for reserves).
β	a parameter indicating the sensitivity of the supply of reserves to the deviation of O/N interest rates from the repo rate expected by the central bank $(IR_t^{S,O/N,e} - REPO_t^s - p)$ for actual day.
u_t and v_t	random errors with standard characteristics

The values β are influenced by the intensity of direct O/N interest rate stabilization carried out by the central bank and by its willingness to cover changes in the demand for reserves. In this scenario, the error of liquidity prediction by the central bank can be expressed by the function:

$$\begin{aligned}(R_t^S - R_t^D) = {} & (MRR_t^{S,e} - MRR_t^{D,e}) + (ER_t^S - ER_t^{D,e}) + (AF_t^{S,e} - AF_t^{D,e}) + \beta(IR_t^{S,O/N,e} - REPO_t^s - p) - \\ & - \alpha\left[(IR_t^{D,O/N,e} - REPO_t^s) - (IR_{t+1}^{D,O/N,e} - REPO_{t+1}^{D,s,e})\right] + (v_t - u_t)\end{aligned} \qquad (7)$$

It is assumed that errors in liquidity prediction are composed of purely random errors in estimating the satisfaction of minimum reserve requirements. However other errors are also possible. These errors include errors in estimating the influence of autonomous factors, different expectations of O/N interest rate development, systematic errors in estimating the satisfaction of excess reserves and the central bank's low sensitivity to speculative changes in the demand for reserves. It is argued in this research that the time series of liquidity prediction errors is a stationary process with zero mean and constant variability that may exhibit some signs of serial correlation.

When modeling the spread between O/N interest rates and the repo rate for actual trade days, a change in the spread is a function of liquidity prediction errors. Even though the volume of liquidity supplied or withdrawn by the central bank cannot be higher than total demand of banks for reserves or the supply of excess reserves, it is argued here that even positive liquidity prediction errors may signal changes in the money market. This occurs because the central bank has better information on the demand for reserves, by virtue of the cash fulfillment of state budgets, and may foresee either future reserve deficits or excesses.

In addition, it is possible to identify the existence of some regularity in the behavior of the spread between O/N interest rates and the repo rate in the form of calendar effects and maintenance period end effects. Variations in the spread between these interest rates may show some features of an autoregression process if prediction errors are serially correlated. Information on individual bank expectations of the level of O/N interest rates is not available so questions about the influence of bank speculation on movements of O/N interest rates can not easily be tested. Variations in the spread between O/N interest rates and the repo rate are modeled as follows, where the variables are defined in Table 2:

$$\Delta(IR_t^{O/N} - REPO_t^s) = \sum_{q=1}^{r} \lambda_q \Delta(IR_{t-q}^{O/N} - REPO_{t-q}^s) + \pi(R_t^S - R_t^D) + \sigma^i D^i + \sum_j^J \sigma_j^i D_j^i + e_t \qquad (8)$$

Table 2: Definition of Variables

$\sum_{q=1}^{r} \lambda_q \Delta(IR_{t-q}^{O/N} - REPO_{t-q}^s)$	expresses the autoregression process of variation in the spread between O/N interest rate and the repo rate of *r*-th degree
λ_q ($-1 < \lambda_q < 1$)	parameters of this process
Rr	expresses the rate of inertia of the change in the spread between O/N interest rates and the repo rate
π ($-1 < \pi < 1$)	measures the sensitivity of the spread change to the actual error of liquidity prediction
D^i	a dummy variable taking the value one if the actual trade day falls on the i-th day of the maintenance period
I	the number of days in the maintenance period
σ_j^i	measures the intensity of the influence of the j-th calendar effect on the change in the size of the spread between these interest rates,
D_j^i	a dummy variable assuming the value one if at the i-th day of the maintenance period the j-th calendar effect occurs
J	the number of calendar effects
e_t	a random error term

ANALYSIS OF LIQUIDITY PREDICTION ERRORS IN REPO OPERATIONS OF CNB

Unlike the other central banks, CNB withdraws excess liquidity from the money market during open market operations. Thus, repo operations are a simple agreement between CNB and other banks to secure the claim of a bank against CNB by transfer of debt securities. Repo operations are carried out in the form of American type repo tenders. CNB demands liquidity in the money market and banks make bids to deposit excess reserves with CNB. CNB invites the repo tender every trading day at about 9.30 a.m. The results of the repo tender are announced regularly at 10.00 a.m. In response, banks that win the bid create a deposit with CNB.

The repo tender of CNB can be viewed as a special form of auction with a variable interest rate. The total volume of withdrawn liquidity is not known to banks in advance. This auction procedure gives banks an opportunity to make their bids to CNB to create a deposit with a fixed fortnight maturity. In submitting their orders, banks specify not only the amount but also the price of money to be deposited with CNB. The level of the announced repo rate limits the required interest rate.

In the examined period 1998-2004(2Q), 1642 repos from the Czech National Bank (CNB) tenders were conducted. An overwhelming majority of these repo tenders absorbed excess liquidity from the money market. The policy of covering changes in the supply of reserves and interest rate targeting was accompanied by errors in prediction of the excess liquidity volume in the market (see Figure 1). The supply of excess liquidity of banks was unsatisfied on average on the level of 10% (see Figure 2). Figure 2 also shows that the level of unsatisfied supply of excess liquidity is quite unstable. In this case, banks are faced with the risk of re-balancing their liquidity position with potential effects on equilibrium O/N interest rate.

Figure 1: Errors of Liquidity Prediction by CNB (Day Data)

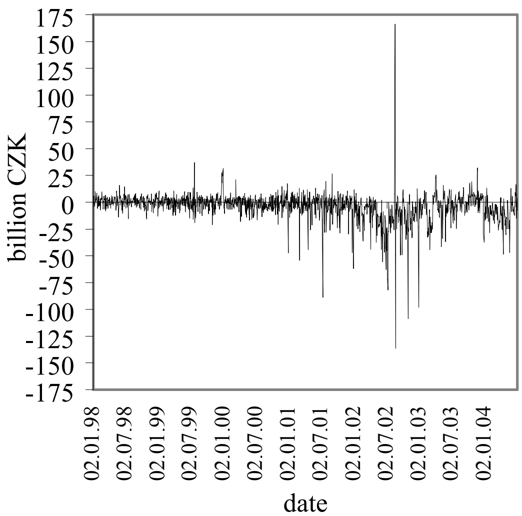
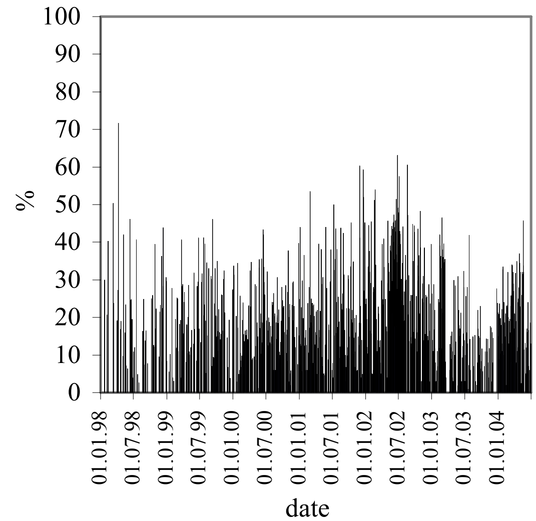


Figure 2: The Volume of Unsatisfied Supply of Excess Liquidity of Banks (Day Data)

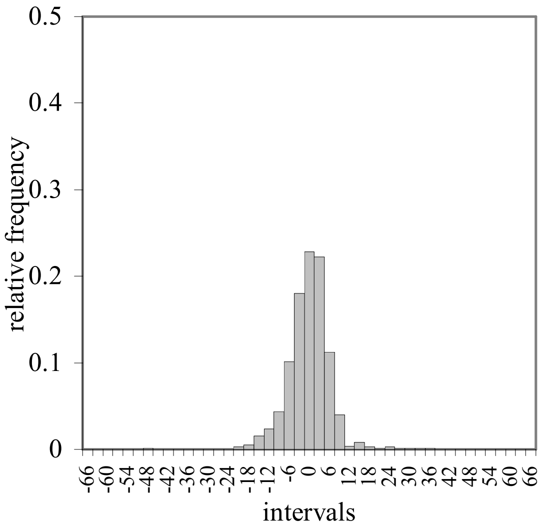


The analysis of liquidity prediction errors shows that the period examined can be divided into two subsets. In these two subsets, the prediction errors have different statistical characteristics. From 1998-2000 (see Figure 3a and Table 3), prediction errors are relatively small and they are distributed very close to zero. The variability of prediction errors is relatively low and the frequency of extreme values is low. Distribution of frequencies is almost perfectly symmetric with relatively higher frequency of values close to the average error prediction. Analysis of the sampling partial autocorrelation function indicates that the process generating the time series of liquidity prediction errors is an AR(0) process, where prediction errors are random and are not serially correlated.

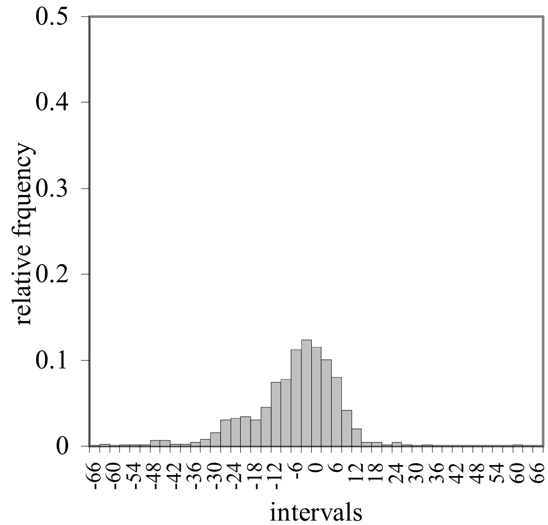
Beginning in 2001 (see Figure 3b and Table 3) the size of prediction error increases markedly, and the errors are no longer concentrated in the proximity of zero. On the contrary, CNB systematically underestimates the amount of excess liquidity supply. The results are significant at the 1% significance level using a Mann-Whitney test (the absolute value of the test criterion z is 11.608). Simultaneously, variability of prediction errors increases markedly. There is an increase in the frequency of extreme values and their distance from zero. The symmetry of the frequency distribution around the mean does not change significantly, but the kurtosis of the distribution increases. Moreover, the partial autocorrelation function indicates that the process generating liquidity prediction errors has transformed to an AR(2) process, where actual prediction errors are correlated with prediction errors from two preceding trade days.

Figure 3a and 3b: Relative Frequencies of Liquidity Prediction Errors (Day Data, Interval Size = 6 Billion CZK)

a) 1998-2000



b) 2001-2004(2Q)



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ges in the characteristics of excess reserve predictions in the money market are connected with a rapid increase in the volume of withdrawn liquidity in 2001 and 2002. This withdrawal was an immediate response to frequent intervention in the foreign exchange market by CNB during the period. The average level of bank claims against CNB increased from around 250 billion CZK in November 2000 to around 500 billion CZK in November 2002. Intervention in the exchange rate market allowed CNB to satisfy the high demand for Czech crown for a short time. However, this resulted in resources in the money market for which there was not an appropriate long-term use in the banking sector. The volume of reserve requirement account deposits were a little more than 5% of total banking sector deposits with CNB. The amount of excess reserves is lower by an order. These resources are returned to CNB in repo operations as excess liquidity.

The reasons for systematic underestimation of excess liquidity supply are somewhat unclear. It could be explained by CNB reducing the volume of withdrawn liquidity and thereby decreasing the high interest costs of repo operations. The underestimation of excess liquidity could also be connected to growth of variability in liquidity prediction errors. These prediction errors occur when CNB did not respond flexibly enough to increases in the volatility of excess liquidity supply on the banking sector side.

Table 3: Main Characteristic of Liquidity Prediction Errors

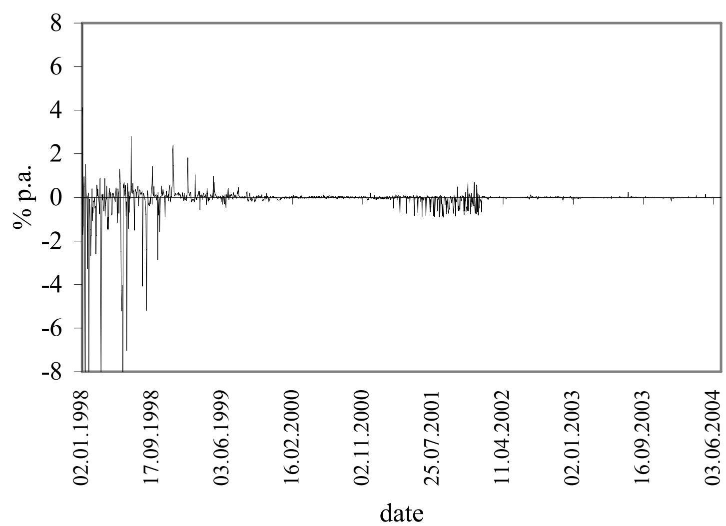
	1998-2000	2001-2004(2Q)
Mean	-0.094	-6.711
Standard errors	6.343	16.475
Skewness	-0.014	0.068
Kurtosis	7.509	24.294
Minimum	-47.254	-136.410
Maximum	37.164	166.430

ANALYSIS OF THE STABILISATION MECHANISM OPERATION IN THE CZECH INTERBANK MARKET

The development of ultra-short interest rates in the Czech money market is documented through an example. The example involves interest rates O/N PRIBOR (Prague Interbank Offered Rate). The overnight PRIBOR reference rates express the simple arithmetic mean of offer interest rates quoted by the most important market makers in the interbank market between 10.30 and 10.45 a.m. PRIBOR is determined with a 15-30 min delay after the results of the repo tender are announced. As determination of the PRIBOR rate begins, PRIBOR may immediately reflect the liquidity prediction errors of CNB.

Figure 4 shows that the spread between O/N PRIBOR and the repo rate was highly volatile in 1998 and in the first six months of 1999. From the last third of 1999 to the end of the examined period these rates were stabilized close to the level of the announced repo rate. This change in behavior of ultra-short interest rates was an immediate consequence of the introduction of intraday credit by CNB on August 3, 1999. With this introduction, banks were given the opportunity to use an interest-free credit from CNB during the trading day in the event of a reserve shortage. Banks were required to return all resources used during the trading day to the CNB account before the end of the trading day. If not returned, the intraday credit automatically becomes a loan with potentially higher interest rates than the O/N interest rate.

Figure 4: The Spread between O/N PRIBOR and the Repo Rate (1998-2004(2Q), Day Data)

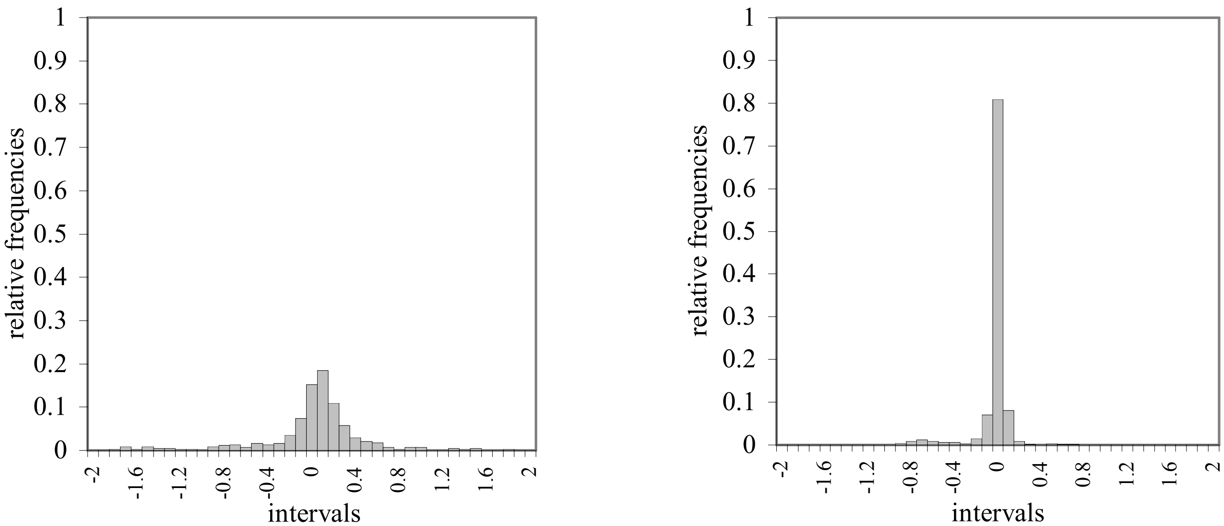


Before intraday credit was introduced (see Figure 5a and Table 4), the average level of O/N PRIBOR was 20 basis points below the level of the repo rate. In this period extreme deviations of O/N PRIBOR from the repo rate occurred. Specifically noteworthy is the great repo rate undershooting of 1998. High variability in the spread between O/N PRIBOR and the repo rate is also clearly identified. Analysis of the autocorrelation function and partial autocorrelation function indicates the existence of serial autocorrelation and suggests that the process generating the spread between O/N PRIBOR and the repo rate is an MA(4) process. The distribution of frequencies is slightly negatively skewed.

With the introduction of intraday credit, the average level of O/N PRIBOR approached the level of the repo rate (see Figure 5b and Table 4). A Mann-Whitney test confirms this movement is statistically significant at the 1% significance level (the absolute value of the test criterion z is 7.814). On the contrary, extreme values of the spread do not exceed 100 basis points in absolute terms. Moreover, this situation is accompanied by a rapid decrease in the volatility of O/N PRIBOR deviations from the repo rate. A decrease in the variability of the spread between both interest rates is reflected in an increase in the serial autocorrelation of the spread between O/N PRIBOR and the repo rate. The negative skewness of the frequency distribution is reduced only slightly while there is a larger decrease in its kurtosis.

Figure 5a and 5b: Relative Frequencies of the Spread between O/N PRIBOR and the Repo Rate (Interval Size = 5 bps)

a) 1. 1. 1998 - 2. 8. 1999 b) 3. 8. 1999 - 30. 6. 2004



One of the causes of a decrease in the average spread between O/N PRIBOR and the repo rate may have been more intense speculation by banks for a decrease in the repo rate in 1998-1999. These decreases may not always have been realized due to CNB's somewhat hesitant attitude. On the other hand, a steep reduction in volatility of the spread between both interest rates can be explained by noting that the amount of unsatisfied orders by banks to create a deposit with CNB are not identical for each bank. Excess reserves are accumulated in the largest banks while smaller banks or branches of foreign banks suffer from the lack of reserves. Therefore, the use of intraday credit significantly weakened the overall demand for, and instability of, liquidity.

Table 4: Main Characteristics of the Spread between O/N PRIBOR and the Repo Rate

	1.1.1998-2.8.1999	3.8.1999-30.6.2004
Mean	-0.233	-0.027
Standard errors	1.490	0.154
Skewness	-4.192	-3.131
Kurtosis	23.212	14.854
Minimum	-11.150	-0.910
Maximum	4.120	0.690

Experiments with estimations of the regression parameters of equation (10) confirm that variations in the spread between O/N PRIBOR and the repo rate behave in a different way before and after the introduction of intraday credit.

a) 1. 1. 1998 - 2. 8. 1999

$$\Delta(IR_t^{O/N} - REPO_t^s) = -0{,}319\Delta(IR_{t-1}^{O/N} - REPO_{t-1}^s) - 0{,}419\Delta(IR_{t-2}^{O/N} - REPO_{t-2}^s) - 0{,}212\Delta(IR_{t-3}^{O/N} - REPO_{t-3}^s) - 0{,}153\Delta(IR_{t-4}^{O/N} - REPO_{t-4}^s) - 0{,}038(R_t^S - R_t^D) + 0{,}44D^1 - 0{,}432D^{10}$$

b) 3. 8. 1999 - 30. 6. 2004

$$\Delta(IR_t^{O/N} - REPO_t^s) = -0{,}803\Delta(IR_{t-1}^{O/N} - REPO_{t-1}^s) - 0{,}763\Delta(IR_{t-2}^{O/N} - REPO_{t-2}^s) - 0{,}645\Delta(IR_{t-3}^{O/N} - REPO_{t-3}^s) - 0{,}615\Delta(IR_{t-4}^{O/N} - REPO_{t-4}^s) - 0{,}525\Delta(IR_{t-5}^{O/N} - REPO_{t-5}^s) - 0{,}392\Delta(IR_{t-6}^{O/N} - REPO_{t-6}^s) - 0{,}248\Delta(IR_{t-7}^{O/N} - REPO_{t-7}^s) - 0{,}147\Delta(IR_{t-8}^{O/N} - REPO_{t-8}^s) - 0{,}001(R_t^S - R_t^D)$$

In the period before intraday credit was introduced, actual variations in the spread were influenced not only by serial autocorrelation but also by errors of excess liquidity prediction and calendar effects. These calendar effects at the beginning and end of the maintenance period were very important. The parameters of the autoregression process and liquidity prediction errors are statistically significant at the 1% significance level while the parameters of calendar effects are statistically significant at the 5% level. The model explains 25% of variability in the spread of both interest rates.

The addition of intraday credit resulted in a marked weakening of the influence of liquidity prediction errors on movements of the spread between O/N interest rates and the repo rate, and simultaneously removed systematic calendar effects. Therefore, variations in the spread between both interest rates should be explained by the 8^{th}-degree autoregression correlation and only minimally by the influence of liquidity prediction errors. All parameters are statistically significant at the 1% significance level and the model explains 42% of the spread variability.

The high degree of autoregression is apparently a consequence of lowering spread volatility between O/N PRIBOR and the repo rate. It is somewhat surprising that the increase in volatility of liquidity prediction errors in 2001-2004 did not result in a deviation of O/N PRIBOR from the proximity of the repo rate. This result may stem from banks having a sufficient volume of these securities to secure intraday credit. Recall that a high portion of public debt is financed by Treasury Bills. Therefore, banks may not have to buy these resources in the interbank market.

Opposite signs in regression parameters of liquidity prediction errors and calendar effects confirm that CNB has better information on the daily need for liquidity in the interbank market than banks themselves. This information stems from variations in state budget flows that are hard to predict. It is evident from the CNB's systematic underestimation of the supply of excess reserves that higher volatility of liquidity prediction errors do not increase the volume of excess liquidity in the market and do not influence the movements of O/N interest rates. Reverse parameter signs for the first and last day of the maintenance period are explained by an overall excess of liquidity in the home interbank market. Banks can satisfy minimum reserve requirements from their own sources and need not borrow for their creation from CNB. The efforts of banks to valorize the excess of reserves in the interbank market at the last day of the maintenance period may play a role.

CONCLUSION

The monetary policy of stabilizing ultra-short interest rates in the proximity of the repo rate is the basic prerequisite to achieve set monetary targets. Perfect management of ultra-short interest rates assumes that the volatility of O/N interest rates do not exceed the announced level of the repo rate by a large margin. The volume of liquidity in the money market is in line with the needs of banks. That is, the supply of liquidity by the central banks mirrors the demand of banks for reserve resources through open market operations.

The study of basic theoretical approaches of ultra-short interest rate determination shows elements of a changing demand for reserves. These changes in bank demand for reserves occurred mainly in the context of intertemporal substitution of reserves. This paper demonstrates that the development of reserve demand was fundamentally different when the central bank ensured the stability of ultra-short interest rates through targeting of market interest rate than when it targeted the effective repo rate through open market operations.

The empirical analysis of the behavior of O/N PRIBOR explicitly demonstrates CNB's ability to stabilize O/N interest rates in near proximity of the repo rate. It also identified some structural changes in the money market. First, introduction of intraday credit significantly reduced instability of the demand for reserve resources in the interbank market and decreased the volatility of ultra-short interest rates. We also document a relatively rapid increase in the volatility of liquidity prediction errors on CNB's part in the 2001-2004 period and underestimation of the general concern of banks in the deposition of excess liquidity with CNB. This underestimation resulted in weakening the direct relationship between O/N PRIBOR and the success of the repo tenders carried out by CNB.

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