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Norwegian overnight interbank interest rates*

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Abstract

This paper addresses the lack of reliable information about overnight interest rates in the Norwegian interbank market. We infer actual interest rates from interbank transactions recorded in the real-time gross settlement (RTGS) system of Norges Bank over the period October 2006–November 2010. We propose a new measure of overnight interest rates, NONIA, which may be calculated daily as a value-weighted average of overnight interest rates on individual loans. This may supplement information provided by indicative interest rates such as NIBOR. We also calculate an indicator based on dispersion of interest rates across individual loans and the spread between NONIA and the Norges Bank's overnight deposit rate. This indicator may be useful for assessing whether overnight interest rates are close to the central bank key policy rate.

Keywords: *Interbank money market, Interest rates, RTGS.*

JEL Codes: *G21, E42, E43, E58.*

*This paper draws on Akram and Christophersen (2010). The views expressed in this paper are those of the authors and should not be interpreted as reflecting those of Norges Bank (the central bank of Norway). We have received useful comments from colleagues in the Department for Market Operations and Analysis at Norges Bank, especially Erna Hoff, Arne Kloster and Olav Syrstad. We are also grateful to Reidar Bolme of DnB NOR and Andreas Heiberg of Nordea for sharing their market insights with us. Corresponding author: Casper Christophersen, e-mail: casper.christophersen@norges-bank.no.

1 Introduction

Information about interbank interest rates is required for active management of money market liquidity and short-term money market rates. Central banks influence money market interest rates through their deposit and lending rates and by regulating the liquidity stance in the money markets; see e.g. Nautz and Scheithauer (2009). Information about actual interest rates is also of interest from a financial stability perspective; see e.g. Rochet and Tirole (1996) and Furfine (2001). As overnight lending in the interbank market is uncollateralized, actual interest rates paid by a bank may indicate the solvency of the borrowing bank and the credit risk associated with corresponding loans.

However, actual interbank overnight interest rates are generally not public information, as a loan's terms are agreed upon bilaterally between borrowing and lending banks. Published money market interest rates used as reference values are an average of interest rates quoted by major banks acting as market makers in the respective markets. For example, a widely used indicator for Norwegian overnight interest rates, the Norwegian Interbank Offered Rate (NIBOR) is an average of the major banks' ask quote on Reuters.[1] The NIBOR is purely indicative, and banks are not obliged to trade on their interest rate quotes; cf. Norges Bank (2010).[2]

A central bank can, however, infer actual interest rates in real time from interbank transactions recorded in its real-time gross settlement (RTGS) system; see e.g. Furfine (1999, 2001). RTGS data are available to central banks due to their provision of clearing and settlement services to other banks. By careful examination of the flow of funds between banks one may get fairly precise information about amounts borrowed and overnight interest rates paid by banks; see Furfine (1999, 2001). Several recent studies have inferred the overnight interest rates from RTGS data; see e.g. Bech and Atalay (2008) and Rørdam and Bech (2009).

In this paper, we follow the procedure proposed by Furfine (1999, 2001) and infer overnight interest rates from transactions settled in the RTGS system of Norges Bank between 9 October 2006 and 19 November 2010. To summarize inferred overnight interest rates, we create a value-weighted average of the interest rates. We refer to this new index as the Norwegian Overnight Index Average, or NONIA, reflecting its comparability to e.g. EONIA, its euro-area counterpart.[3] Our data set includes the period before and after the height of the recent financial crisis. This enables us to evaluate the reliability of the suggested indicator NONIA relative to NIBOR and an additional indicator based on market information in calm and turbulent periods. It is shown that

[1] In this paper, NIBOR will refer to the NIBOR tomorrow-next (T/N) rate.

[2] Six banks established in Norway currently quote NIBOR for periods from tomorrow-next (T/N, the rate from tomorrow until the next business day) and up to 12 months. The reference rate calculation – the fixing - is done at noon every day by Reuters which calculates the average rate after eliminating the highest and the lowest rates among the six quotes. The NIBOR panel banks themselves set the rules regarding which banks should participate in the fixing.

[3] The two differ in terms of the information on overnight trades. Whereas EONIA relies on a sample of banks which report all their trades, our NONIA is derived using the Furfine algorithm described in this paper. However, both rates are calculated as a weighted average of sampled interest rates.

NONIA may prove a reliable indicator of actual overnight interest rates in general and especially in a financial crisis.

One objective of Norges Bank's liquidity policy is to obtain interest rates close to the key policy rate. To aid assessment of deviations from this objective, we calculate an index that reflects dispersion in interest rates across banks and their deviation from the key policy rate. The index increases if there is an an increase in interest rate variation across banks and/or an increase in the weighted average of interest rates, NONIA, relative to the key policy rate.

The paper is organized as follows. The next section, Section 2, briefly describes key institutional features of the overnight Norwegian money market. Section 3 presents the data and the method employed for identifying overnight interbank loans. This section also sheds light on the activity in the Norwegian overnight interbank market. Section 4 analyzes overnight lending and the interest rates identified by the method used. Values of NONIA over the sample period are presented and compared with other available reference rates. Section 4 also analyzes the dispersion in interest rates across banks and over time relative to the key policy interest rates. Section 5 presents the paper's conclusions.

2 The Norwegian interbank market

Transactions between banks due to e.g. interbank loans and transfers between customers of different banks are settled across the books of a settlement bank. Banks need to have short-term liquidity available with their settlement bank to cover their debit positions. Such liquidity generally consists of drawing rights and deposits in banks' accounts with their settlement bank.

Norges Bank is the ultimate settlement bank in Norway. All banks established in Norway including branches and subsidiaries of foreign banks may keep deposit accounts with Norges Bank. The overnight deposit rate on these accounts is Norges Bank's key policy interest rate; cf. Bernhardsen and Kloster (2010). The lending rate on overnight overdrafts (the overdraft rate) has been one percentage point above the deposit rate since 16 March 2007; it was two percentage points above the deposit rate before that.

Norges Bank aims to ensure that the deposit rate prevails in the money market and that banks have adequate liquidity to meet their short-term obligations stemming from day to day activities.[4] To this aim, it targets a level of aggregate liquidity considered consistent with its objectives. Aggregate liquidity is measured as the sum of banks' deposits in Norges Bank from one business day to the next. Norges Bank offers banks that have deposit accounts with it and can pledge sufficient eligible collateral, short-term liquidity through auctions and its overdraft facility.[5]

[4] There are no reserve requirements imposed in the implementation of Norges Bank's monetary policy.

[5] Norges Bank auctions loans with fixed interest rates and fixed maturities, usually ranging from a few days to six weeks. Successful bidders receive loans at their interest rate bids, which are usually just above the key policy rate. Auctions are scheduled when actual or predicted aggregate liquidity falls short of operational targets for aggregate

2.1 Interbank overnight interest rates

The central bank lending rate on overnight overdrafts usually acts as a ceiling on interest rates on interbank overnight loans. Banks would rather borrow from other banks in the overnight interbank market than pay the relatively high rate on overdrafts. As the banking system as a whole would be in a deposit position overnight due to fixed maturity loans provided by Norges Bank, some banks will have deposits in Norges Bank which they may lend to other banks at an interest rate higher than the key policy rate. Overnight loans in the interbank market are not secured through collateral. Hence, banks would rather deposit at the central bank than lend to other banks in the overnight interbank market at a rate lower or equal to the central bank deposit rate. Therefore, the key policy rate usually acts as a floor for interbank overnight rates.

Overnight interbank interest rates usually vary across banks and over time within the floor and ceiling defined by central bank interest rates on overnight deposits and loans. Their levels depend on short-term liquidity available in the market and banks' characteristics determining e.g. liquidity and credit risks associated with their interbank loans, see e.g. Akram and Christophersen (2010).

Occasionally, however, overnight interbank interest rates may not remain within the floor and ceiling defined by the central bank interest rates. For example, foreign banks with no deposit account at Norges Bank may deposit excess Norwegian krone (NOK) liquidity in the interbank market (through their correspondent banks) at a lower interest rate than the central bank deposit rate. This can be the case at e.g. the end of a trading day when a foreign bank with excess NOK liquidity is facing the prospect of keeping it in an account with its correspondent bank, possibly at zero interest rate. Banks with a deposit account in Norges Bank would be willing to accept such excess liquidity at a lower rate than the central bank deposit rate, at which they themselves can deposit it overnight.

One reason for interbank overnight lending rates exceeding the central bank lending rate is that interbank loans are uncollateralized whereas loans from the central bank are collateralized. To economize on possible costs of pledging collateral with the central bank, a bank may prefer to pay a few basis points more for borrowing uncollateralized than pledge collateral to borrow at the central bank lending rate. Another reason could be possible stigma associated with borrowing overnight from the central bank; see e.g. Goodhart (2009, Ch. 7). That is, if a bank fears that an overnight overdraft at the central bank would be interpreted as a sign of that bank's failure to obtain funding from its peers in the interbank market, possibly because of their perception of excessive credit risk associated with lending to the needy bank, the bank may be willing to borrow at a higher interbank rate than the overnight overdraft rate at the central bank.

liquidity. The overdraft facility primarily aims to enable banks to honor their debts in the payment settlements. Such overdrafts are interest-free if repaid before the end of the day.

2.2 The FX SWAP market and the Norwegian money market

Major banks in Norway mainly borrow NOK through the NOK-USD foreign exchange swap market, rather than directly in the Norwegian money market. The NOK-USD swap market is an important market for financing and investing for large Norwegian banks and institutional investors. It is also important for oil companies who need to exchange their revenues in USD for NOK for payment of petroleum taxes; see e.g. Fidjestøl (2007). Partly because of these factors, the NOK-USD swap market is more liquid than the Norwegian money market where one borrows and lends directly in NOK.

Due to the importance of the USD market for the funding of Norwegian banks, major banks quote their lending rates on the basis of a rate derived from the formula for covered interest rate parity. The main reference rate for Norwegian overnight interest rates, (NIBOR), would therefore depend on the USD lending interest rate ($i^{*,a}$) and the NOK-USD swap exchange rate ($F^a - S^b$), where F^a is the outright forward exchange rate for buying USD while S^b is the spot exchange rate for selling USD, as in (1).

$$i^a_{swap} = i^{*,a} + \frac{(F^a - S^b) \times (1 + i^{*,a})}{S^b}. \tag{1}$$

Superscripts 'a' and 'b' refer to ask and bid quotes, respectively.[6]

Large banks in Norway quote lending and borrowing rates for tomorrow-next (T/N) transactions throughout the day in light of (1). Since NIBOR is an average of indicative ask quotes, it generally differs from prices at which banks actually trade (see Section 1 and footnote 2).

Not all banks choose to access the USD market for funds, however. A large number of smaller Norwegian banks are active mainly in the Norwegian money market. Larger banks are active in both. Still, the implied NOK interest rate for borrowing (and lending) through the USD market must remain close to the corresponding interest rate in the market for direct interbank borrowing (and lending) in NOK. Possible differences may diminish relatively quickly depending on arbitrage pressure; see Akram et al. (2009). Banks and other market participants in need of funds would borrow directly in the interbank market for NOK if it is cheaper than borrowing through the NOK-USD swap market and vice versa. In a state of equilibrium, the interest rate for overnight borrowing via the swap market should equal the interest rate for borrowing directly in the interbank NOK market.

[6] The formula used by market participants to obtain overnight interest rates in per cent is: $i^a = i^{*,a} + \frac{(F^a - S^b) \times (360 \times 100 + i^{*,a})}{10^4 \times S^b}$, where $(F^a - S^b)$ refers to market quotations of the swap exchange rate in pips, which are divided by 10^4.

3 Data

To infer interest rates paid by Norwegian banks, we study all gross transactions settled in Norges Bank's real-time gross settlement (RTGS) system. More than 140 banks have access to the system, and between 30 and 40 banks are active in the system daily. Most of the active banks use the system for gross settlement of large-value and time-critical payments, such as the in- and out-legs of overnight interbank loans. Transactions between relatively small banks that are settled through systems operated by a few large private banks are not recorded in this system.

From the RTGS system, we extract a record of 878 809 transactions over the period 9 October 2006 to 19 November 2010. This enables us to base our analysis on extracted interbank loans for 1 019 business days.[7] The average daily value of these transactions is on the order of NOK 200 billion. However, only a small share of these transactions is associated with interbank lending.

3.1 Identifying overnight loans and interest rates

In order to separate overnight loans from all other transactions, we employ the procedure used by Furfine (1999, 2001).[8] In essence, the procedure classifies a pair of transactions between two banks on consecutive business days as an overnight loan if the amount transferred on a day, V_t, is a round number and the amount returned on the subsequent day (V_{t+1}) equals the transferred amount plus an amount that may be considered a payment for accrued overnight interest rates. It is common to restrict the transferred amount to a round number as banks do not usually borrow non-round values; cf. Furfine (2001).

Specifically, we identify a pair of transactions as an overnight loan if the transferred value is a round value in NOK million and the implied interest rate (ii):

$$ii = \left(\frac{V_{t+1}}{V_t} - 1\right) \times 365, \tag{2}$$

lies within a predefined band. The width of the band depends on what we consider to be reasonable variation in interbank interest rates.

In this analysis, we consider values of ii on day t that are between $i^b_{cb} - 0.1$ and $\text{NIBOR}_{t-1} + 0.1$, where i^b_{cb} is Norges Bank's deposit rate and NIBOR_{t-1} is the T/N rate the preceding day (for delivery "tomorrow" and repayment the "next" day).[9] That is, we allow possible interest rates to fluctuate within an interest rate corridor of between 10 basis points below the deposit rate and 10 basis points above NIBOR.[10] The number of transactions identified as loans increases with the

[7] There were no available data from the RTGS system on nine days in 2007 and on two days in 2008. Moreover, due to an RTGS system change on 17 April 2009, we lack data for two weeks preceding the change.

[8] An open-source implementation of the Furfine algorithm developed as part of this project is available on FinancialNetworkAnalysis.com.

[9] We use the effective NIBOR rate published on Norges Bank's web-site. This rate is based on a 365-day convention, which is also the case for Norges Bank's lending and depositing rates. To ease comparison, we also use 365 days in Equation 2 to derive interest rates per annum.

[10] The adjustment factor representing 10 basis points is based on our conversations with market participants to

width of the band. In section 4.3, we consider alternative bands for permissible values of overnight interest rates, *ii*.

Within the interest rate band specified, the algorithm identifies 27 809 overnight interbank loans among the transactions in our sample.[11] The transactions reflects uncollateralized loans in the NOK market and in some cases interbank loans through the foreign exchange swap market. Whether loans through the swap market are among the transactions depends on how each trade is carried out. For example, a bank can at time t borrow USD $\frac{1}{S^b}$ and sell it to obtain NOK 1.[12] At the same time, it will agree to buy back USD $\frac{1}{S^b}$ for NOK $\frac{1}{S^b} \times F^a$ at time $t+1$ through a swap contract. In a separate deal, it could buy the accrued interest rates on the USD loan, $\frac{1}{S^b} i^{*,a}$, for NOK $\frac{F^a}{S^b} i^{*,a}$ through a forward contract or use available USD to pay for the accrued interest on the initial loan. Alternatively the borrowing bank may choose to include accrued interest in the forward contract; cf. Levi (2005, Ch. 8). The procedure used requires that a loan is paid back with a single return transaction in NOK which includes the borrowed amount and the accrued interest. Hence, it would be able to infer the interest rate involved in the latter case, but not in the first case as there would be more than one return transactions involved.

3.2 Interbank market activity

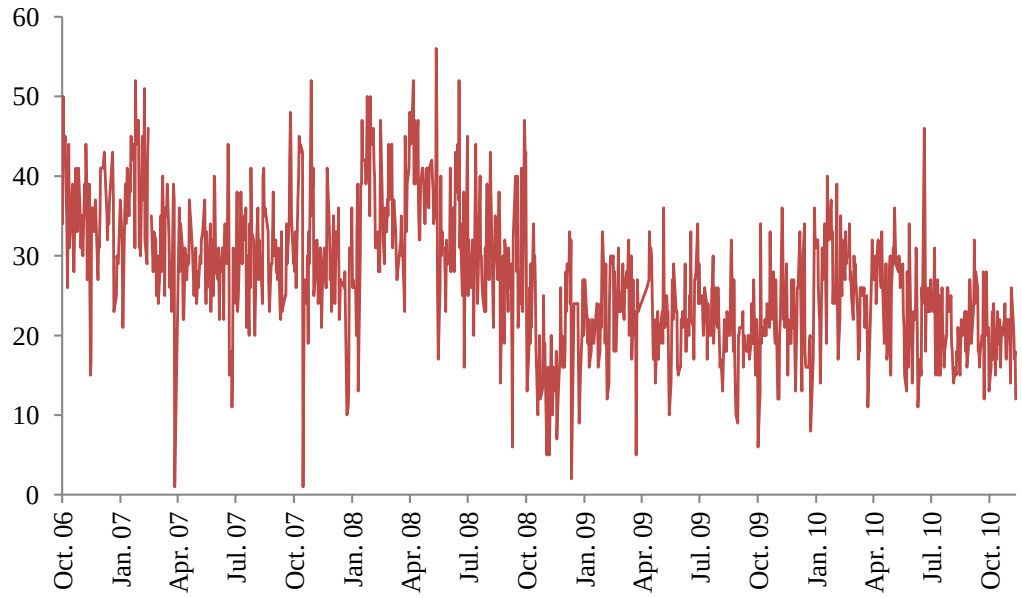
Our sample of overnight loans show that overnight lending takes place between around 30 banks, constituting less than 1/4 of the banks that have access to the RTGS system. These banks are the largest Norwegian banks and branches and subsidiaries of foreign banks. Together they hold more than 75% of the total assets of banks established in Norway. The number of market participants differ across trading days. There are one to 16 borrowers and one to 20 lenders on a day during our sample period. About half of the banks are active on more than 1/4 of the days in the data set.

The number of overnight loans, their values and corresponding overnight interest rates vary substantially over the sample period. Figure 1.a shows that the number of overnight loans varies between 1 and 56 on different days while Figure 1.b shows variation in the total value of loans per day from NOK 124 million to NOK 26 billion. The figures also show that the number of loans per day and their values experienced a marked decline in October–December of 2008. The number of loans and their values were particularly low in November 2008. The average level and variation in total values of loans per day seem to have returned to the pattern before the autumn of 2008. In contrast, the average number of loans per day and perhaps also their daily variation seem to have not returned to their levels before the autumn of 2008.

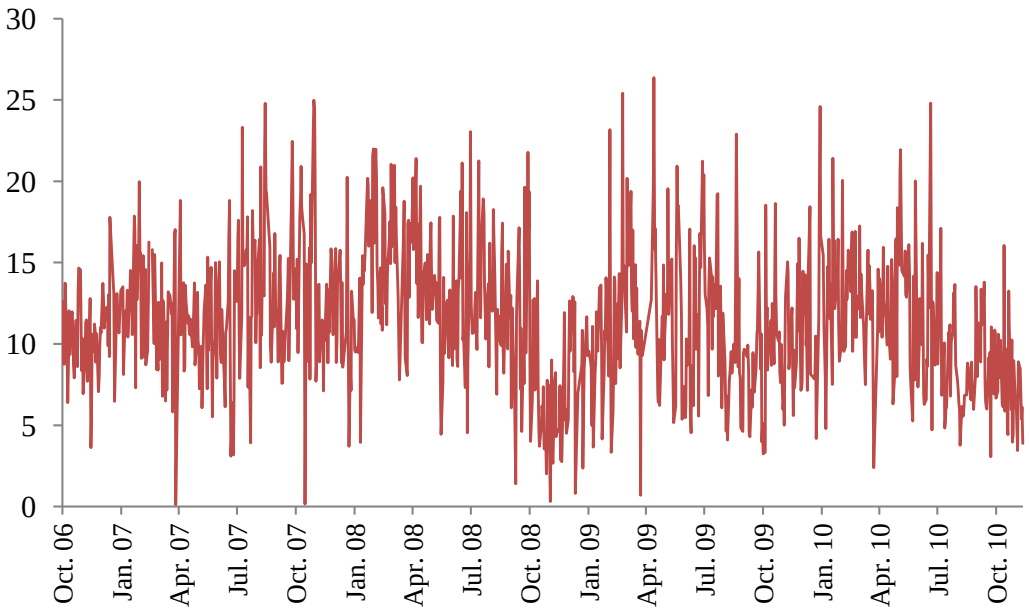
take into account interbank loans on behalf of foreign banks and loans with a rate higher than the (trimmed) average ask rate of the banks in the NIBOR panel.

[11] In a small number of cases, an outgoing transaction has been matched with more than one potential return transaction, resulting in two possible interest rates. In such cases, we have chosen the interest rate closer to the key policy rate.

[12] If the bank already possesses USD, it may obtain NOK through the FX swap without first borrowing USD.



(a) Number of loans



(b) Total value of loans

Figure 1: *(a) Number of loans and (b) the total value (in* NOK *billion) of loans. Daily observations over the period 9 October 2006 to 19 November 2010.*

Table 1 provides more details on the size of loans. The table shows that the value of a single loan varies from NOK 1 million to NOK 2.14 billion while total overnight borrowing by different banks varies in the range NOK 2 million to NOK 18 billion over the sample period. The table also shows that the average daily turnover in the overnight market is around NOK 11.5 billion.

Table 1: ***Descriptive statistics of overnight borrowing in the interbank market***

	Individual loans	Daily borrowing	Total daily turnover
Mean	420.5	1 479.6	11 475.5
Median	294.0	850.0	11 175.0
Std. Dev	427.4	1 698.9	4 345.2
Min	1.0	2.0	124.0
Max	2 140.0	17 987.0	26 369.0

Note: The unit is NOK million. The descriptive statistics are based on the sample period 9 October 2006 to 19 November 2010.

4 Overnight interest rates

Figure 2 shows interest rates associated with all of the identified overnight loans over the sample period. A dot represents an overnight interest rate, *ii*, while the solid and dashed lines represent the central bank overnight deposit and lending interest rates, respectively. The central bank interest rates have been changed on several occasions over the sample period.

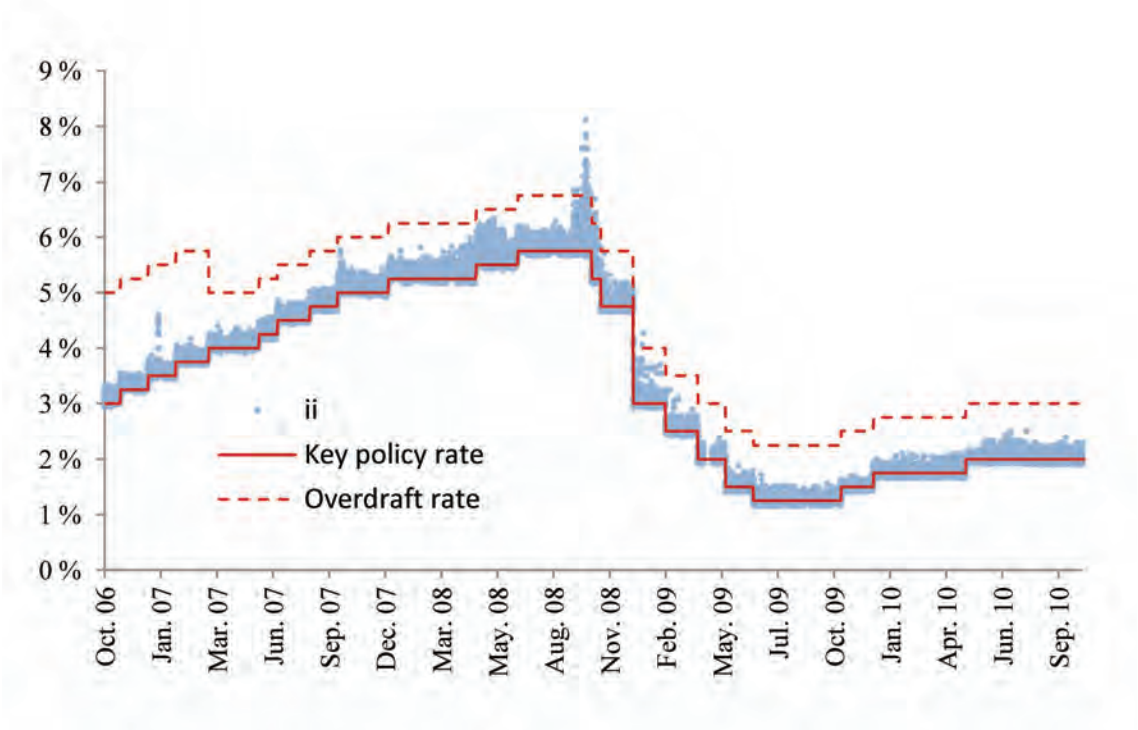


Figure 2: *Interest rates on identified loans (ii) and central bank deposit and lending rates. The spread between the latter interest rates has been one percentage point since 16. March 2007. Daily observations over the period 9 October 2006 to 19 November 2010. Interest rates in per cent per annum.*

We observe that most of the overnight interest rates are within the corridor defined by the deposit rate and the lending rate, as expected. There are, however, a non-negligible number of interest rates outside this corridor. Observations of interest rates below the central bank deposit rate are consistent with the interpretation that they are associated with foreign banks (without a subsidiary or a branch in Norway) depositing excess NOK liquidity with banks with deposit accounts at Norges Bank. The latter can deposit excess liquidity with Norges Bank at its deposit

rate and may therefore accept excess liquidity from foreign banks at a lower rate, as a charge for immediacy.[13]

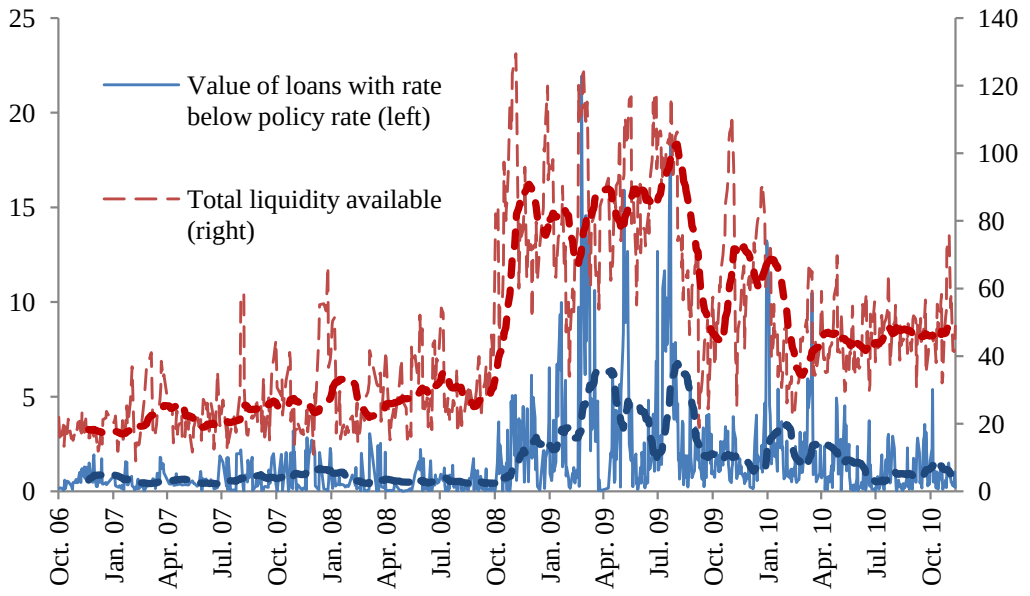


Figure 3: *Value of loans per day with interest rates below the central bank deposit rate (left-hand axis) and total liquidity as the sum of all bank deposits at Norges Bank (right-hand axis). Daily observations over the period 9 October 2006 to 19 November 2010. The thick dotted lines represent 30-day rolling averages of the corresponding series. All series in* NOK *billion.*

One would expect overnight lending below the key policy rate to occur more often when there is ample liquidity in the market. In such conditions, foreign banks active in NOK are more likely to have excess liquidity at the end of the day while Norwegian banks have sufficient liquidity, weakening their incentives to take on more liquidity. Interest rates below the deposit rate appear to occur mainly after the liquidity injections provided by Norges Bank in response to actual and presumed liquidity shortages during the financial crisis. Figure 3 shows that value of loans at interest rates below the key policy rate increases substantially after the start of liquidity support measures by Norges Bank to raise the total liquidity available to banks. The extraordinary liquidity supply measures were effective from October 2008 and were gradually phased out by the end of 2009. The figure shows that the value of loans with interest rates below the central bank deposit rate decline with the declines in total liquidity available to banks.

Figure 2 also shows observations of loans with interest rates above the central bank lending rate. Such observations are consistent with the interpretation that banks in need of liquidity may prefer to borrow from their peers to borrowing from the central bank. This could reflect banks' desire

[13]Such practice is not unusual. For example, US government sponsored entities (GSEs) are not eligible to receive interest on balances held with Reserve Banks. They therefore lend to other banks that are eligible to receive interest on their balances. The banks pay the GSEs interest rates below the interest rate paid on reserves; cf. Bech and Klee (2009).

to economize on the use of collateral required for borrowing from the central bank and therefore their preference for borrowing in the interbank market at relatively higher interest rates. However, such high interest rates could also reflect banks' aversion to sending signals that they are unable to obtain (unsecured) overnight funds in the market. We observe 90 loans with an interest rate higher than the central bank lending rate. Most of these observations refer to the period between 15 September 2008 and the end of the year 2008.

A close look at the data set reveals, however, that banks borrowing at interest rates above the central bank lending rates also obtain loans at lower interest rates during the same period. Hence, interest rates above the central bank lending rate should be interpreted with care, as they need not indicate persistently high credit risk premiums associated with lending to the corresponding banks; cf. Rochet and Tirole (1996) and Furfine (2001).

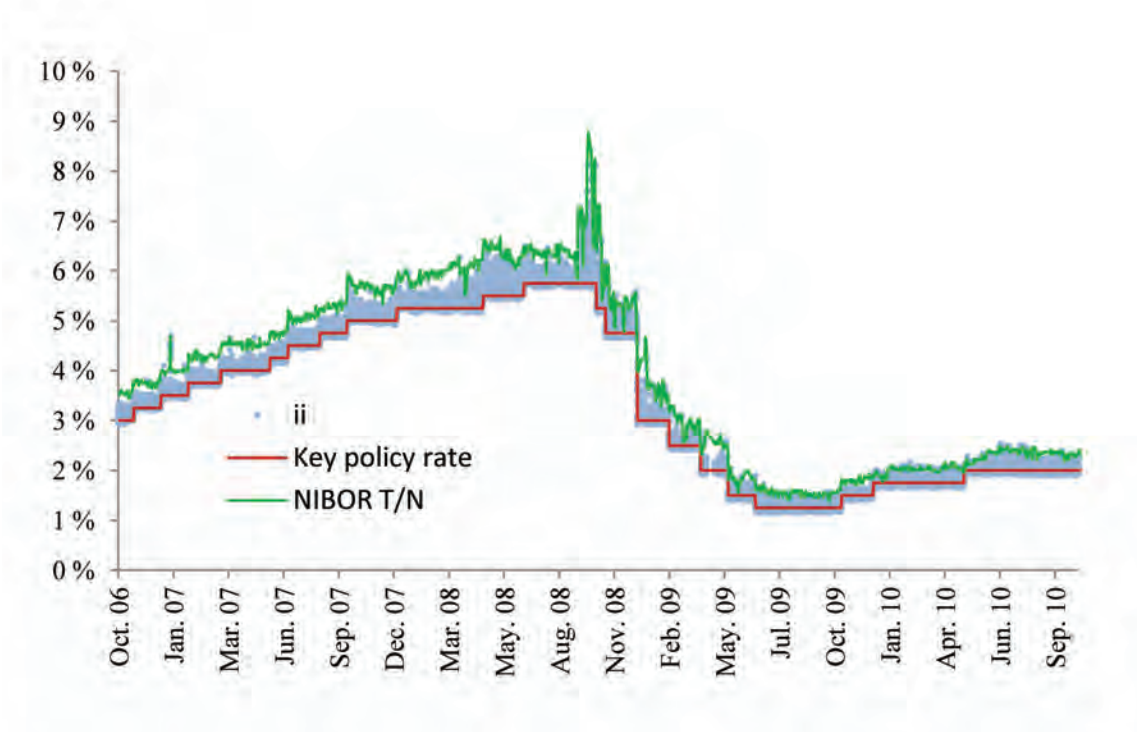


Figure 4: *Interest rates on identified loans (ii), Norges Bank deposit rate and* NIBOR *T/N. Daily observations over the period 9 October 2006 to 19 November 2010. Interest rates in per cent per annum.*

Figure 4 shows that NIBOR is generally above the derived overnight interest rates by several basis points. However, NIBOR appears to be closer to the key policy rate and the derived interest rates at the end of the sample than at the beginning, possibly marking a shift around May 2009. We also note that almost all rates are identified below NIBOR, even though we allow for interest rates above NIBOR as well.

4.1 Norwegian OverNight Index Average

To summarize actual overnight interest rates, given the relatively large variation in overnight interest rates across loans (and banks), we construct an indicator of the actual overnight interest rates. Using interest rates on all identified loans on a given day, we calculate a value-weighted average interest rate, which we term Norwegian OverNight Index Average (NONIA). Each of the interest rates is weighted in accordance with the value of the corresponding loan relative to the total value of all loans on a given day:

$$NONIA_t = \sum_{j=1}^{J_t} \omega_{j,t} ii_{j,t} \ , \tag{3}$$

$$\omega_{j,t} = \frac{V_{j,t}}{\sum_{j^*=1}^{J_t} V_{j^*,t}} \ , \tag{4}$$

where $\omega_{j,t}$ represents the weight given to interest rate j on day t. The weight depends on $V_{j,t}$, which represents the value of a loan j on a day t, while $\sum_{j^*=1}^{J_t} V_{j^*,t}$ sums the values of all loans on day t; J_t denotes the number of different loans (and interest rates) on a day t.

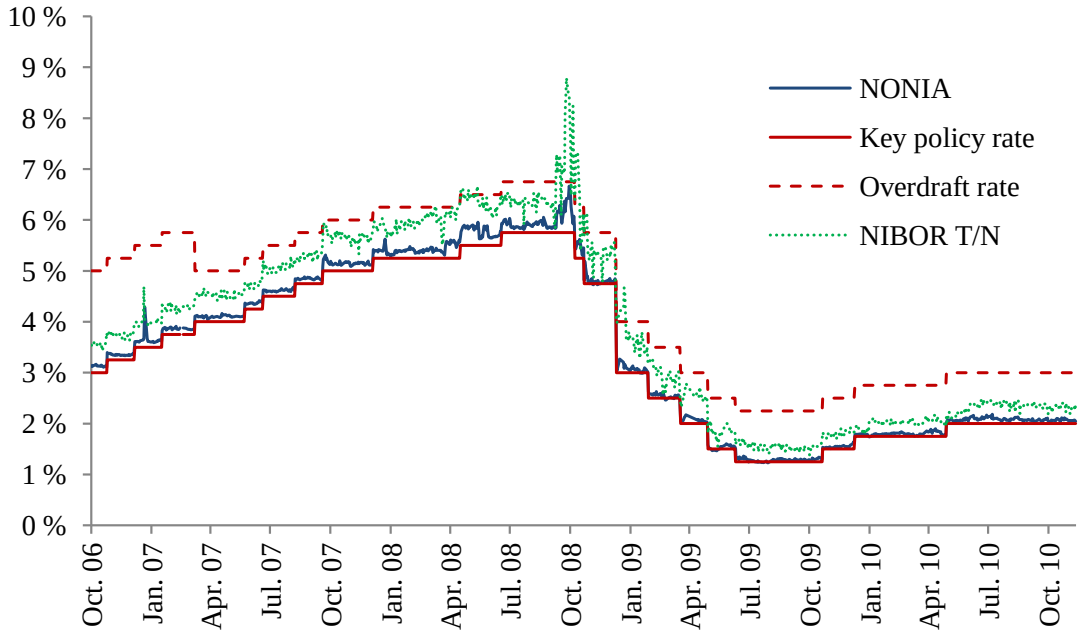


Figure 5: NONIA, NIBOR *T/N, central bank deposit and lending rates. Daily observations over the period 9 October 2006 to 19 November 2010. Interest rates in per cent per annum.*

Figure 5 plots NONIA against the key policy rate, the central bank lending rate and the published NIBOR. Observations of NONIA are almost always within the central bank interest rate corridor and lies much closer to the key policy rate than NIBOR. The average value of NONIA over the

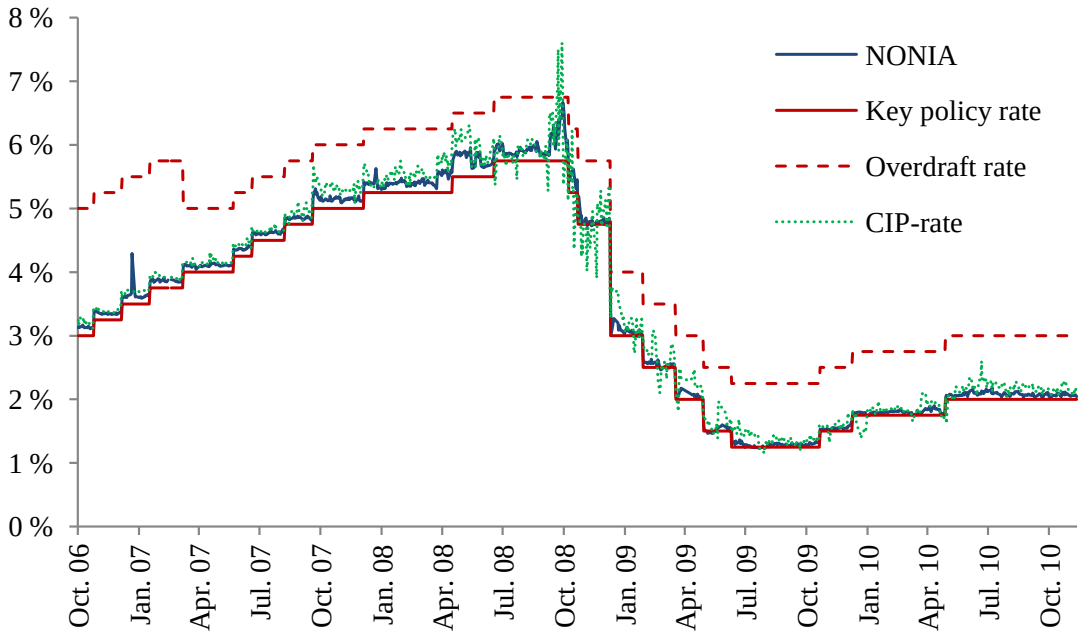


Figure 6: NONIA, CIP-*rate, Norges Bank deposit and lending rates. Daily observations over the period 9 October 2006 to 19 November 2010. Interest rates in per cent per annum.*

whole sample period is around 11 basis points above the deposit rate. In the midst of the financial crisis (15 September to 15 October 2008) the average value of NONIA was 42 basis points above the central bank deposit rate. In contrast, values of NIBOR were on average close to 38 basis points above the key policy rate over the whole sample and 128 basis points above the deposit rate at the height of the financial crisis. This suggests that liquidity in the overnight market was less strained than suggested by NIBOR, especially in September–October 2008. The relatively large increase in NIBOR during this period may reflect unusual values of the NOK-USD swap rate and of US short term lending rates during this period. These findings are consistent with the view that NIBOR overstates actual interest rates in the overnight market. The main reason for the relatively high NIBOR is that the indicative foreign exchange swap points, $F^a - S^b$, used by banks in (1) and thereafter used in the NIBOR fixing are relatively high. This is supported by the fact that the tradeable foreign exchange swap points on Reuters' electronic trading platform (Spot Matching) were lower.

To obtain a more reliable interest rate indicator to compare with NONIA, we employ an interest rate based on covered interest rate parity (1), which is obtained by using tradable quotes for foreign exchange swap points and the spot exchange rate S^b. For USD lending interest rates, $i^{*,a}$, an average interest rate based on quotes from two large brokers is used. The source of tradable quotes of the swap and spot exchange rates is Reuters Spot Matching. In the following we refer to

the interest rate implied by covered interest rate parity as the CIP-rate.[14]

Figure 6 compares NONIA with the CIP-rate. The figure shows that NONIA and the CIP-rate follow each other well and that the CIP-rate is much closer to NONIA than NIBOR. The CIP-rate, however, is much more volatile than NONIA during the recent financial crisis. In this period the CIP-rate is below the deposit rate quite often. The relatively large and frequent occurrences of CIP-rates below the central bank deposit rate do not appear to be consistent with information provided by market participants. It is well known that covered interest rate parity fails to hold during crises and especially during the recent one; see e.g. Coffey et al. (2009). Hence it is not unexpected that the CIP-rate becomes less reliable in the autumn of 2008.

The relatively small differences between NONIA and the CIP-rate, especially before the financial crisis, suggest that we are able to quite accurately capture market activity and interest rates with the Furfine algorithm. Moreover, NONIA appears to be a more reliable indicator of actual overnight interest rates than both NIBOR and the CIP-rate, especially during the financial crisis.

4.2 Assessment of Norges Bank's liquidity policy

The objective of Norges Bank's liquidity management is to ensure that short-term money market rates remain close to the key policy rate: its overnight deposit interest rate. This objective may be expressed as that of minimizing the following loss function:

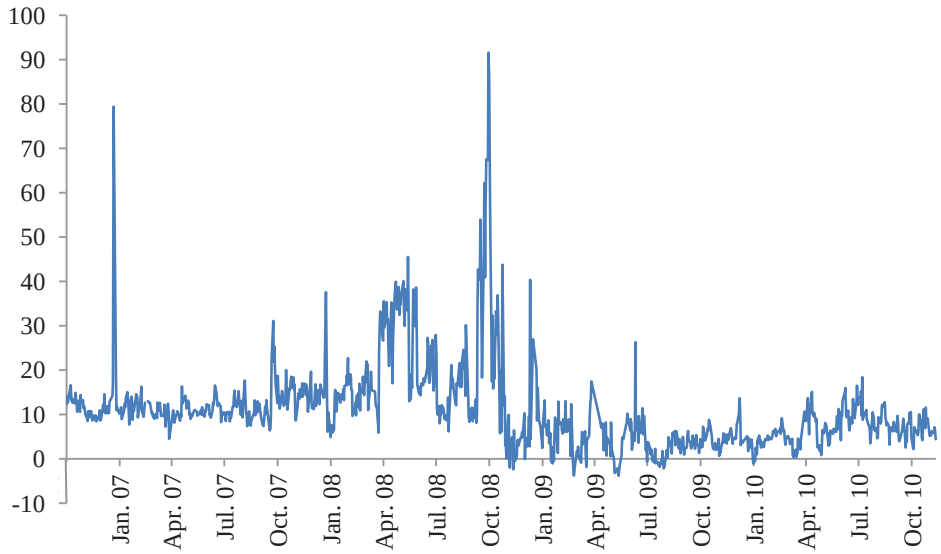
$$L_t = \sum_{j=1}^{J_t} \omega_{j,t}(ii_{j,t} - i^b_{cb,t})^2 \ , \tag{5}$$

where $ii_{j,t}$ represents the actual overnight interest rate on loan j (on day t), $i^b_{cb,t}$ is the central bank deposit interest rate and $\omega_{j,t}$ is the value of the loan j relative to the total value of all overnight loans on date t, as defined in (4). The loss function L_t can be expressed as a quadratic function of a (weighted) standard deviation of overnight interest rates and the spread between a weighted average of interest rates, i.e. NONIA, and the key policy rate:

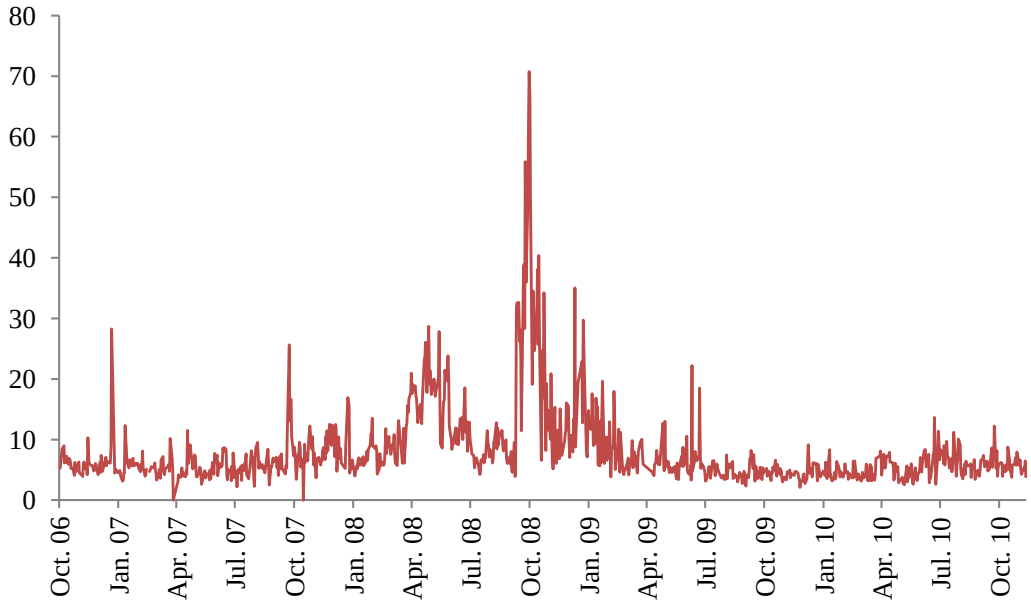
$$\begin{aligned} L_t &= \sum_{j=1}^{J_t} \omega_{j,t}(ii_{j,t} - NONIA_t)^2 + (NONIA_t - i^b_{cb,t})^2 \\ &= \text{Std.deviation}_t^2 + \text{Spread}_t{}^2. \end{aligned} \tag{6}$$

NONIA is defined above in (3)–(4), while Std.deviation_t is defined as $\sqrt{\sum_{j=1}^{J_t} \omega_{j,t}(ii_{j,t} - NONIA_t)^2}$ and Spread as $(NONIA_t - i^b_{cb,t})$. It follows that the central bank loss on a given day increases with the variation in overnight interest rates across loans and the spread between NONIA and the central bank deposit rate. Values of the square root of L_t can be termed as Root Mean Square Spread (RMSS).

[14] This series has been kindly made available to us by the Department for Market Operations and Analysis at Norges Bank.



(a) Spread between NONIA and the key policy rate



(b) Standard deviation of daily interest rates across banks

Figure 7: *(a) Spread between* NONIA *and the key policy rate and (b) standard deviation of daily interest rates across banks. Daily observations over the period 9 October 2006 to 19 November 2010. Both series in basis points.*

Figures 7.a–b show the two determinants of RMSS, i.e. the weighted standard deviation of overnight interest rates on each day and the spread between NONIA and the key policy rate. Values of the spread are in the range of −4 to 91 basis points. In normal times, the spread appears to be around 10 basis points. However, at the height of the recent financial crisis, the spread increased substantially; cf. Section 4.1. Values of the daily standard deviation of overnight interest rates

are in the range 3 to about 70 basis points. The difference in interest rates across loans is mostly below 10–15 basis points. Particularly large differences in interest rates across banks as reflected in the standard deviation series refer to the spring and the autumn of 2008. It should be kept in mind that daily values of the standard deviation are based on a varying number of loans and may therefore not be equally representative over time; see Figure 1. In particular, during periods of little activity in the interbank market leading to few loans, such as the last days of a year, interest rates on particular loans may influence values of the standard deviations, showing up as spikes in its series. Finally, we note that increases in the spread go together with increases in the standard deviation. The sample correlation between the two series is 0.80.

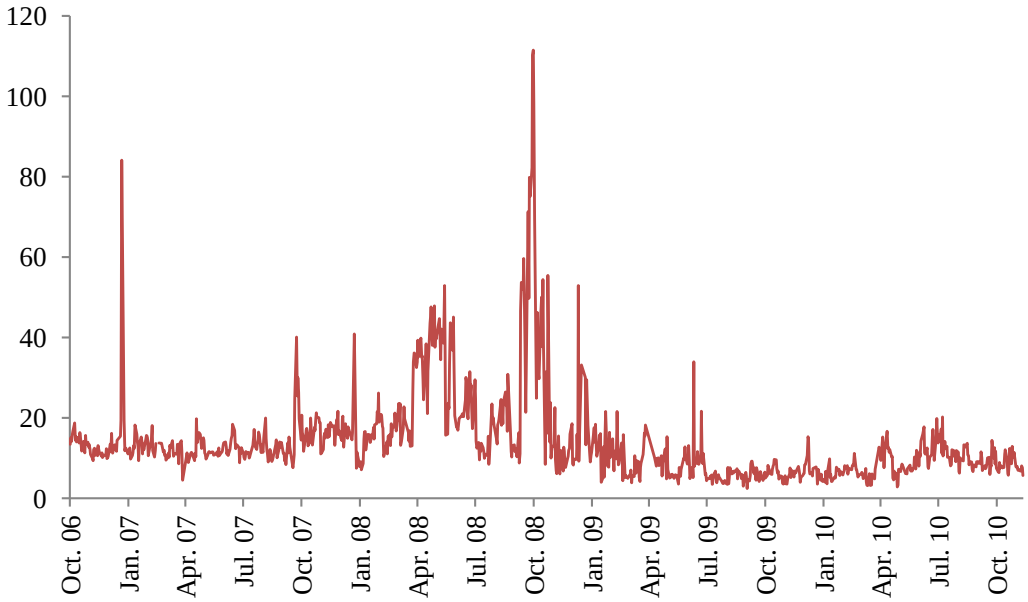


Figure 8: *Values of* RMSS. *Daily observations over the period 9 October 2006 to 19 November 2010. Series in basis points.*

Figure 8 shows values of the square root of L_t, i.e. of RMSS, expressed in basis points. These values reflect the relatively large variation in overnight interest rates across different loans and banks within any given day and the deviation between NONIA and the central bank deposit rate, especially during the height of the financial crisis. The following features are notable. First, RMSS appears to be lower than 20 basis points on typical business days, which suggests that overnight interest rates are mostly in line with their target rate: the central bank deposit rate. Second, we observe a substantial increase and volatility in RMSS during the recent financial crisis. The increase is notable during the spring and autumn of 2008, which can be mainly associated with the bail-out of Bear Sterns in March 2008 and the default of Lehman Brothers in September 2008. And third, as with the standard deviation, we observe indications of end-of-year effects, as values of RMSS

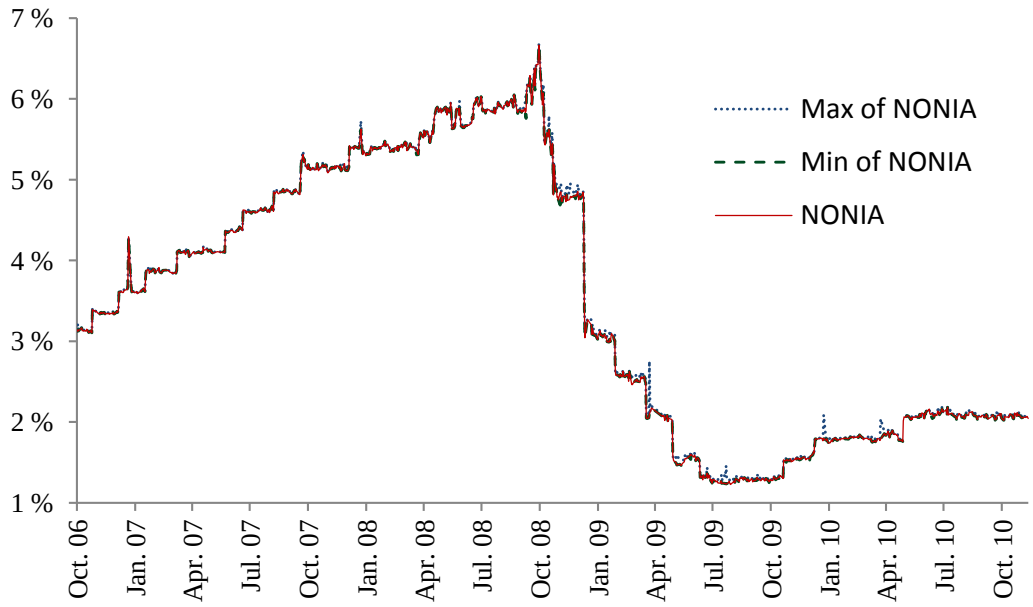


Figure 9: *Rate span for* NONIA *(min and max). Daily observations over the period 9 October 2006 to 19 November 2010. Interest rates in per cent per annum.*

spike at the end of years 2006, 2007 and 2008.

4.3 Robustness of NONIA and RMSS

In this section, we test the robustness of NONIA and RMSS to different widths of the band for allowed interest rates. As mentioned in Section 3.1, the set of identified interest rates is affected by the width of the chosen band for allowed interest rates. There are two reasons for this. First, there may be actual overnight loans with an interest rate outside the chosen band, i.e. indicating that the chosen band is too narrow. The second reason is misclassification of transactions as overnight loans. As the risk of misclassification increases with the band, this calls for a narrower band. The chosen band thus has to balance these two opposing concerns.

In order to test how differences in the band affect NONIA and RMSS, we calculate the two series under two different assumptions about the interest rate band. In the first case, we allow only rates between the key policy rate and NIBOR (the narrow band). In the second case we allow the rates to fluctuate between 15 basis points below the key policy rate and 15 basis points above the highest of the deposit rate and NIBOR (wide band).[15]

The results show that even with large changes in the band, the total number of identified interest rates changes by merely 1 to 3%. On most days, there are no changes. More importantly, calculated values of the proposed measure of overnight interest rates, NONIA, and the measure of

[15] This represents a much wider band than the one we use in the main analysis, which was between 10 basis points below the policy rate and 10 basis points above NIBOR.

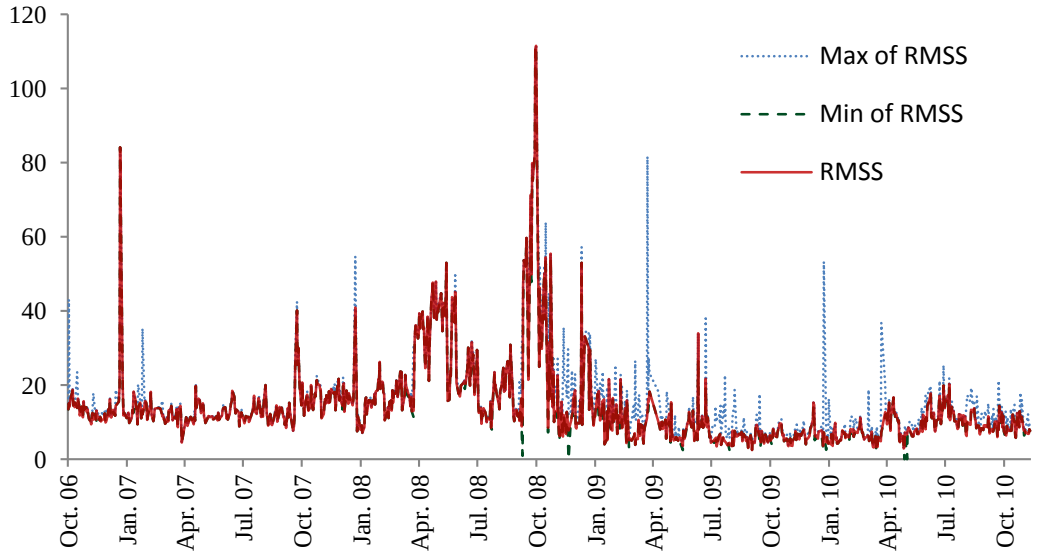


Figure 10: *Span for* RMSS *(min and max). Daily observations over the period 9 October 2006 to 19 November 2010. Series in basis points.*

deviations from the liquidity policy objective, RMSS, do not change much when we alter the width of the interest rate corridor. Figure 9 plots, for each day, the highest and lowest values of NONIA obtained with the two different bands, together with the values of NONIA presented in section 4.1. Deviations from the previously presented results appear to be almost non-existent before the autumn of 2008. A close look at the graph reveals small deviations on a few occasions after that. These deviations occur mainly between October 2008 and May 2009. In that period we observed relatively high volumes of loans with an interest rate below the key policy rate; cf. Figure 3. These loans are not included when the narrow band is imposed, which results in a slightly higher NONIA in this period. Increasing the width of the band, however, does not seem to affect NONIA in the same way. One reason for the relative robustness of NONIA to changes in the width of the band could be that we are equally likely to capture observations stemming from misclassification above and below the set of correctly identified loans. When these (relatively few) loans above and below the value-weighted average are added to the sample, they do not change the average noticeably.

Similarly, Figure 10 plots the highest and lowest values of RMSS obtained with the different bands, together with the RMSS presented earlier. The differences in the calculated values of RMSS seem small on most days, with the more persistent differences being observed in the autumn of 2008 and spring of 2009.

Although small differences do occur when we impose different restrictions on the interest rate band, these results suggest that both NONIA and RMSS are fairly robust to the band used.

5 Conclusions

This paper has addressed the lack of reliable information on actual overnight interest rates. Such information is required for successful liquidity management policy aimed at ensuring overnight interest rates close to the central bank deposit rate, which is the key policy rate of Norges Bank.

We have inferred actual overnight interest rates from transactions recorded in the payment settlement system of Norges Bank. These transactions have enabled us to shed light on activity in the Norwegian interbank market during calm and turbulent periods. There is a relatively large variation in actual overnight interest rates over time and across loans. We have found that on typical business days, overnight interest rates are relatively close to the central bank deposit rate. During the recent financial crisis, however, dispersion in overnight interest rates as well as the deviations from the deposit rate increased by a large amount. Notably, derived interest rates were substantially below NIBOR, especially during the recent crisis.

We have derived a new measure of actual overnight interest rates, NONIA, by value-weighting individual overnight interest rates. NONIA supplements available measures of overnight interest rates. We show that NONIA may be a more reliable indicator of actual overnight interest rates than the published NIBOR and an alternative interest rate implied by covered interest rate parity, especially during times of market turmoil. Values of NONIA suggest that the liquidity stance in the Norwegian money market has been less strained than that suggested by the latter measures.

Furthermore, to assess deviations of individual overnight interest rates from the key policy rate, we have calculated daily values of RMSS (Root Mean Square Spread), which depends on dispersion in interest rates across individual loans, as measured by their standard deviation, and the spread between NONIA and the central bank deposit rate. Both NONIA and RMSS may be used for active management of money market liquidity and short-term money market rates.

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