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Inferring interbank loans and interest rates from interbank payments - an evaluation

Q. Farooq Akram and Casper Christophersen*

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Abstract

We investigate whether overnight interbank loans and interest rates can be reliably inferred at the market and bank level from central banks' interbank payments data. We identify overnight loans and interest rates among interbank payments for 11 banks in Norway and compare them with the actual overnight loans and interest rates reported daily by these banks to the Norwegian central bank since October 2011. We find that interbank payments can provide reliable information about overnight lending and overnight interest rates at the market level, and even at the bank level, for relatively small overnight lenders and large overnight lenders that mostly lend on their own behalf.

Keywords: Furfine; Overnight interbank rates; Interbank payments.

JEL Codes: *G21, E42, E43.*

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*This Working Paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank. We have received useful comments from Dan Thornton, Arvid Raknerud, Anders Svor, Olav Syrstad and seminar participants at Norges Bank. We are grateful to Finance Norway and Norges Bank for access to the data used in this paper. Corresponding author: farooq.akram@norges-bank.no.

1 Introduction

Actual interbank interest rates are generally not public information, as a loan's terms are agreed upon over-the-counter, bilaterally between borrowing and lending banks or through a broker.[1] Researchers of interbank markets commonly infer such information from interbank transactions recorded in the real-time gross settlement (RTGS) systems of central banks using an algorithm first suggested by Furfine (1999, 2001). RTGS data are available to central banks due to their provision of clearing and settlement services to other banks within their domains. The Furfine approach essentially amounts to filtering RTGS data to extract sent and received interbank payments that seem to be interbank loans. This approach has been widely used in numerous studies of interbank markets across the world; see e.g. Bech and Atalay (2010), Rørdam and Bech (2009), Wetherilt et al. (2009) and Akram and Christophersen (2013).

Information about actual interbank interest rates and lending volumes are particularly useful for central banks' management of interbank liquidity and interest rate decisions. Understated overnight interest rates might give central banks the impression of sufficient interbank liquidity and may therefore delay necessary adjustments to the liquidity provision. Overstated overnight interest rates can have the opposite implications for liquidity provision. Measures based on indicative interest rate quotes such as LIBOR have proved to be inaccurate indicators of the actual liquidity stance in interbank markets as well as for pricing of financial claims. One possible reason has been the alleged misreporting of borrowing rates by some banks for the calculations of market-wide interest rates.

However, despite its widespread use, the reliability of the Furfine approach for inferring overall or bank-specific interbank interest rates and trading has not been thoroughly examined. This is due to researchers' lack of access to information about

[1] Published money market interest rates used as reference rates are an average of interest rates quoted by major banks acting as market makers in the respective markets. For example, the Norwegian Interbank Offered Rate (NIBOR) is an average of the major banks' ask quotes on Reuters. Six banks based in Norway currently quote NIBOR for periods from tomorrow-next and up to 12 months. Calculation of NIBOR - the fixing - is done at noon every day by Reuters, which calculates the average rate after eliminating the highest and the lowest interest rate quotes among the six quotes.

actual interest rates and trading. Recently, Armantier and Copeland (2012) have questioned the reliability of Furfine-type procedures for identifying overnight interbank loans among interbank payment transactions. Exploiting confidential information about the returned values of the US federal funds granted by two relatively large banks over the period 2007–2011, they have found 64–93 percent of the transactions classified as overnight interbank loans to be false. They also report the median value of Furfine-based inferred overnight rates to be 13 basis points lower than the median value of lending rates they assume to be correct. It remains to be investigated, however, whether their results can be generalised to the interbank lending of other participants of the federal funds market and to other interbank markets, which may differ in structure, activity and the behaviour of market participants.[2] Transactions data from some interbank markets could be more conducive to the performance of the Furfine procedure than others owing e.g. to the features of the market and participants in the settlement system. For example, Arciero et al. (2013) using the euro area data, have reported much lower erroneous classifications than those reported in Armantier and Copeland (2012).

We investigate the accuracy of a Furfine-based algorithm in identifying different banks' overnight interbank loans and lending rates individually and at an aggregate level. We use data for 11 banks that regularly participate in the Norwegian interbank market. We estimate these banks to have accounted for 93% of the overnight lending volume and 76% of the overnight loans in the Norwegian interbank market over our sample period, 1 October 2011 to 31 July 2012. These banks have constituted a fixed panel of 11 banks, which submit their actual daily overnight interbank lending and corresponding value-weighted lending rates daily to Norges Bank for its calculation and publication of the official market level interbank interest rate, the Norwegian Overnight Weighted Average interest rate (NOWA).[3] Norges Bank has kindly provided us payment systems data from its RTGS system, and access to

[2] As pointed out by Armantier and Copeland (2012), one source of the discrepancy could be that the two banks are important correspondent banks and hence the Furfine-type algorithm would be capturing all of their overnight transactions, both on own behalf and on behalf of their customers. In particular, the algorithm could pick up loans conducted on behalf of wealth management funds, hedge funds, or even firms outside the financial sector.

[3] The identity of the NOWA panel banks is public information; see www.fno.no.

reports submitted by the NOWA panel banks on their actual overnight interbank lending, with the consent of the trade organisation for Norwegian financial institutions, Finance Norway (FNO). The data sample covers the period 1 October 2011 to 31 July 2012, i.e. starting from the day of the first release of NOWA.

The paper is organized as follows. The next section (2) briefly describes how overnight interbank loans and interest rates may be inferred from interbank payment systems data; cf. Furfine (1999). Section 3 presents our data on actual trading and interest rates. Section 4 compares and analyses inferred and actual loans and interest rates at both the bank and market level. It also investigates whether the reliability of the Furfine algorithm vary with some bank characteristics such as size, lending activity and home-country affiliation. Section 5 concludes.

2 Interbank loans and rates from RTGS data

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. Central banks generally serve as the ultimate settlement banks for banks resident in their countries. Data from the real time gross settlement (RTGS) systems of central banks contain information about the time and value of individual interbank transactions. The purpose of a transaction is, however, not indicated in general. Moreover, interbank transactions involving interbank loans seem to constitute a relatively small share of total transactions. Given the lack of identifiers, it is therefore challenging to separate them from other transactions. Procedures based on Furfine (1999, 2001) are commonly employed to separate overnight loans from all other interbank transactions.

A Furfine-based procedure classifies a pair of transactions between two banks on consecutive business days as an overnight loan if the amount transferred on a day, Out_t, is a round number and the amount returned on the subsequent day, In_{t+1}, equals the transferred amount plus an amount that may be considered a payment for accrued overnight interest rates. It is common to require the transferred amount to be a round number as banks do not usually borrow in non-round lots; cf. Furfine (2001).

Specifically, a pair of interbank transactions indicated by i is associated with an overnight loan if the amount transferred from bank j on day t, $Out_{i,j,t}$, is a round number (e.g. in millions of NOK) and the derived interest rate ($\hat{r}_{i,j,t}$):

$$\hat{r}_{i,j,t} = \left(\frac{In_{i,j,t+1}}{Out_{i,j,t}} - 1 \right) \times 365, \tag{1}$$

lies within a predefined band. The width of the band depends on what is considered to be a reasonable variation in interbank interest rates. It is also common to restrict $(100 \times \hat{r})$ to a value rounded to one or two decimal places. The transferred amount $Out_{i,j,t}$ will be considered an overnight loan from bank j, $\hat{l}_{i,j,t}$, if it satisfies the above criteria.

Using derived overnight interest rates on all identified loans on a given day, a value-weighted average interest rate can be computed as an indicator of market-level overnight interest rates. Derived interest rates are weighted with the value of the associated loans relative to the total value of all loans on a given day.

In general terms, settlement data used in Furfine-based procedures have two main limitations. First, such data sets do not (explicitly) reveal whether the overnight transaction has been initiated by the sending or receiving bank. It is therefore not known whether inferred interest rates are overnight deposit interest rates or overnight lending interest rates. And second, such data sets do not reveal whether a bank is transacting on its own behalf or on the behalf of other banks for whom it is a correspondent bank. In particular, foreign banks that do not have access to the settlement system of the local central bank and the associated liquidity facilities may only participate in an interbank market through their local correspondent banks. In the settlement data, such loans would appear as transactions between local banks and thereby lead to an overestimation of loans between the local banks. This could especially be the case for relatively large banks that act as correspondent banks for e.g. foreign banks.

2.1 Interbank loans and interest rates in the RTGS data

To infer overnight interbank loans and interest rates in Norway, we study all gross transactions settled in Norges Bank's RTGS system over our sample period. All banks established in Norway, including branches and subsidiaries of foreign banks, have access to the central bank's RTGS system. While more than 140 banks have access to this system, between 25 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 Norges Bank's RTGS system.

From the RTGS system, we extract a record of 254 906 interbank transactions over the period 1 October 2011 to 31 July 2012, covering 260 business days. While applying the Furfine algorithm to these interbank transaction data, we only consider values of derived interest rates ($\hat{r}$s) on a day t that are round numbers at the second decimal and lie between $i^b_{cb} - 0.10$ and $\text{NIBOR}_{t-1} + 0.10$. The variable i^b_{cb} denotes Norges Bank's overnight deposit rate, which is the key policy rate, while NIBOR_{t-1} refers to the tomorrow-next (T/N) rate the preceding day (for delivery 'tomorrow' and repayment the 'next' day); see Equation (1). That is, we allow possible interest rates to fluctuate within an interest rate band of between 10 basis points below the key policy rate and 10 basis points above NIBOR.[4] The width of the band implied by the choice of 10 basis points is based on our conversations with market participants, and the findings in Akram and Christophersen (2013). The width is also in line with our observations of the NOWA rate whose lowest value in our sample is 7 basis points below the key policy rate. The chosen band-width seems sufficient to take into account interbank loans on behalf of foreign banks, loans below the key policy rate resulting from the (overnight deposits) quota system employed by Norges Bank, and loans with a rate higher than the (trimmed) average ask rate of the banks in the NIBOR panel, i.e. NIBOR, which can exceed the central bank overnight lending

[4] As we use the NOWA-reports to assess the reliability of the Furfine algorithm, we specify the parameters in the algorithm using NIBOR rather than NOWA to avoid influencing the reliability of the algorithm.

rate.

Using the interest rate band specified above, the algorithm classifies 3106 interbank transactions as overnight interbank loans. That constitutes 1.2% of total interbank transactions over the sample period. About 76% of the total transactions considered to be overnight loans, i.e. 2344, are ascribed to the 11 banks in the NOWA panel.[5]

However, the relatively small share of interbank transactions classified as overnight unsecured interbank loans in the NOK market can also include some interbank loans through the foreign exchange swap market.[6] Whether loans through the swap market are among these transactions depends on whether such loans are repaid in one or more than one return transactions. To identify interest rates, the algorithm requires that a loan is paid back in one return transaction in NOK that includes the borrowed amount and the accrued interest.[7]

3 The NOWA rate

Since 29 September 2011, 11 banks in Norway have reported their unsecured overnight loans and overnight lending rates daily to Norges Bank. These banks have reported

[5]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.

[6]Our data set does not allow us to identify transactions which are part of foreign exchange swaps. However, the share of such transactions is likely to be negligible. First, as we are only concerned about overnight trades in NOK, our data set is restricted to transactions where interest rates are round numbers at the second decimal. While overnight loans in NOK would comply with this requirement, it is unlikely that the NOK transactions of foreign exchange swaps would do so since the derived rates would represent the interest rate difference between the two currencies, corrected for the currency forward price. And second, if a considerable number of foreign exchange swaps were present in the sample, we would have observed a larger degree of overprediction of volume and underprediction of interest rates for banks which are active in the foreign exchange swap market (i.e. the algorithm would consistently overpredict volumes and underpredict rates for those banks). This is not the case in our data set.

[7]For example, a bank can at time t borrow USD $\frac{1}{S^b}$ and sell it to obtain NOK 1. If a bank already possesses USD, it may obtain NOK through the FX swap without first borrowing USD. 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 funds 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). To identify interest rates, the procedure used requires that a loan is paid back with a single return transaction in NOK that includes the borrowed amount and the accrued interest. Hence, it would be able to capture the interest rate involved in the latter case, but not in the first case as there would be more than one return transaction involved.

their total overnight loans and the associated loan-weighted average interest rate to Norges Bank daily after the Norwegian interbank market closes.[8] It is required that loans and interest rates must have been set in agreements concluded by banks, either directly or via a broker. These loans must represent solely own lending and not be on behalf of any financial or non-financial customer. Moreover, the loans must have been paid out on the day of the agreement with repayment the following banking day.[9] Banks included in the panel have to be active in the Norwegian interbank market and regularly offer unsecured loans in NOK in this market.

The Norwegian Overnight Weighted Average interest rate, NOWA, is calculated by Norges Bank every business day as an average of the (loan-weighted average) reported interest rates. NOWA is calculated when data is available from at least three banks and their total reported loan volume is at least NOK 250 million. NOWA is estimated as an unweighted average of estimated overnight interest rates if these conditions are not fulfilled. These estimates are provided by selected panel banks. This happened 12 times during our sample period.

Specifically, daily loan volume for a bank j, $L_{j,t}$, its weighted lending rate ($r_{j,t}$) and the market lending interest rates, NOWA (r_t), may be defined as:

$$L_{j,t} = \sum_{i=0}^{I_{j,t}} l_{i,j,t} \tag{2}$$

$$r_{j,t} = \sum_{i=1}^{I_{j,t}} \frac{l_{i,j,t}}{L_{j,t}} r_{i,j,t} \tag{3}$$

$$r_t = \sum_{j=1}^{J_t^N} \frac{L_{j,t}}{L_t} r_{j,t} \tag{4}$$

where $L_t = \sum_{j=1}^{J_t^N} L_{j,t}$ defines the daily sum of all loans (daily turnover) and $0 \leq J_t^N \leq 11$ indicates the number of overnight lenders on day t in the NOWA bank

[8] Loans smaller than NOK 25 million may be excluded from the calculations. The Furfine algorithm finds 41 loans below NOK 25 million among the sample of 2344 loans identified as originating among the 11 NOWA banks. These loans are retained in the sample.

[9] If a panel bank has been unable to report actual interest rates, it can occasionally be requested to submit an estimate of the interest rate at which it would be willing to issue loans. This can be the case if an insufficient number of panel banks has reported overnight trading for Norges Bank to calculate the NOWA rate.

panel. Subscript i refers to an overnight loan while $I_{j,t}$ denotes the total number of such loans by bank j on day t; j = 1, 2, 3,...,J^N. Values of individual loans ($l_{i,j,t}$) and associated overnight interest rates ($r_{i,j,t}$) are not reported by the banks, only their total daily loan volumes ($L_{j,t}$) and loan-weighted overnight interest rates ($r_{j,t}$). Norges Bank uses the reported information to derive and publish NOWA (r_t) daily.

We have been granted access to information submitted to Norges Bank by the NOWA panel banks over the period 1 October 2011 to 31 July 2012. The NOWA panel has consisted of the same 11 banks over this period. Some of these banks are branches or subsidiaries of foreign banks. The banks also vary substantially in terms of their size (total assets). Some of the banks act as correspondent banks for their customer banks. The considerable heterogeneity in the panel of NOWA banks enables us to investigate whether the reliability of the algorithm varies with banks' characteristics.

The next section evaluates the reliability of the Furfine algorithm by comparing daily loan volumes ($L_{j,t}$), turnover (L_t) and loan-weighted overnight interest rates ($r_{j,t}$) reported by NOWA panel banks and values of NOWA (r_t) published by Norges Bank with estimates of these variables based on the algorithm ($\widehat{L}_{j,t}$, $\widehat{L}_t$, $\widehat{r}_{j,t}$ and $\widehat{r}_t$). The latter estimates are obtained by aggregating the algorithm-based values of individual loans and corresponding interest rates for the 11 NOWA panel banks.

4 Empirical analysis

We use the Furfine algorithm to derive daily values of individual loans ($\widehat{l}_{i,j,t}$), associated overnight interest rates ($\widehat{r}_{i,j,t}$), the daily number of such loans by each of the banks ($\widehat{I}_{j,t}$), the total number of banks involved in overnight lending on a day ($\widehat{J}_t$) and the number of NOWA panel banks among these ($\hat{J}_t^N$); j = 1, 2, 3,...,$\hat{J}_t^N$,...,$\widehat{J}_t$.[10] The derived values of these variables are then used to estimate the daily turnover of each bank ($\widehat{L}_{j,t}$) and its loan-weighted average overnight lending rate ($\widehat{r}_{j,t}$). Finally, we calculate total daily turnover by NOWA panel banks ($\widehat{L}_t$) and the loan-weighted

[10] An open-source implementation of the Furfine algorithm which has been developed as part of this project is available on http://code.google.com/p/financial-network-analyzer/.

average overnight interest rate as an estimate of NOWA ($\widehat{r}_t$); These calculations are based on j = 1, 2, 3,...,$\hat{J}_t^N$.

The algorithm identifies 24 banks as participants in the overnight interbank market over the whole sample period. This is comparable to the number of banks found to be active in the overnight interbank market over the period August 2006–November 2009 by Akram and Christophersen (2013). All banks in the NOWA panel are among the market participants identified by the algorithm. Market shares of (derived) overnight lending of all interbank market participants over the sample period suggest that the 11 banks in the NOWA panel have accounted for about 93% of overnight lending during the sample period.

In the following section (4.1), for each of the NOWA panel banks, we compare measures of their overnight lending based on the Furfine algorithm with those based on their NOWA reports to Norges Bank. Overnight interest rates at both the market and bank level are analysed in Section 4.2, while the accuracy of the algorithm on lower than daily frequencies is assessed in Section 4.3. Section 4.4 investigates a possible relationship between measures of the reliability of the Furfine algorithm and selected bank characteristics. The appendix summmarises the predictability of the Furfine algorithm in terms of Root Mean Square (prediction) Errors (RMSEs).

4.1 Overnight interbank lending

Figure 1 compares monthly aggregates of overnight interbank loans for the NOWA panel banks identified by the Furfine algorithm (NOWA-F loans) with those based on their daily reports (NOWA loans). The aggregated loan volumes based on the algorithm are comparable to those based on the NOWA reports over the sample period. However, the algorithm overpredicts actual lending in 8 of the 10 months in our sample. Such overprediction (NOWA-F loans - NOWA-loans ≥ 0) is in line with the presumption that the algorithm may also identify loans on behalf of other banks and non-banks, while such loans have to be left out in the NOWA reports. There does not, however, seem to be a relationship between the extent of overprediction and actual loan volumes.

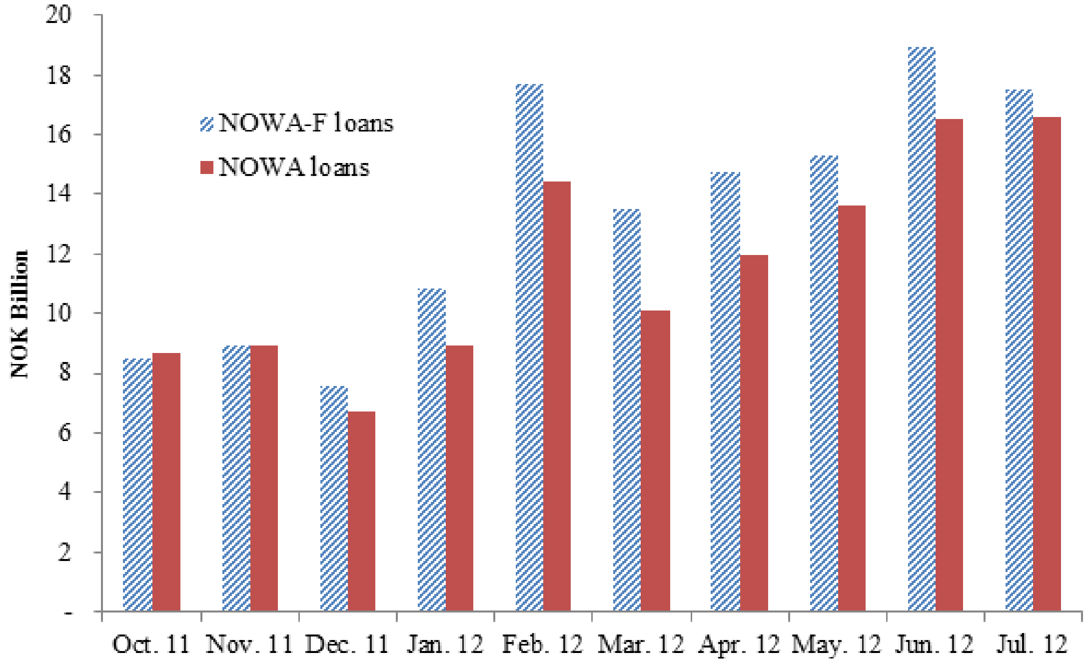

Figure 1: *Monthly value of all overnight loans by the 11 NOWA panel banks identified by the Furfine algorithm (NOWA-F loans) and monthly values of overnight loans by these banks based on their reports of actual lending submitted to Norges Bank (NOWA loans). Here and elsewhere in this paper, results are based on data from 1 October 2011 to 31 July 2012.*

Table 1 measures the predictability of the Furfine algorithm regarding the market shares of the NOWA panel banks. Column 2 shows the misprediction of market shares to be less than 1 percentage point for all banks except for bank number (10) and (11), for which mispredictions are around 5 percentage points.[11] Differences between reported and identified overnight loans are substantial in some of the cases if measured relative to market shares (defined as $ms_j = \sum_{t=1}^{T} L_{j,t} / \sum_{t=1}^{T} L_t$ for each bank $j = 1, 2, ...11$) based on their reported lending, denoted as $\widehat{ms}_j / ms_j$ in column 3. For some lenders, the algorithm suggests up to 2.5 times larger market shares than those based on the NOWA reports.

In the following, we further examine differences in overnight lending based on the Furfine algorithm and the NOWA reports. We first consider the share of business days over the sample period when the algorithm accurately predicts lending by each individual bank (not all banks are active on all days). Table 2 presents in columns 2–5, respectively, the shares of days in our sample when both the algorithm and NOWA reports indicate lending, the shares of days when only the Furfine algorithm or only

[11]To preserve the anonymity of the banks, individual market shares are not reported.

Table 1: *Deviations between derived and reports-based market shares in overnight lending*

Bank	Difference in percentage points	$\widehat{ms}_j / ms_j$
(1)	0.03	1.12
(2)	-0.04	0.98
(3)	-0.15	0.94
(4)	-0.17	0.94
(5)	0.17	1.84
(6)	0.32	1.73
(7)	0.45	1.01
(8)	-0.73	0.85
(9)	0.83	2.52
(10)	4.46	1.33
(11)	-5.18	0.66

Note: Differences in (percentage points) are calculated by subtracting market shares of individual NOWA panel banks in percentage points from corresponding market shares based on the Furfine algorithm, i.e. $(\widehat{ms}_j - ms_j)$. The banks are sorted according to the absolute difference between $\widehat{ms}_j$ and ms_j.

the NOWA reports indicate lending and the shares of days when both the Furfine algorithm and NOWA reports suggest no lending activity. If our null hypothesis is that of no lending activity, then entries in column 3 may be interpreted as estimated probabilities of type 1 errors (false positive, T1), while those in column 4 may be interpreted as probabilities of type 2 errors (false negative, T2). The shares of correctly identified days per bank is given in column 6. Entries in this column are the sums of the shares in columns 2 and 5 and represent the shares of days when interbank participation suggested by the Furfine algorithm is confirmed by the NOWA reports.

Table 2 shows that for 9 of the 11 banks, the algorithm correctly indicates lending or no lending on at least 77% of the days; the shares of days with correct indication are in the range 77% to 96%. These 9 banks account for 82% of overnight lending over the sample period. For the two remaining banks in the NOWA panel, shares of correct indication are relatively low, 51% and 62%, respectively.

Although the algorithm performs better for some of the banks with relatively small market shares in overnight interbank lending, we have not found a clear (linear) negative relationship between a bank's size proxied by its market share and the

Table 2: *Shares of days with overnight interbank lending*

Bank	Share of days				
	Both	Furfine only (T1)	NOWA only (T2)	None	**Correct**
(1)	0.07	0.04	0.01	0.89	**0.95**
(2)	0.21	0.04	0.02	0.73	**0.94**
(3)	0.41	0.14	0.07	0.38	**0.79**
(4)	0.18	0.13	0.36	0.33	**0.51**
(5)	0.08	0.07	0.01	0.84	**0.92**
(6)	0.07	0.07	0.00	0.86	**0.93**
(7)	0.77	0.16	0.00	0.08	**0.84**
(8)	0.51	0.03	0.02	0.45	**0.96**
(9)	0.13	0.22	0.00	0.66	**0.78**
(10)	0.63	0.22	0.01	0.14	**0.77**
(11)	0.61	0.00	0.38	0.01	**0.62**

Note: Shares of days when the Furfine algorithm and NOWA reports jointly or individually suggest interbank lending or no interbank lending. T1 and T2 denote type 1 and type 2 errors, respectively, as defined in the text.

accuracy of the algorithm. The five instances of shares of days with correct indications above 90% are associated with relatively small banks, accounting for just 15% of overnight lending over the sample period. However, the smallest share of correct indication, 51%, is also associated with a relatively small bank (4) accounting for 3% of overnight lending. There is more variability in the shares of the correct indications for the relatively large banks. For the three large interbank lenders, the shares of correct indications are around 75% on average, i.e. 84%, 77% and 62%. We also note that the algorithm overpredicts lending activity for almost all of the banks, i.e. for 9 out of 11 banks (see columns 3 and 4 in Table 2). This is partly consistent with the algorithm also reflecting overnight lending on behalf of other banks than themselves.

We now examine daily turnover values for NOWA panel banks in detail. Table 3 shows the shares of days when the algorithm either overpredicts or underpredicts total daily volumes relative to NOWA reports. Lending volumes are only counted as exact if the lending predicted by the algorithm equals the actual lending volume reported. The results refer to only those days over the sample period when both the algorithm and the NOWA reports indicate overnight lending.

The second column of Table 3 shows that for 8 out of 11 banks, the algorithm

Table 3: *Over- and underprediction of volumes. Shares of days*

	Shares of days		
Bank	Exact	Overprediction	Underprediction
(1)	1.00	0.00	0.00
(2)	1.00	0.00	0.00
(3)	0.77	0.05	0.18
(4)	0.33	0.19	0.47
(5)	1.00	0.00	0.00
(6)	1.00	0.00	0.00
(7)	0.75	0.18	0.07
(8)	0.93	0.04	0.03
(9)	0.88	0.12	0.00
(10)	0.35	0.55	0.10
(11)	0.02	0.22	0.77

Note: Column 2 reports shares of the banks' lending days when daily loan volumes suggested by the Furfine algorithm are equal to those in the corresponding NOWA reports. Columns 3 and 4 show shares of the banks' lending days when the Furfine algorithm overpredicts and underpredicts, respectively, loan volumes relative to reported daily loan volumes. Calculations are based on data for those days in our sample when both the Furfine algorithm and NOWA reports indicate that a bank has been involved in overnight lending.

accurately predicts reported volumes on 75% to 100% of their lending days. The accuracy of total daily volumes is relatively low for the other three NOWA panel banks, ranging from 2% to 35%.

The third column of Table 3 shows the shares of days when the algorithm overpredicts total daily volumes relative to NOWA reports. The share of days with overprediction ranges from 4% to 55%. There does not seem to be a linear relationship between the banks' market shares of overnight lending and shares of days with overprediction.[12] Both relatively high and low shares are associated with relatively large overnight lenders.

The last column presents the share of days when volumes are underpredicted by the algorithm relative to NOWA reports. The share of days with underpredictions of volumes ranges from 0% to 77%. We have not found any obvious relationship between the share of days with underprediction and the market shares of lenders.

In sum, Table 3 suggests that the algorithm overpredicts as well as underpredicts lending volumes. It also suggests relatively large variation across banks in the

[12]To preserve the anonymity of the banks, individual market shares are not reported.

accuracy of the algorithm in identifying values of daily volumes. However, given that loan volumes on a day have been considered accurate only when the Furfine-based and reported volumes matched exactly, even negligible differences between the values of daily volumes predicted by the algorithm and NOWA reports have been considered an over- or underprediction in this table. It is therefore of interest to have a closer look at the the extent of over- and underpredictions.

Table 4: *Distributions of relative deviations in loan volumes over share of lending days*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(. , -0.5)	0.00	0.00	0.02	0.08	0.00	0.00	0.00	0.02	0.00	0.01	0.21
(-0.5, -0.25)	0.00	0.00	0.07	0.06	0.00	0.00	0.02	0.00	0.00	0.02	0.18
(-0.25, 0)	0.00	0.00	0.09	0.33	0.00	0.00	0.05	0.01	0.00	0.08	0.38
(0, 0.05)	**1.00**	**1.00**	**0.77**	**0.33**	**1.00**	**1.00**	**0.88**	**0.96**	**0.88**	**0.40**	**0.08**
(0.05, 0.1)	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.01	0.00	0.04	0.02
(0.1, 0.15)	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.02
(0.15, 0.2)	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.01
(0.2, 0.25)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
(0.25, 0.5)	0.00	0.00	0.01	0.03	0.00	0.00	0.01	0.00	0.04	0.07	0.02
(0.5, 1)	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.04	0.03	0.00
(1, .)	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.04	0.26	0.08

Note: The left column shows the ranges of deviations between overnight loan volumes based on the Furfine algorithm and NOWA reports. The entries in the other columns are shares of lending days associated with the different ranges of deviations. Calculations are based on data for those days in our sample when both the algorithm and NOWA reports indicate that a bank has been involved in overnight lending.

Table 4 presents the share of days by deviations between daily loan volumes based on the Furfine algorithm relative to those based on the NOWA reports. The table shows that overpredictions are relatively small for most of the banks. Specifically, for 8 of the banks accounting for 68% of overnight lending over the sample period, differences between predicted and reported overnight volumes are between 0 and 5% on more than 77% of the lending days (bold row). For these banks, overpredictions exceed the 0–5% range on a relatively small number of days. For two of the three remaining banks, (4) and (11), however, the algorithm underpredicts the loan volumes by up to 25% on 33% and 38% of their lending days, respectively. For the one remaining bank, (10), the overprediction is up to 5% on 40% of its lending days, and more than 100% on 26% of its lending days (see the bottom row). The remaining 34% of its lending days are distributed over under- and overpredictions in the range of –50% to 100%.

4.2 Overnight interest rates

This section examines the reliability of the Furfine algorithm in predicting actual overnight interest rates at the market and bank level. Overnight loan-weighted actual interest rates, NOWA, are used as reference rates for overnight interbank interest rates at the market level.

We find that the average loan-weighted average interest rate for the NOWA panel banks derived using the algorithm is remarkably close to NOWA over the sample period. Figure 2 shows the value-weighted average overnight interest rate based on the algorithm, $\widehat{r}_t$ (NOWA-F), and the reported rate, r_t (NOWA). The two overnight interest rate series follow each other closely over most of the sample period. The average difference between $\widehat{r}_t$ and r_t over the sample period is –1.2 basis points, while the average absolute difference between the two series is 1.4 basis points. There are, however, a few relatively large deviations between $\widehat{r}_t$ and r_t. The range of deviations is up to around 15 basis points on these occasions. Values of $\widehat{r}_t$ are by construction less volatile than corresponding NOWA values given that particularly large potential interest rate values, i.e. values exceeding NIBOR_{t-1} + 10 basis points, have been left out by assumption (see Section 2.1).

Table 5 describes how differences between values of $\widehat{r}_t$ and r_t are distributed over different days over the sample period. It shows that on 48% of the days, the difference between $\widehat{r}_t$ and r_t was less than one basis point. It was less than two basis points on 72% of the days in our sample, and less than ten basis points on 98% of the days.

Table 5: *Share of days by (absolute) difference between $\widehat{r}_t$ and r_t*

Share of days			
$0 < d < 1$	$1 < d \leq 2$	$2 < d \leq 10$	$10 < d$
0.48	0.24	0.26	0.02

Note: d = $|\widehat{r}_t - r_t|$ in basis points. Shares of days are based on 198 lending days over the period 1 October 2011 to 31 July 2012.

At the bank level, however, derived value-weighted interest rates for each of the NOWA panel banks have been found to deviate by up to 23 basis points from those

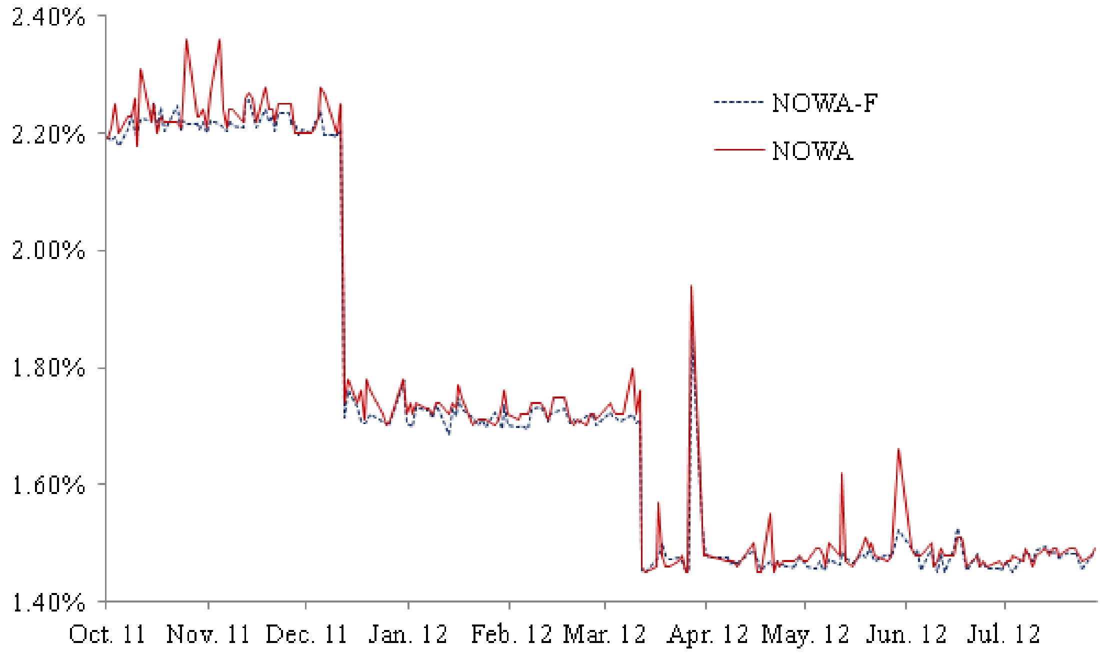

Figure 2: *Overnight interbank interest rates based on the Furfine algorithm, NOWA-F ($\widehat{r}_t$), and NOWA reports (r_t). Daily observations over the period 1 October 2011 to 31 July 2012.*

in their NOWA reports. Nevertheless, for 8 of the 11 NOWA panel banks, deviations between the overnight interest rates based on the algorithm and the NOWA reports are negligible on at least 78% of their lending days. The details are as follows.

Table 6: *Differences between identified and reported average interest rates*

Bank (j)	No difference	$\widehat{r}_{j,t} > r_{j,t}$		$\widehat{r}_{j,t} < r_{j,t}$	
	Share (days)	Share (days)	Avg. diff.	Share (days)	Avg. diff.
(1)	1.00	0.00		0.00	
(2)	1.00	0.00		0.00	
(3)	0.78	0.04	1.60	0.18	-8.68
(4)	0.39	0.14	2.65	0.47	-4.75
(5)	1.00	0.00		0.00	
(6)	1.00	0.00		0.00	
(7)	0.86	0.11	1.64	0.03	-0.95
(8)	0.99	0.01	5.30	0.00	
(9)	0.88	0.04	4.93	0.08	-2.17
(10)	0.60	0.10	5.38	0.31	-4.31
(11)	0.08	0.41	23.13	0.51	-6.90

Note: Column 2 reports share of days when overnight rates based on the algorithm and the NOWA reports do not differ by more than 0.5 basis point in absolute terms, defining 'No difference' as cases where $|\widehat{r}_{j,t} - r_{j,t}| < 1/2$ bp. Column 3 shows share of days when interest rates based on the algorithm exceed those based on the NOWA reports while the 4th column presents averages of such overpredictions. The 5th and the last column present such results for underpredictions of interest rates. Calculations are based on data for those days in our sample when both the Furfine algorithm and NOWA reports indicate that a bank has been involved in overnight lending.

Table 7: *Distributions of interest rate deviations over share of lending days*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(0, 0.5)	**1.00**	**1.00**	**0.78**	**0.39**	**1.00**	**1.00**	**0.86**	**0.99**	**0.88**	**0.60**	**0.08**
(0.5, 2)	0.00	0.00	0.07	0.25	0.00	0.00	0.10	0.00	0.04	0.15	0.23
(2, 4)	0.00	0.00	0.07	0.14	0.00	0.00	0.04	0.00	0.04	0.09	0.13
(4, 6)	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.01	0.04	0.05	0.13
(6, 8)	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.06	0.05
(8, 10)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
(10, 12)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
(12, 14)	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.04
(14, 16)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
(16, 18)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
(18, .)	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.26

Note: The first column shows the ranges of deviations between overnight rates based on the Furfine algorithm and NOWA reports. The entries in the other columns are shares of lending days associated with the different ranges of interest rates deviations. Calculations are based on those days when both the algorithm and NOWA reports indicate that a bank has been involved in overnight lending.

To investigate possible differences between interest rates based on the algorithm and NOWA reports for each of the banks, we restrict our sample to those days when both the algorithm and NOWA reports indicate that a given bank has participated in the overnight interbank market. Table 6 presents differences between derived and reported average interest rates per bank. The second column shows the share of days with "no difference", which is defined as a difference of less than half a basis point. We note that even for those banks where the algorithm overpredicts volume, the average daily interest rate tends to be relatively close to the reported one (see columns 3 and 4). For 8 out of the 11 banks, there is no difference on at least 78% of their lending days. Moreover, 10 out of 11 banks accounting for 85% of overnight lending do not overpredict overnight rates by more than 5 basis points on average. For these banks, the algorithm overpredicts overnight rates on at most 14% of their lending days. For the 11th bank, however, the overprediction occurs on 41% of its lending days and by up to 23 basis points on average.

The remaining two columns (5 and 6) of Table 6 show statistics for those lending days when derived overnight rates are lower than in the NOWA reports. Except for two cases, the share of days with underpredictions is larger than the share of days with overpredictions. In all cases, however, the algorithm does not underpredict by more than 9 basis points on average. For the bank with the highest share of underpredictions (51%), the underprediction is 7 basis points on average.

Table 7 shows distributions of deviations between interest rates based on the algorithm and the NOWA reports over shares of lending days in the sample. For 8 out of the 11 banks, the difference is less than half a basis point on at least 78% of their lending days. The difference between the derived and reported overnight rates is less than half a basis point for the banks with relatively small shares of interbank loans on all of their lending days. In contrast, for the major lenders accuracy varies more. However, evidence does not suggest that the reliability of the algorithm deteriorates with the overall lending activity of a bank in the interbank market. Overall, the algorithm seems to derive interest rates relatively close to those based on NOWA reports for most of the NOWA panel banks. For one of these banks, however, the difference between derived and reported overnight rates is more than 10 basis points on more than one third of its lending days.

4.3 Accuracy of the Furfine algorithm in aggregate data

The analysis above suggests that Furfine-based results can be more reliable at aggregate levels than at the level of individual banks or days; cf. Figures 1 and 2. In the following, we further investigate the predictability of the Furfine algorithm for aggregated (derived) overnight lending and interest rates across banks and over time. Such an evaluation may be informative about the reliability of Furfine-based measures at market level and e.g. weekly or monthly frequency compared with those at the business day frequency for individual banks.

Table 8 presents the sample averages of the absolute differences between Furfine-based and reported volumes and interest rates at the (business) daily, weekly (5-day) and monthly (20-day) frequencies.[13] The table suggests that results based on the Furfine algorithm are likely to be more reliable if derived values of overnight interest rates and loans are aggregated over time. For example, while the sample average of

[13]Table 8 aims to establish the effects of aggregation over time. As not all banks are active on all days, however, we define 5 days and 20 days as the period of 5 and 20 consecutive days, respectively, after days without strictly positive lending have been disregarded for individual banks. The aggregation of interest rates is based on values of interest rates as deviations from the key policy rate, as the 5- and 20- day sample may overlap with a change in the key policy rate.

Table 8: *Differences between $\widehat{r}$ and r when aggregated over time*

	Interest rates (bp)			Volumes (percent of NOWA reporting)		
	Daily	5 days	20 days	Daily	5 days	20 days
Market	1.22	0.90	0.63	20 %	16 %	17 %
(1)	0.00	0.00	NC	0 %	0 %	NC
(2)	0.00	0.00	0.00	0 %	0 %	0 %
(3)	1.10	0.85	0.52	8 %	8 %	5 %
(4)	0.62	0.79	0.52	10 %	10 %	2 %
(5)	0.01	0.01	NC	0 %	0 %	NC
(6)	0.00	0.00	NC	0 %	0 %	NC
(7)	0.30	0.27	0.24	2 %	2 %	1 %
(8)	0.04	0.03	0.02	1 %	1 %	1 %
(9)	0.80	0.41	0.17	38 %	37 %	37 %
(10)	0.47	0.63	0.44	26 %	64 %	28 %
(11)	4.84	3.10	2.35	21 %	21 %	19 %

Note: We define 5 days and 20 days as the period of 5 and 20 consecutive days, respectively, after days without strictly positive lending have been disregarded for individual banks over the sample period. 'NC' denotes that it was not meaningful to aggregate up to 20 days. The aggregation of interest rates is based on values of interest rates as deviations from the key policy rate, as the 5 and 20 days sample may overlap with a change in the key policy rate.

daily absolute differences between derived and reported NOWA rates, $\widehat{r}_t$ and r_t, is 1.22 basis points, it is 0.90 and 0.63 basis points when we take sample averages based on rolling samples of 5 and 20 days, respectively. A similar pattern is observed for (loan-weighted average) overnight lending rates of each of the NOWA panel banks. For overnight lending volumes, the results are more nuanced, however. While the Furfine-based overnight volumes at the monthly frequency tend to deviate less from corresponding volumes based on the NOWA reports, there is not much difference between the reliability of the Furfine algorithm at the daily and weekly frequencies. We also observe that for bank number (10), the reliability of the Furfine algorithm does not increase with temporal aggregation.

Aggregation of Furfine-based observations of interest rates and lending volumes across banks, however, does not generally increase the reliability of the Furfine-based results when compared to individual bank results for most of the banks. For example, in Table 8 the average of absolute deviations between the estimated rates, $\widehat{r}$, and NOWA (r), referred to as 'Market', are higher than corresponding deviations for overnight interest rates for 10 out of the 11 NOWA panel banks. In the case of lending volumes, absolute deviations between Furfine-based aggregate volume and that based on NOWA reports are higher than those for 8 out of the 11 NOWA panel banks. One possible explanation is that particularly large (average) deviations associated with even one bank can contribute to increase the aggregate deviation. Less reliable Furfine-based results may therefore be found at the aggregate level than at the bank level for many banks. It is therefore useful to investigate whether some bank characteristics can be associated with a higher reliability of the Furfine algorithm.

4.4 Interest rate deviations and bank characteristics

In the following, we first test whether mispredictions, i.e. deviations between derived and reported overnight rates, for the different NOWA panel banks are statistically significant. We then investigate whether possible mispredictions can be associated with selected bank characteristics.

Table 9: *Average size of mispredictions*

	Average		Std. dev
Pooled	0.62	*	0.34
(1)	0.00		0.00
(2)	0.00		0.00
(3)	-1.53		1.08
(4)	-1.88	**	0.75
(5)	0.00		0.00
(6)	NE		NE
(7)	0.17	***	0.05
(8)	0.04		0.05
(9)	0.02		0.25
(10)	-0.79	**	0.34
(11)	5.93	***	1.81

Note: Column 2 reports average size of deviations between overnight rates based on the Furfine algorithm and NOWA reports and the associated standard deviations. ***, ** and * indicates significance at the 1%, 5% and 10% level, respectively. The estimates are based on observations for those days when both the Furfine algorithm and NOWA-reports indicate that a bank has been involved in overnight lending. The data sample is from 1 October 2011 to 31 July 2012.

We find that the average sizes of the mispredictions are less than 2 basis points in all, except in one case where it is 5.93 basis points and statistically significant.

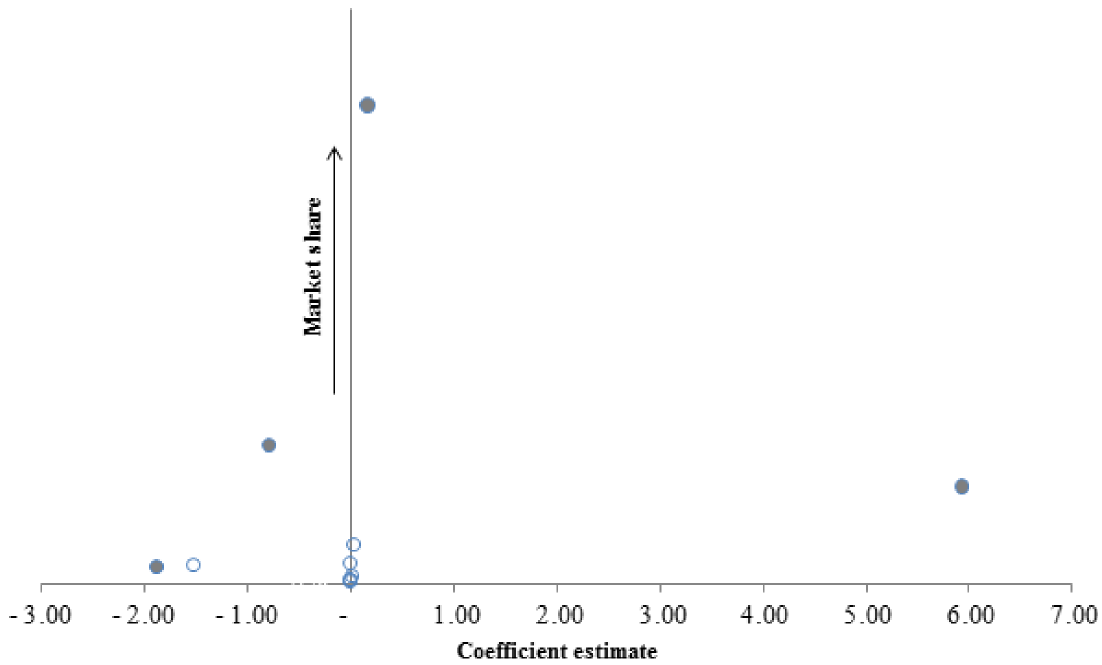

Figure 3: *A cross plot of average sizes of deviations (as reported in Table 9) against shares of overall daily loan volumes of NOWA panel banks (market shares). A filled circle implies significance at least at the 10% level (see Table 9). To maintain the anonymity of the banks, the values of the market shares are not reported.*

In detail, Table 9 shows results based on regressing differences between derived and reported overnight rates on intercept terms. The first row reports results for all of the banks by estimating the relationship by pooled OLS. The pooled result suggests that, overall, the algorithm overpredicts the derived rate by 0.62 basis point, which is significantly different from zero only at the 10% level of significance. The results in the remaining rows for the individual banks suggest overpredictions as well as underpredictions, i.e. both positive and negative values of average deviations, by the Furfine algorithm. For most of the banks, the average deviations are numerically and statistically close to zero. For two of the banks, the average deviations are significantly different from zero at the 1% level of significance. Numerically, however, one of these average deviations is close to zero (0.17 basis point) while the second one is close to 6 basis points. We also note that for two of the other banks the average deviations are significantly different from zero at the 5% level. Numerically, these are about 1 and 2 basis points.

Three of the four average deviations that are statistically significant (at least) at the 5% level of significance are associated with banks that have relatively high market shares of overnight lending. However, we have not observed any clear relationship between the numerical values of the estimates and market shares (see Figure 3). For example, the average deviation of 0.17 basis point, which is statistically significant even at the 1% level, is associated with a bank that has a relatively high market share of overnight lending over the sample period.

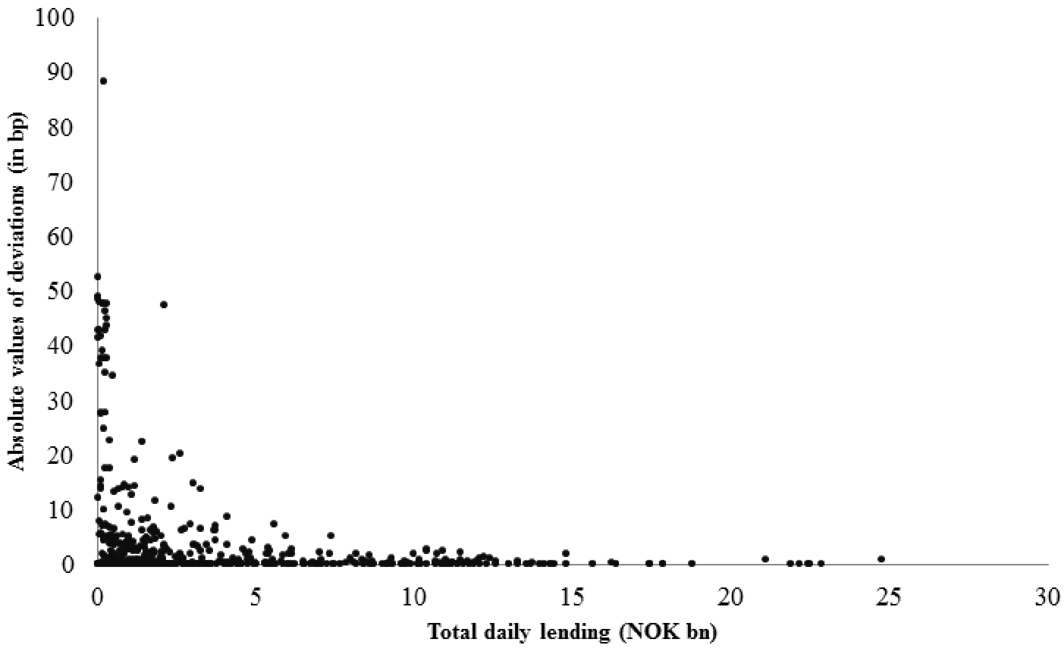

Figure 4: *A cross plot of deviations (in absolute values) between overnight rates based on the Furfine algorithm and NOWA reports against their total daily lending.*

Scatter plots in Figures 4–5 suggest a negative relationship between absolute values of deviations between derived and reported interest rates and total overnight lending. Figure 5 displays cross plots for the four banks for which there are statistically significant deviations between derived and reported interest rates at least at the 5% level of significance. The cross plots suggest that relatively low absolute values of the deviations tend to be associated with relatively high total overnight lending by banks. This is also supported by the multivariate regressions analysis in Table 10, where absolute values of interest rate deviations for the different banks have been regressed on their total daily lending, size and home-country affiliation.

Such an inverse relationship may be explained in the light of the law of large numbers. Large values of total daily lending would usually be on days with a relatively large number of overnight loans. Hence, (value-weighted average overnight)

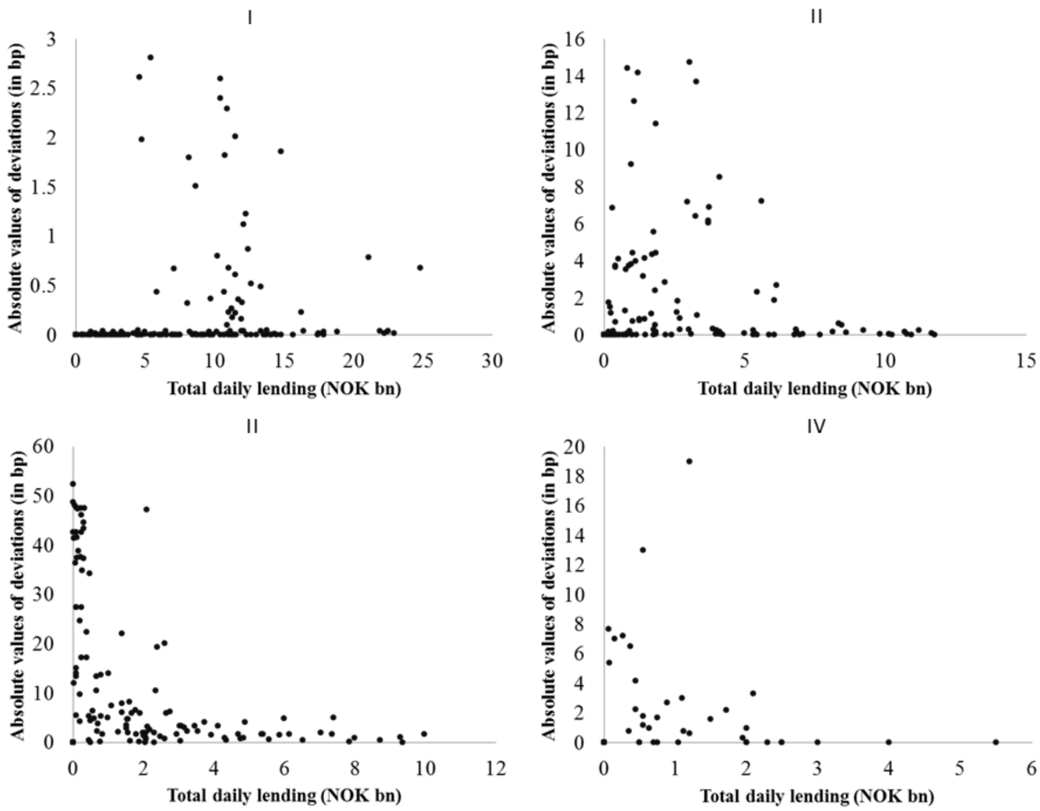

Figure 5: *Cross plots of deviations (in absolute values) between overnight rates based on the Furfine algorithm and NOWA reports against their total daily lending. The four cross plots refer to the four banks ((4), (7), (10) and (11)) with statistically significant average deviations (mispredictions) at the 10% level.*

interest rates reported by banks are likely to be based on a relatively large number of associated interest rates and thereby less influenced by some atypical values of interest rates. The number of interest rates derived using the Furfine algorithm are also likely to be relatively large on these days owing to the observed correlation between interbank activity revealed by the algorithm and the NOWA reports (see Table 2). The corresponding value-weighted average of derived interest rates would therefore probably be based on a relatively large number of derived interest rates. It is therefore reasonable to expect that possible deviations between derived and reported (value-weighted average) interest rates would be smaller on days with relatively high total lending than on days with relatively low total lending.

Table 10 tests for the presence of a negative relationship between the (absolute) size of deviations between derived and reported values of overnight rates and banks' daily lending. It also tests whether the size of deviations varies with a bank's size

Table 10: *Interest rate deviations and bank characteristics*

Bank characteristic	Coefficient	
Daily lending	-2.74	***
	(0.35)	
Size (assets)	2.17	***
	(0.26)	
Domestic bank	-7.34	***
	(0.90)	
Observations	723	
Adjusted R-squared	0.28	

Note: The linear model has been estimated by pooled OLS using data for days when both the Furfine algorithm and NOWA reports suggest overnight lending by a NOWA panel bank. *** indicates significance at the 1% level. Robust standard errors (White) are presented in the parentheses below the average deviations.[14]

and whether it is a domestic bank or branch or subsidiary of a foreign bank. The results suggest that (absolute) deviations between derived and reported overnight rates decline significantly with the value of the total daily lending of all NOWA panel banks. The results also suggest that deviations between derived and reported rates associated with domestic banks tend to be lower than those associated with branches and subsidiaries of foreign banks. However, deviations between derived and reported interest rates tend to increase with the size of banks as measured by their total assets. This is consistent with the Furfine algorithm also including overnight lending by relatively large banks on behalf of their customer banks, while the NOWA reports explicitly exclude such overnight lending.

5 Conclusions

Using a novel Norwegian data set, we have investigated to what extent interbank payments data can provide reliable information about interbank overnight loans and interest rates at the market and bank levels. We find that market level indicators of overnight interbank loans and lending rates based on the Furfine algorithm are fairly reliable. There are, in general, relatively small positive deviations between measures of overnight lending based on the Furfine algorithm and those based on reported interbank lending by a panel of 11 banks (NOWA reports). Such an upward bias in the estimates of overnight lending is consistent with the Furfine algorithm including overnight lending by relatively large banks on behalf of their customer banks in contrast to the NOWA reports which explicitly exclude such overnight lending. The loan value-weighted average overnight interest rate for the 11 NOWA panel banks (NOWA) and the corresponding rate based on the Furfine algorithm follow each other closely over the sample period. On average, there is a one basis point difference between NOWA and the corresponding interest rate based on the Furfine algorithm.

At the bank level, however, the Furfine algorithm is less reliable for identifying banks' participation in the overnight interbank market, overnight lending and value-weighted overnight interest rates. The algorithm has provided fairly reliable results for 8 of the 11 NOWA panel banks, accounting for 68% of overnight lending during the sample period. That is, on at least 77% of these banks lending days, overnight lending for each of these 8 banks do not exceed those given in their NOWA reports by more than 5% while their overnight interest rates do not deviate by more than half a basis point. On the remaining days, however, lending volumes can deviate from those in the NOWA reports by up to about 100%. However, interest rates do not deviate by more than 6 basis points on any of the days in the sample. For the remaining 3 of the 11 NOWA panel banks, the Furfine algorithm is not informative about overnight lending volumes, as the deviations are distributed over relatively wide ranges. For overnight interest rates, however, the results are somewhat more informative. For these banks, most deviations from the respective overnight rates in the NOWA reports are in the range of 0 to 2 basis points, while the maximum deviation can be up to about 23 basis points.

The reliability of the algorithm has been found to increase with temporal aggregation of derived values of overnight interest rates and loans. Accordingly, weekly and monthly aggregates of derived values of overnight interest rates and loans are in general more reliable than corresponding daily values.

Our results also suggest that the Furfine algorithm may provide more reliable results for relatively small overnight lenders than for relatively large overnight lenders. Two of the banks for which the algorithm has performed poorly are the second and third largest interbank overnight lenders in our sample. The algorithm has also provided more reliable results for domestic banks than for foreign branches and subsidiaries, which tend to more active as correspondent banks than domestic banks.

In sum, our results are fairly encouraging regarding the reliability of the Furfine algorithm for the relatively small Norwegian interbank bank market. However, further investigations based on data from interbank markets in other countries as well as for longer time periods are required to shed further light on the reliability of the Furfine algorithm under various market conditions.

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Appendix: Predictability of the Furfine algorithm

The ability of the Furfine algorithm to identify overnight interbank loans and interest rates of the different banks can be summarized by corresponding values of the Root Mean Square prediction Errors (RMSEs). Table 11 reports RMSE statistics of overnight loan values and interest rates at the daily frequency. Overall, the RMSEs for the loan volumes and interest rates are close to zero for about half of the NOWA panel banks. Such high predictability for loan volumes tends to go together with particularly high predictability in overnight interest rates. On the other hand, there is no obvious relationship between RMSE values for loans and interest rates, for banks with non-zero values of RMSEs. For one of the banks (11), the performance of the Furfine algorithm for identification of overnight interest rates is quite poor, as indicated by the relatively high value of the RMSE for overnight interest rates: 20.6. The poor results for this particular bank is in line with results presented earlier. The corresponding value of the RMSE for overnight loans is third highest, 0.64, among the 11 banks.

Figure 6 shows a cross plot of the NOWA panel banks' market shares in overnight lending against the performance of the Furfine algorithm in identifying overnight interest rates of these banks as measured by their RMSE values. We do not observe an obvious relationship between the market shares of the banks and the RMSE values.

Table 11: *Summarising mispredictions via RMSEs*

	RMSE volume in % of average daily lending	RMSE rate in basis points
(1)	0.00	0.00
(2)	0.00	0.01
(3)	0.22	9.83
(4)	0.53	4.80
(5)	0.00	0.01
(6)	0.00	0.00
(7)	0.08	0.63
(8)	0.06	0.53
(9)	1.60	1.23
(10)	0.47	3.86
(11)	0.64	20.60

Note: RMSE statistics for daily loan values are provided in percent of average daily lending to preserve the anonymity of the banks. Volume in NOK million and rates in basis points. Calculations are based on data for those days in our sample when both the Furfine algorithm and NOWA reports indicate that a bank has been active in overnight lending.

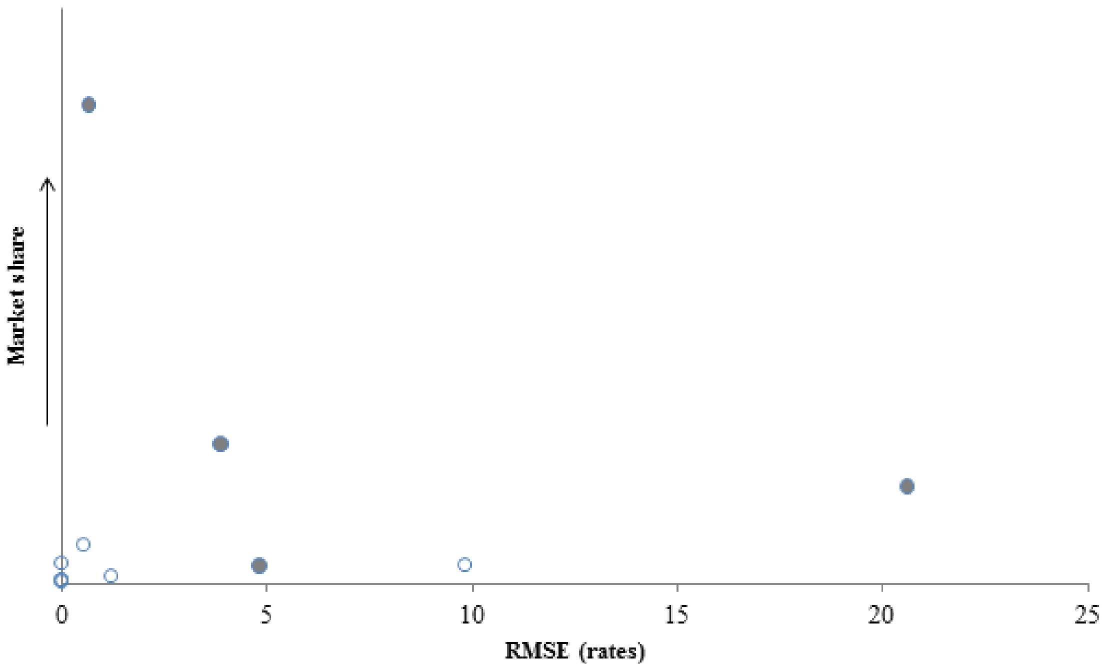

Figure 6: *A cross plot of Root Mean Square (prediction) Errors (RMSEs) of overnight rates based on deviations between overnight rates predicted by the Furfine algorithm and those based on the NOWA reports against share of overall daily loan volumes of NOWA panel banks (vertical axis). A filled circle implies that mispredictions as provided in Table 9 are significant at least at the 10% level. To maintain the anonymity of the banks, individual market shares in overnight lending are not reported.*