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Identification of interbank loans and interest rates from interbank payments - A reliability assessment

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Abstract

We investigate the reliability of the 'Furfine filter' often used to identify interbank loans and interest rates from interbank payments settled at central banks. To this end, we have been granted access to records of all unsecured overnight interbank loans during a month from the banks that participated in Norges Bank's real-time gross settlement system. The filter applied was able to identify each of these loans and correctly derive the associated interest rates. The filter's reliability is also supported by additional evidence based on the Norwegian Overnight Weighted Average (NOWA) interest rates beyond the survey month. Sensitivity analyses suggest the share of false or overlooked loans may remain small if the filter design largely incorporates interbank market conventions regarding loan size requests and interest rate quotes.

Keywords: Overnight interbank market, Furfine-algorithm, RTGS.

JEL Codes: *C63, G21, E43, E58.*

*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 are thankful to colleagues especially Bjørn Bakke, Marie Lerbak and Kjetil Watne for useful comments and discussions.

1 Introduction

A well functioning interbank market contributes to an efficient distribution of central bank liquidity conducive to timely banking transactions. It is also important for the transmission of monetary policy rates to various interest rates prevailing in the economy. Information on interbank loans and interest rates helps assess liquidity demand relative to supply and points to possible frictions limiting interbank lending overall or to specific banks.

However, information on actual interbank loans and interest rates is generally not available as loan terms are agreed upon bilaterally between borrowing and lending banks or through brokers.[1] Many central banks therefore infer interbank loans and associated interest rates using data from their real-time gross settlement (RTGS) system for interbank transactions. Using an algorithm first suggested by Furfine (1999, 2001), RTGS data is essentially filtered to extract sent and received interbank payments that resemble interbank loans; see e.g. Bech and Atalay (2010), Wetherilt et al. (2010) and Akram and Christophersen (2013). However, available evidence on the reliability of the 'Furfine filter' regarding identification of interbank loans and associated interest rates is limited and ambiguous; cf. Armantier and Copeland (2015), Kovner and Skeie (2013), Arciero et al. (2016), Frutos et al. (2016), Akram and Christophersen (2014) and references therein.[2]

We evaluate a Furfine filter applied to RTGS data from Norges Bank, the Norwegian central bank, using information from a survey conducted among effectively all (23) banks that settled their transactions through its RTGS system in an arbitrarily cho-

[1] Commonly, averages of indicative interest rates, e.g. various IBOR rates, reflecting supposed offers to (from) selected banks from (to) prime banks regarding unsecured loans for various maturities are publicly available. However, the indicative interest rates may not be representative of interest rates faced by or offered to relatively smaller banks or to banks with relatively lower credit ratings. Moreover, as the indicative interest rates are submitted by the selected banks for (trimmed) averaging close to a specific time of the day (11am or 12pm), they may deviate substantially from interest rates actually agreed with their prime counterparts at other times of a day; see e.g. documentation of Euribor, Libor, Stibor and Nibor at their publishers' websites. Market interest rates based on actual loan transactions by major banks also suffer from possibly inadequate representation of interest rates faced by many banks; cf. www.FNO.no for details on NOWA interest rates based on actual overnight interbank transactions by selected banks.

[2] This study goes beyond Akram and Christophersen (2014) who used aggregated information reported to Norges Bank by a panel of 11 banks about their daily lending and loan-weighted average interest rates.

sen month, August 2015. These banks were requested by Norges Bank to report details of their individual interbank loans and corresponding interest rates during the chosen month.

Our evaluation focuses on the filter's ability to correctly identify the reported unsecured overnight interbank loans and corresponding interest rates under various assumptions regarding characteristics of loans as well as interest rates. In particular, we evaluate the performance of a 'one-sided' version of the filter that aims to identify overnight loans in real-time based on characteristics of outgoing transactions only. A one-sided filter could be considered as a market monitoring device in times of uncertainty regarding liquidity conditions and high counterparty risk. We focus solely on the unsecured overnight market as longer maturity unsecured loans seems to be rare in the Norwegian market. Unsecured overnight trading accounts for around 3/4 of total overnight trading and around 90 percent of total unsecured trading in the Norwegian money market; see e.g. Norges Bank (2015a,b).

As an additional test of the reliability of the Furfine filter, we calculate the transactions-based Norwegian Overnight Weighted Average (NOWA) interest rates series using RTGS data for the survey month, August 2015, as well as for August 2016 and August 2017 and compare them with the official series published by Norges Bank for these months.[3] The latter is based on information from a panel of eleven banks about their daily lending and loan-weighted average interest rates.[4] The additional test offers an 'out-of-sample' evaluation of the Furfine filter complementing the survey-based evidence.

We find the Furfine filter applied to RTGS data from Norges Bank to be highly reliable, being able to correctly identify all of the unsecured overnight interbank loans and the associated interest rates that it aimed to identify. Moreover, there are only negligible deviations between the official and filter-based NOWA interest rate series, during the survey month and beyond. The filter's design in the light of interbank market conventions regarding loan size requests and particularly interest rate quotes seems to be crucial for its reliability. The one-sided version of the filter therefore

[3]See https://www.norges-bank.no/en/Statistics/Interest-rates/NOWA-daily/
[4]For details see: https://www.finansnorge.no/tema/nibor-nowa/nowa/

turns out to be quite unreliable when applied continuously from opening to closing hours of the RTGS system. However, its performance can be substantially improved if applied from late afternoons onwards, i.e. from the time when banks interbank loans are likely to take place based on banks' experience of their transaction flows and expectations of end-of-day liquidity positions.

In terms of filter design and data use, our approach is comparable to e.g. Arciero et al. (2016) and Frutos et al. (2016) in their evaluations of the Furfine filter based on detailed trading data from the Italian trading platform (e-Mid) and the Spanish central bank's post-trade database for credit institutions, respectively. While our trading data set covers just a month, it contains a complete record of unsecured overnight interbank loans transacted between effectively all users of a RTGS system. Even though our study suggests relatively higher reliability of a (well designed) Furfine filter than in most earlier studies, it essentially corroborates the evidence of relatively high reliability of the Furfine filter presented by e.g. Arciero et al. (2016), Frutos et al. (2016) and Leon et al. (2016) for overnight interbank markets. Beside that, our study offers an evaluation of a one-sided version of the Furfine filter which we have not seen so far in the relevant literature.

The paper is organised as follows. The next section (2) briefly describes Norges bank's RTGS system and the Furfine filter. Section 3 summarises the survey and the reported overnight loans and interest rates and compares these with the results from the employed Furfine filter. It also compares the official and filter-based NOWA series with each other during and after the survey month. Section 4 examines the reliability of the filter in response to various changes in its underlying assumptions. Section 5 offers the main conclusions.

2 RTGS system and the Furfine filter

Transactions between banks due to e.g. interbank loans and transfers between customers of different banks are settled at a settlement bank. Central banks are generally the ultimate settlement banks for banks resident in their countries. Data from

the 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 induced by interbank loans usually constitute a relatively small share of total transactions. In absence of identifiers, it therefore becomes challenging to separate them from the other transactions. Filters based on Furfine (1999, 2001) are commonly employed to separate overnight loans from the other interbank transactions.

In essence, a Furfine filter 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 value and the amount returned on the subsequent business 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 outgoing amounts to round values as banks generally do not borrow non-round values by market convention.

Specifically, a Furfine filter considers a pair of transactions as an overnight loan if the outgoing value (V_t) is a round value in the units traded and the implied interest rate (ii), defined as:

$$ii_t = \left(\frac{V_{t+1}}{V_t} - 1 \right) \times D, \tag{1}$$

is within a predefined band and has just up to two or three non-zero decimals. D denotes number of days in a year, equal to 360 or 365 by market convention. The bandwidth depends on that which one considers to be reasonable variation in interbank interest rates around the key policy rate. The decimal requirement is consistent with the market convention of quoting interest rates in annual terms and with two decimals, or for particularly large amounts, three decimals; cf. Demiralp et al. (2006), Arciero et al. (2016) and Frutos et al. (2016).

2.1 Norges Bank's RTGS system and the filter design

In Norway, close to all resident banks including branches and subsidiaries of foreign banks have a settlement account at Norges Bank and access to its RTGS system (NBO) for the settlement of transactions in NOK between any of the banks. NBO,

however, is only actively used for interbank transactions by around 25 banks, while the remaining banks, around 100, hold NBO accounts to be used in contingency situations. The latter banks usually settle their transactions through two major banks (DNB Bank ASA and Sparebanken 1 SMN) that act as settlement banks. Transactions between customer banks of the two settlement banks as well as those between the settlement banks are ultimately settled through NBO. Customer banks of these settlement banks as well as those of other sizable banks may not only include resident banks but also foreign banks without any branch or subsidiary in Norway.

When applying the Furfine filter to data from NBO, we assume outgoing amounts to equal or be above NOK one million, assuming NBO users do not borrow smaller amounts than a million. Moreover, outgoing amounts are assumed to be rounded to the nearest NOK 0.1 million. To define repayments of overnight loans the following business day, we set number of days in a year to 365 in line with the convention followed by NBO users when trading central bank liquidity. We require implied interest rates to have been plausible interest rates quotes, that is numbers with no more than three decimals when expressed in percent per annum.[5] The survey conducted confirms the market convention of using two or three decimals as none of the interest rates set in loan agreements during the survey month had more than two decimals except one with three decimals, the third being equal to 5. In addition, the implied interest rates are required to lie within a bandwidth of +/- 10 basis points around the key policy rate, i.e. Norges Bank's main overnight deposit rate, which was one percent during the survey month. The specified bandwidth is discussed in more details in Section 4.

[5] As Akram and Findreng (2017) we take into account that NBO operates with two decimals for NOK payments as the smallest monetary unit is 'øre', equal to 1/100 of a NOK. A repayment transaction (V_{t+1}) can therefore potentially have a rounding error up to NOK 0.005. Consequently, an implied interest rate can deviate slightly from the corresponding actual interest rate if agreed with three decimals between two banks. An implied rate in percent ($ii \times 100$) is therefore treated as a valid interest rate if it does not disagree with its rounded value, down to three decimals, by more than the maximum of the potential rounding error in the repayment transaction.

3 Reported and identified loans and interest rates

To gain insight into especially the Norwegian overnight interbank market, Norges Bank sent a questionnaire to 23 banks that had participated in the interbank market in August 2015, a more or less typical month. NBO was almost exclusively used by these 23 banks as they accounted for 99.8 percent of its total turnover in the survey month.[6] The questionnaire particularly sought details of every unsecured interbank loan by or to each of the 23 banks in that month. Requested information included the date, loan maturity, lent/borrowed amount, repaid amount, interest rates with all decimals, counterparty and whether the loan was made on behalf of another institution, e.g. a foreign bank without an account at Norges Bank. All of the banks replied to the questionnaire as requested. The initial replies included several typos as well as inconsistencies between lenders and borrowers regarding loans and interest rates, however. Additional calls were made to the relevant banks to clarify the inconsistencies, which owed to reporting errors.

In total, the survey respondents reported 1599 unsecured overnight loans with a total value of about NOK 395 billion. These constituted 342 loans settled at NBO and 1257 loans settled outside NBO. Their total values were reported to be NOK 282 billion and NOK 112 billion, respectively. The loans settled outside NBO were with major banks including the two settlement banks and settled over the books of the latter banks. The 342 loans settled at NBO included 119 loans (valued at NOK 60 400 billion) reported to be with foreign counterparties with interest rates calculated using 360 days per annum, in contrast with the 365-days convention for loans directly between NBO participants. In addition to the latter loans where the reporting banks were one of the counterparties, there may be transactions between reporting banks that are actually loans between foreign counterparties, i.e. non-NBO members. Such loans would not be covered by the survey as these were not recorded

[6]The remaining participants accounting for 0.2 percent of the monthly turnover are 106 relatively small banks and 9 institutions including the BIS, a few CCPs, foreign central banks, Norwegian government and Norges Bank itself. RTGS data for the survey month show that the remaining participants only transacted with the 23 banks that were sent the questionnaire. This implies that none of the interbank loans were between the remaining RTGS participants. Their interbank loans with the survey respondents are therefore part of our information set through the reports by the 23 respondents.

as loans by the reporting banks.

The following analysis focuses on the filter's ability to identify unsecured overnight interbank loans directly between NBO participants. This limitation is due to unavailable settlement information from the commercial settlement banks and the lack of information regarding loans solely between foreign counterparties settled at NBO through their correspondent banks. Due to the possibility of the latter loans, the survey information on loans involving foreign counterparties may be incomplete and hence not a valid reference for the evaluation of the Furfine filter. As interest rates on loans with foreign counterparties are based on 360 days per annum while loans between NBO participants are based on 365 days per annum, we can focus exclusively on the latter loans by our design of the Furfine filter, which we partly specify with 365 days per annum and the decimal restriction.[7]

Panel I of Table 1 summarises the characteristics of (unsecured) overnight interbank loans reported by the survey respondents. In total 223 loans with a total value of NOK 222 000 billion were made between the 23 NBO participants on their own behalf. The loans range from NOK 5 million to 8200 million with a standard deviation of NOK 1430 million. The mean and median values of the loans equal NOK 994 million and 400 million, respectively. Interest rates on these loans are in the range of 0.95 and 1.05 percent with a standard deviation of 1.8 basis points. Their mean as well as median values equal 0.97 percent.[8]

The Furfine filter as outlined above was able to correctly identify each of the 223 reported loans, constituting just 1.82 percent of the 12 223 settled gross interbank transactions. It also pointed out three additional transactions bearing resemblance to overnight interbank loans. Upon inquiry, these three transactions were confirmed

[7]Simulations available on request show that the probability of confusing a 360-days loan with a 365-days loan is infinitesimally small due to the decimal restriction.

[8]This is three basis points below the key policy rate of one percent during the survey month. Interest rates below the key policy rate, which is Norges Bank's main overnight deposit rate, are not uncommon. Actually, Akram and Findreng (2017) find 96 percent of the overnight loans to be below the key policy rate since the change in Norges Bank's liquidity policy in October 2011. Banks with liquidity in excess of their deposit quotas at Norges Bank face the option of depositing it at the so called 'reserve rate', which is one percentage point below the key policy rate, or lending it to other banks at an interest rate closer to the key policy rate. The latter banks may have unutilised deposit quotas at the central bank ensuring them a remuneration at the key policy rate; see e.g. Norges Bank (2014) for details.

Table 1: *Overnight interbank loans and interest rates in the survey month*

I: Reported overnight interbank loans and interest rates

	Number	Mean	Median	Minimum	Maximum	Std. dev.
Loans	223	994	400	5	8200	1430
Rates	223	0.97	0.97	0.95	1.05	0.018

II. Identified overnight interbank loans and interest rates

	Number	Mean	Median	Minimum	Maximum	Std. dev.
Loans	226	989	400	5	8200	1422
Rates	226	0.97	0.97	0.92	1.05	0.018

Note: Panel I summarises information provided by 23 banks regarding their unsecured overnight interbank loans and interest rates in August 2015. Panel II is based on our Furfine filter applied to all transactions settled in Norges Banks RTGS system, NBO, during the survey month.

by the relevant banks to be overnight loans, but to non-banks and hence left out from the banks' responses to the survey, which focused on *interbank* loans. This would not have been considered an overestimation by the applied Furfine filter if the respondents had been asked to also report loans with non-banks.

Panel II of Table 1 summarises the results based on the applied Furfine filter. It shows that the median loan value and the range of the 226 identified loan values are identical to those of the reported loans in Panel I. The summary statistics for interest rates is identical to the one in Panel I except for the minimum value of interest rates (0.92), which refers to two of the overnight loans to non-banks.

3.1 Out-of-sample evaluation of the Furfine filter

As an additional cross-check of the Furfine filter, we used it to calculate the NOWA interest rate series during the survey month as well as for the same month in the two subsequent years 2016 and 2017 and compared them with the official NOWA interest rate series for the corresponding months. The NOWA interest rate is calculated by Norges Bank every business day as an average of the actual (loan-weighted average) interest rates reported by eleven panel banks. 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 also represent own lending and not be on behalf of any financial or non-financial customer.

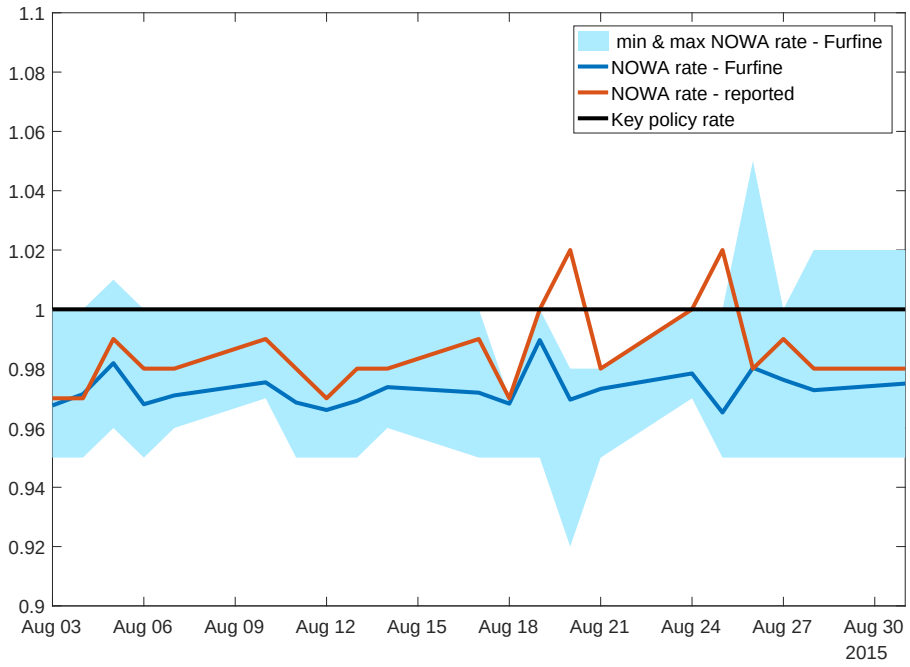


Figure 1: *The official and Furfine filter based* NOWA *interest rates (in percent per annum) together with a band defined by the minimum and maximum interest rates derived on each of the business days. The straight line at 1.00 is the key policy rate over the sample month.*

Figure 1 displays the official NOWA rate during the survey month together with the one based on the Furfine filter utilising the RTGS data for the survey month. The figure also displays a band defined by the minimum and maximum interest rates on individual overnight loans identified by the filter on each of the business days.

The figure shows that the official NOWA rate and the filter-based 'NOWA' rate are quite close but deviate systematically from each other. The filter-based NOWA rate is relatively smoother and systematically lower than the official rate. While the average deviation over the month is just 1.9 basis points, the two series occasionally deviate by up to 5.5 basis points.

One possible reason for the deviations between the two series is that NOWA banks may include overnight interest rates on loans to foreign banks that do not hold an account at Norges Bank. As such loans need not be settled through NBO, a discrepancy can arise between the official NOWA rate and the one based on the Furfine filter which relies on NBO data and only captures loans where the interest rate is based on 365 days per annum. Other possible reasons for the deviations between the two series include upward rounding of loan-weighted average interest

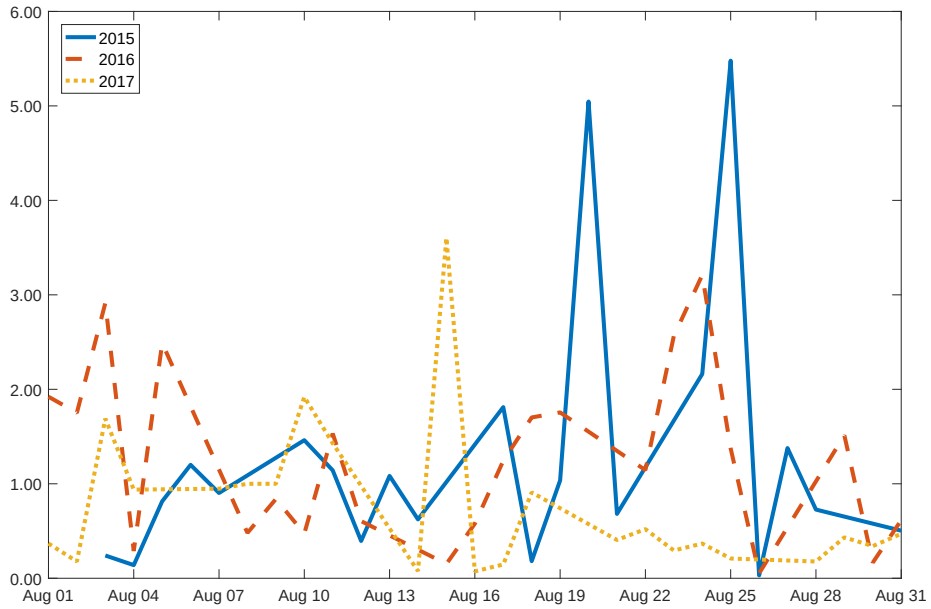


Figure 2: *Deviations between the official NOWA interest rates and the Furfine filter based interest rates during the survey month, August 2015, and during the months of August in 2016 and 2017. The deviations are expressed in basis points.*

rates submitted by the panel banks; submission of interest rate estimates rather than contracted interest rates; and possibly some banks' exercise of the option to exclude relatively small overnight loans and associated interest rates.[9,10]

Figure 2 suggests that the characteristics of deviations between the official and Furfine filter based NOWA interest rates during the two out-of-survey August months are comparable to those during the survey month. Actually, the ranges of the deviations during August 2016 and August 2017 are smaller than during August 2015 as they do not exceed 3.5 basis points. Notably, the average of the deviations during August 2016 is 1.9 basis points, which is identical to the average deviation during August 2015. The average deviation during August 2017 is even somewhat lower as it equals 1.2 basis points.

[9] NOWA is calculated when data is available from at least three of the eleven panel banks and their total reported loan volume are at least NOK 250 million. Banks may exclude loans smaller than NOK 25 million when calculating their total loans and loan-weighted average interest rates. In case of insufficient submissions by the panel banks, a panel bank may be requested to submit an estimate of the interest rate at which it would be willing to issue loans.

[10] The overidentification of three loans by the Furfine filter has a negligible effect on lowering the NOWA rate as the loans associated with these interest rate are relatively small, reducing their contribution to the NOWA rate based on the Furfine filter.

In sum, the characteristics of deviations between the official and filter-based NOWA interest rates during the two subsequent August months are close to those during the surveyed August month. This offers out-of-sample support to the reliability of the applied Furfine filter.

4 Sensitivity analysis of the filter's reliability

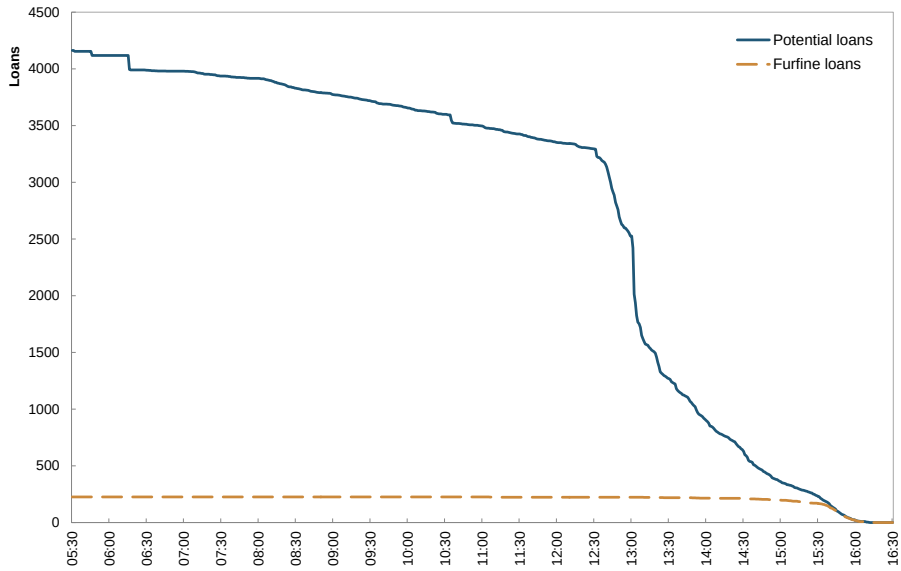
Our Furfine filter embeds four key assumptions: (a) a loan must not be below NOK one million; (b) have value rounded to NOK 0.1 million; (c) have an associated 365-days annualised interest rate with up to three (non-zero) decimals where the third moves in steps of five (a half basis point); and (d) the associated interest rate must be within a bandwidth that is +/- 10 basis points around the key policy rate. The first two assumptions related to outgoing values define lent amounts, while the two interest rate assumptions define their repayments the subsequent business day.

In the following, we examine the reliability of the Furfine filter under alternative assumptions regarding characteristics of lent amount and their repayments. We start with focusing solely on outgoing payments satisfying assumptions (a) and (b) and consider how such a 'one-sided' version of the filter that ignore assumptions (c) and (d) regarding repayments would fare.

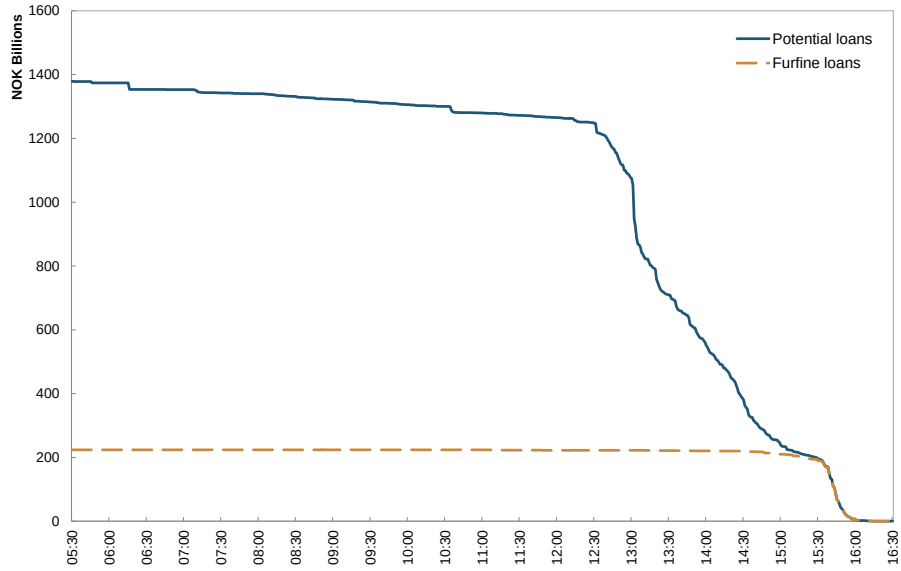
4.1 Sensitivity to the absence of repayment restrictions

Figure 3 illustrates the importance of restrictions on repayments the following business day for the identification of overnight loans. The figure shows how many transactions a 'one-sided filter' would have marked as overnight loans during the survey month if applied at the indicated time on each of the business days in the survey month. Such a filter could be applied if one wishes to identify overnight loans in real time rather than ex-post jointly with interest rates by additionally using information on return transactions.

Figure 4 shows that the one-sided filter would have led to a severe overestimation of loans if applied at the opening of the RTGS system on each of the business days.



(a) Numbers of transactions



(b) Values of transactions

Figure 3: *Numbers of transactions considered as potential loans and their values in* NOK *billions if the 'one-sided filter' and the default ('two-sided') Furfine filter are applied at the indicated times and onwards through the working hours on each of the business days during the survey month. Here, 'Potential loans' are based on the one-sided filter while 'Identified loans' are based on the default Furfine filter.*

We note that when started at 5.30 am, the number of transactions classified as overnight loans are 4163. The extent of overestimation declines as we postpone its start to the afternoon. This reflects that banks generally wait until the afternoon before engaging in overnight lending and borrowing activity; see e.g. Armantier et al. (2008) and Akram and Findreng (2017). The main reason for the delay is that NBO users do not become fully aware of their liquidity positions before the final

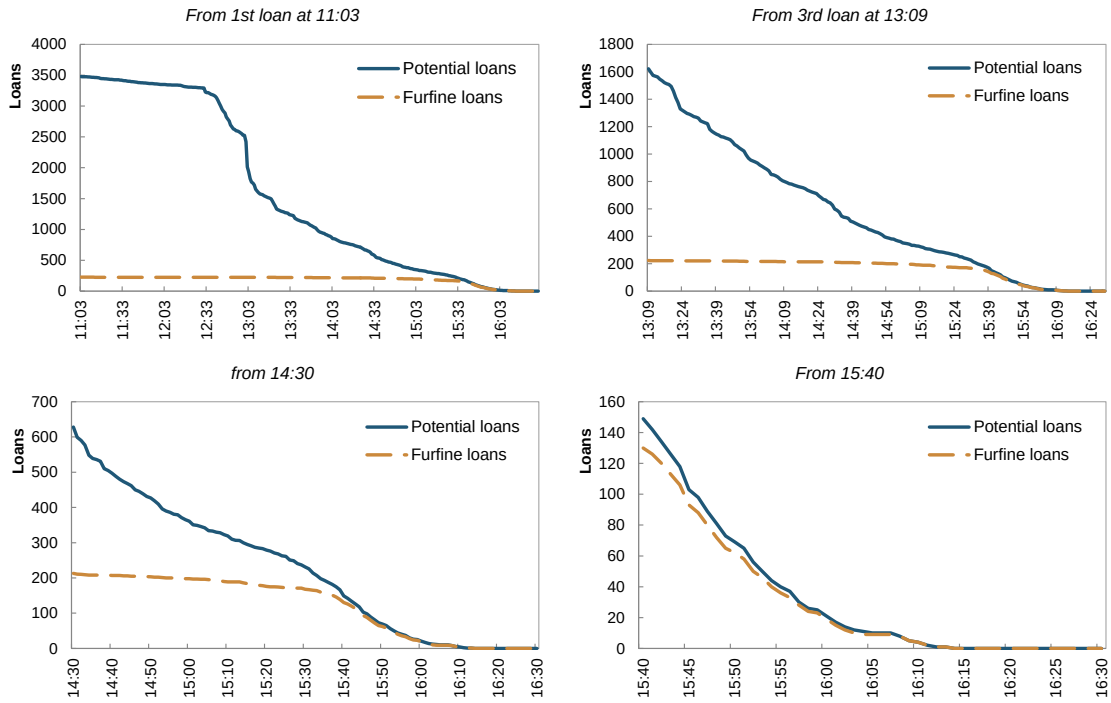


Figure 4: *The numbers of transactions considered as overnight loans. Here 'Potential loans' refer to the number of transactions considered as loans by the 'one-sided filter' while 'Furfine loans' refer to the number of transactions identified as overnight loans by the default ('two-sided') Furfine filter. The horisontal axis indicates the time of the day from when the filters are applied on each of the business days during the survey month.*

settlement of their 'retail' net transactions at around 3.35 pm; see Norges Bank Oppgjørssystem (2016).

The three earliest overnight loans made during the month were transferred between 11.03 am and 1.09 pm. Applying the filter from the timing of the first loan would have suggested about 3500 loans while a start from say 2.30 pm would have suggested more than 600 loans, an overestimation by about 170 percent relative to the actual number of interbank loans, 223; see Figure 4. However, waiting until say 3.40 pm would have led to an underestimation of the number of loans by about 30 percent, but an overestimation of the actual number of overnight loans made after 3.40 pm by about 15 percent as the Furfine filter would have suggested 150 loans after this time while the actual number was 130.

The above analysis suggests the repayment restrictions (c) and (d) are crucial for the reliability of the Furfine filter. In their absence, one risks severe overestimation as well as underestimation of overnight loans. Yet, the analysis suggests that a 'one-sided filter' that disregards repayment restrictions but utilises the typical intra

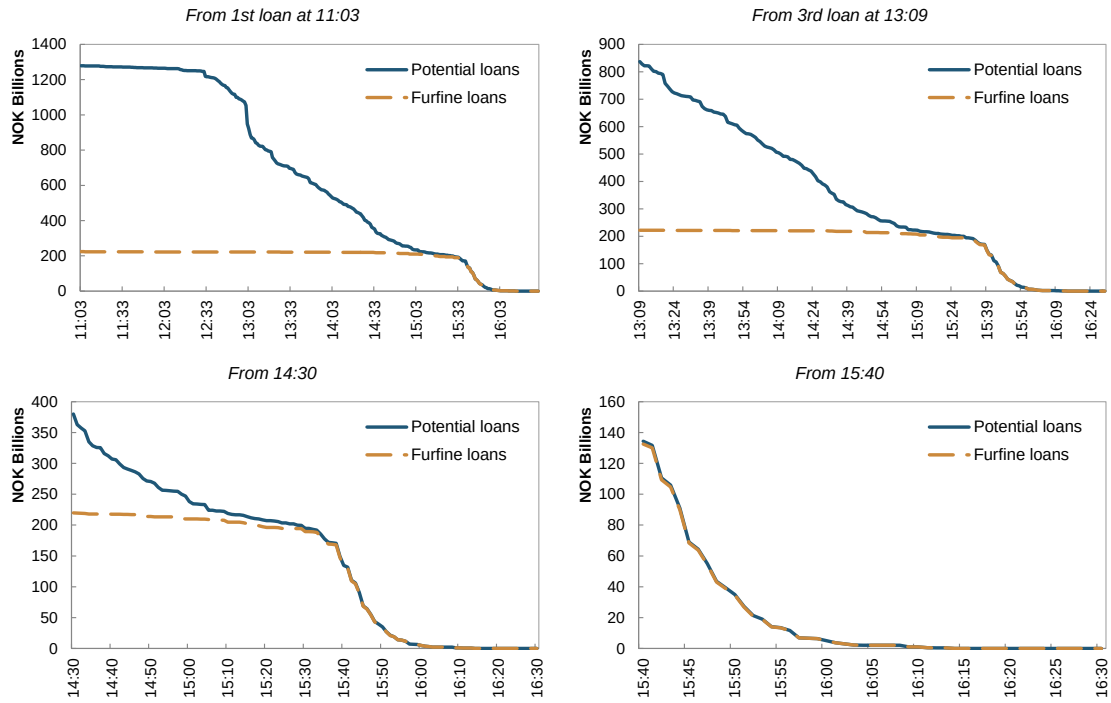


Figure 5: *The values of transactions considered as overnight loans. Here 'Potential loans' refer to values of transactions considered as loans by the 'one-sided filter' while 'Furfine loans' refer to values of transactions identified as overnight loans by the default ('two-sided') Furfine filter. The horisontal axis indicates the time of the day from when the filters are applied on each of the business days during the survey month.*

day pattern regarding overnight lending can offer an impression of overnight lending activity that need not be far-fetched, especially if one is primarily interested in the total value of overnight loans from the late afternoon onwards; see Figure 5. It is seen that despite the difference in the number of transactions classified as loans and actual loans after 3:40 pm, their total values do not differ much when expressed in NOK billions.

4.2 Sensitivity to changes in defining characteristics

Tables 2 and 3 report the sensitivity of the Furfine filter to assumptions regarding outgoing and incoming amounts, respectively. The bold entries highlight over- and underidentification of loans under the default assumptions. As shown, the share of transactions not meeting our criteria for being an overnight interbank loan is 1.3 (= 3/223) percent, while the share of neglected loans is zero.[11]

[11] Even though the three additional loans were overnight loans, we treat them as overidentified loans as they were not between banks.

Table 2: *Sensitivity to assumptions regarding outgoing loan values*

I: Overestimation of overnight loans - Type 1 errors (%)

	Minimum loan value (mill)		
	0	1	10
Value step (mill)			
0.01	1.3 %	1.3 %	0.4 %
0.1	1.3 %	**1.3** %	0.4 %
1.0	1.3 %	0.9 %	0.0 %
10	1.3 %	0.9 %	0.0 %

II: Underestimation of overnight loans - Type 2 errors (%)

	Minimum loan value (mill)		
	0	1	10
Value step (mill)			
0.01	0.0 %	0.0 %	0.9 %
0.1	0.0 %	**0.0** %	0.9 %
1.0	0.4 %	0.4 %	1.3 %
10	21.1 %	21.1 %	21.1 %

Notes: The table shows outcomes of the Furfine filter under alternative assumptions regarding outgoing amounts, i.e. (V_ts in Eq. (1)). The values are expressed in percent of deviations from the actual number of interbank loans (223). Bold entries are the outcome of the Furfine filter under the default assumptions.

In Table 2, we vary the minimum outgoing amount in NOK million from zero to 10 while the rounding of outgoing amounts is varied from NOK 10 000 to NOK 10 million. Panel I of the table shows that the share of false (interbank) loans declines if the minimum outgoing amount is raised to NOK 10 million or only amounts rounded to a million are allowed. The share of false loans decline to zero when both restrictions are imposed. Panel II of Table 2, however, shows that this may lead to the overlooking of loans. By raising the minimum value to NOK 10 million, the share of overlooked loans increases from zero to 0.9 percent, and to 1.3 percent if rounding to a million is also imposed. A further increase of rounding to NOK 10 million causes an underidentification of 21.1 percent of the loans. Obviously, there are relatively few loans in millions that are multiplies of 10.

Table 3 reports the share of false loans and ignored loans when interest rates could be in bandwidths ranging from +/-5 basis points (bp) to +/- 50 basis points relative to the key policy rate. Interest rates can simultaneously vary in ticks of 0.10 to 1 basis point. It is seen that an increase in the tick size is associated with

Table 3: *Sensitivity to assumptions regarding interest rates*

I: Overestimation of overnight loans - Type 1 errors (%)

	Bandwidth (bp)			
	± 5	±10	±20	±50
Decimal rounding				
0.10	0.0 %	1.3 %	4.9 %	4.9 %
0.50	0.0 %	**1.3** %	1.3 %	1.3 %
1.00	0.0 %	0.9 %	0.9 %	0.9 %

II: Underestimation of overnight loans - Type 2 errors (%)

	Bandwidth (bp)			
	±5	±10	±20	±50
Decimal rounding				
0.10	5.8 %	0.0 %	0.0 %	0.0 %
0.50	5.8 %	**0.0** %	0.0 %	0.0 %
1.00	6.3 %	0.4 %	0.4 %	0.4 %

Notes: The table shows outcomes of the Furfine filter under alternative assumptions regarding the plausibility of interest rates, i.e. (iis in Eq. (1)). The values are expressed in percent of deviations from the actual number of interbank loans (223). Bold entries are the outcome of the Furfine filter under the default assumptions.

fewer false loans; their share decline to 0.9 percent when the tick size is increased to 1 basis point, irrespective of the bandwidth choice. This may occur at a higher risk of overlooking overnight loans, however. While the share of overlooked loans is unaffected by an increase in the tick size from 0.1 basis point to 0.5 basis point, an increase to 1 basis point is associated with an increase in the share of overlooked loans by 0.4-0.5 percent.

When the third decimal on interest rate is either 5 or zero, implying the third decimal to move in steps of 0.5 or 1 basis point, respectively, the bandwidth assumption seems to be not important when the bandwidth is at least +/- 10 basis points around the key policy rate. The share of overlooked loans increases to about 6 percent when the bandwidth is reduced to +/- 5 basis points, while an increase of the bandwidth to +/- 50 does not change the extent of over- or underestimation of loans relative to the case with a bandwidth of +/- 10 basis points.

In sum, the sensitivity analysis carried out by varying the assumptions defining the implemented Furfine filter reveals that the share of false loans could have been reduced by restricting the minimum loan size to NOK 1 million and assuming loans

to vary with tick size of one million and interest rates to vary by tick sizes of 1 basis point, i.e. by assuming up to just two non-zero decimals. Under the latter assumption, the bandwidth assumption may even become superfluous.

This suggests the use of sufficiently wide bandwiths to reduce the risk of overlooking loans with particularly high or low interest rates during periods of tight or abundant liquidity conditions, respectively. For example, at the end of quarters or during periods of high uncertainty, interest rates may be abnormally high in general or on loans to specific counterparties; cf. Afonso et al. (2011). Due to concern for a potential stigma associated with utilising a central bank's overdraft facilities, overnight interest rates can even exceed the overnight overdraft rate, which in Norway is 100 basis points above the key policy rate; cf. Armantier et al. (2015). A relatively narrow bandwidth can also contribute to the underestimation of loans as banks with surplus liquidity facing the prospect of depositing it at the so called 'reserve rate', i.e. an interest rate 100 basis points below the key policy rate, could be content with receiving an interest rate that is just above the reserve rate; cf. Norges Bank (2014).

5 Conclusions

The Furfine filter employed to identify Norwegian unsecured overnight interbank loans and interest rates can be considered highly reliable regarding overnight loans that are settled by the counterparties themselves at Norges Bank. It was able to correctly identify each of such 223 loans and the associated interest rate from a month's RTGS data.

Moreover, Furfine filter based NOWA interest rates are close to the official series during the survey month as well as during the same month in the two subsequent years. The characteristics of the deviations between the two series during the out-of-survey months are comparable to those during the survey month.

A sensitivity analysis of the underlying assumptions reveals that the shares of false interbank loans or the shares of overlooked may remain relatively small for

reasonable changes in the assumptions, especially in the light of information about market conventions regarding quoting of both loans and interest rates. A 'one-sided' version of the filter solely based on loan-size characteristics can therefore prove quite unreliable for real-time money market monitoring. It's reliability can however be improved if applied from late afternoon onwards when overnight loans are mostly traded.

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