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Peer Monitoring vs. Search Costs in the Interbank Market: Evidence from Payment Flow Data in Norway

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Peer Monitoring vs. Search Costs in the Interbank Market: Evidence from Payment Flow Data in Norway*

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Abstract

Bilateral payment flows between banks may provide private information about a borrowing bank's liquidity position. This paper analyses whether private information on the bilateral payment flow of central bank reserves foster peer monitoring or whether the information is used to reduce search costs in the unsecured interbank market. In the former, banks with outflows of liquidity are penalized by their counterparties, while in the latter, these banks benefit through reduced search costs to find a liquidity provider. I use data from Norges Bank's real time gross settlement system over the period 2012 to 2015 to identify unsecured overnight interbank loans and payment flows. The results suggest that banks are using private information from payment flows to reduce search costs and not for peer monitoring. This has important implications for regulators' assessment of the pros and cons of a centralized versus a decentralized interbank market.

Keywords: *Peer monitoring, search cost, unsecured overnight interbank market, interest rates, central bank liquidity policy and OTC markets*

JEL Codes: G21, E42, E43, E58

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1 Introduction

A decentralized interbank market, where trading of central bank reserves is over the counter and unsecured, creates incentives for banks to monitor their peers. Overnight unsecured funding requires the lender to make daily decisions about whether it will roll over funding or stop lending. If the lender decides to stop lending, the bank with liquidity needs may run into liquidity problems. The right to stop lending, if one becomes suspicious about the borrower's risk, makes it in the interest of the lender to monitor the borrower. In turn, the value of the lender's option can benefit the borrower through reduced funding cost. This argumentation follows Calomiris and Kahn (1991) and Diamond and Rajan (2001), who analyze the role of demandable debts in banks. A decentralized interbank market with peer monitoring among banks is in accordance with the third pillar in the Basel II recommendations aiming at encouraging market discipline (BIS (2005)).

Effective peer monitoring may have positive implications for the stability of the financial system and the overall economy. See for example Freixas and Holthausen (2005), Furfine (2001), Rochet and Tirole (1996) and Flannery (1996). However, there are also costs associated with decentralized markets. Rochet and Tirole (1996) argue that the incentives for peer monitoring are weak due to short maturities, market interventions by the central bank, moral hazard and asymmetric information. Further, Rochet and Tirole (1996) and Flannery (1996) point out that a decentralized interbank market increases systematic risk and imposes some welfare loss due to asymmetric information. They argue that if information banks can obtain about other banks can also be obtained and utilized by regulatory authorities, then there is no particular reason to encourage decentralization of the interbank market.

Alternatively, interbank trading could be organized through a central clearing house where the borrowers post collateral and are anonymous. See Holmstrom (2015) for a discussion on how opacity in money markets can increase liquidity. More generally, a set-up with electronic auctions can result in better prices and more liquidity (see for example Hendershott and Madhavan (2015)).

Information sources for peer monitoring can be everything of interest about the counterparty, such as rumours or public and private information. One potential source of peer monitoring is payment flow data. This paper examines whether lenders in the unsecured overnight interbank market use bilateral payment flows to assess borrowers' liquidity risk. The idea of using transaction data for monitoring is not new. Black (1975) argues that if a borrower has all their transactions through one single bank, the bank has full control over the borrower's financial situation. Similarly, Fama (1985) argues that transaction history provides useful information for monitoring borrowers and especially borrowers with repeated short-term loans. Mester et al. (2007) find evidence that transaction data can help the lender monitor the value of collateral that a commercial borrower has posted for an operating loan by using monthly and annual transaction data for small business borrowers. In the case of interbank trading, one could argue that the payment flow of reserves reveals information about banks' liquidity positions. One aspect of liquidity risk is whether banks have the ability to meet an immediate request for payment (Ruozi and Ferrari (2013)). The first hypothesis I propose is that a potential lender is reluctant to lend to a bank that has revealed a negative signal about its liquidity position through its payment flow.

An alternative use of payment flow data is to reduce search costs to find a counterparty. Search cost are likely a relevant factor in a decentralized interbank market. In an over-the-counter market, prices are set through a bilateral bargaining process that reflects the participants' alternatives to immediate trade, including search costs (Duffie et al. (2005)). In an interbank market where reserves are continuously reshuffled through the system, a bank with negative liquidity is incentivized to search for a lender, and a bank with too much liquidity will be incentivized to search for borrower.[1] It is obvious that if one bank transfers a large amount of reserves to another bank, the two banks are likely to have opposite liquidity needs following the transaction. The two banks can then agree on an offsetting interbank trade with limited search costs. Thus, I propose a second and competing hypothesis that a net flow of funds from one bank to another increases the likelihood of an interbank loan taking place within that banking relationship in the opposite direction.

I test the two competing hypotheses on transaction data from the real time gross settlement system in Norway over the period 2012-2015. As transaction level data on interbank lending is not publicly available, an algorithm proposed by Furfine (1999) and modified by Akram and Findreng (2017, 2021) is used to identify unsecured overnight interbank loans. My dataset includes gross bilateral lending between 272 bank pairs. I analyze how the bilateral payment flow affects participation in the unsecured overnight interbank market. I control for liquidity positions at both banks at the time of trade and relationship- and time fixed effects.

The results suggest that banks use the bilateral payment flow to reduce search costs to find a counterparty with an opposite liquidity need. That is, if bank i transfers reserves to bank j, the probability that a loan follows from bank j to bank i increases after controlling for the actual liquidity positions at the time of trade. In Section 6, I extend the analysis to look at pricing of loans and find that the bilateral payment flow does not affect pricing. This verifies that the payment flow is used to reduce search costs as opposed to a situation where the borrower with an outflow of reserves is trapped within the relationship and is forced to borrow at unfavourable terms. This could occur if all other banks are reluctant to lend because of asymmetric information.

The paper contributes to the literature on determinants for lending terms in the interbank market. See for example Furfine (2001) and Afonso et al. (2011), who

[1] How strong incentives banks have for trading reserves depends on the liquidity management system in place at the relevant central bank.

find evidence that counterparty risk, measured through bank characteristics such as type of bank, performance ratios, and credit default swap prices, affects volume and price, indicating that some kind of peer monitoring exists. However, this information is typically not updated frequently and may lose its relevance when counterparties in the unsecured overnight interbank market are evaluated on an ongoing basis. Ashcraft and Duffie (2007) show that the liquidity position relative to the banks' normal liquidity position is an important factor in matching lenders and borrowers.

The paper also contributes to the literature on the role of relationships in money markets. See for example Cocco et al. (2009) and Bräuning and Fecht (2012), who find that banking relationships matter for accessibility and pricing in the interbank market. Controlling for risk factors, borrowing banks typically borrow at better terms within a banking relationship. However, this is reversed if the private information known to the lending bank is negative. As an example, Bräuning and Fecht (2012) find that relationship lenders to some extent anticipated the financial crisis by increasing rates in the preceding period.

I contribute to this existing literature by analysing how private information from bilateral payment flows is used within banking relationships. There are indications from the literature that private information plays a role in the interbank market. Afonso et al. (2011) find that larger banks with easy access to interbank borrowing found that access to the interbank market was more limited during the Lehman crisis. However, the banks with less access before Lehman where able to increase borrowings. A similar finding was made by Furfine (2002), who finds that during the autumn of 1998, when Russia defaulted on its sovereign bonds and the hedge fund Long-Term Capital Management nearly collapsed, the spread between active and less active institutions declined.

My findings are relevant to the debate on whether central bank liquidity policy should incentivize interbank trading[2], or, in the more extreme, whether there should be a decentralized interbank market at all. The results point in the direction that decisions about interbank trading are motivated by reducing search costs and that banks are not using bilateral payment flow to asses counterparty risk. In isolation, these results favour a centralized system for trading interbank reserves.

2 Institutional Background

Banks established in Norway, including branches and subsidiaries of foreign banks, may have a deposit account with Norges Bank. When a client of one bank transfers funds to a client in another bank, the amount is debited and credited in the banks' respective accounts with Norges Bank. These transactions go through, and are recorded, in the real time gross settlement (RTGS) system.[3] In 2017, 130 banks, three central counterparties and the government held an account with Norges Bank. The daily average gross volume of settlements in the RTGS system was NOK 236 bn with five banks settling about 90% of this.[4] Smaller banks often use correspondent banks to settle transactions and hold an account with Norges Bank for contingency purposes. Most payment transactions are netted at fixed times through clearing institutions, such as small retail transactions through NICS, foreign exchange through CLS, while securities are netted through VPS. However, in terms of volume, these transactions amounted to only about NOK 38 bn each day. The largest share of the volume (NOK 197 bn) is settled gross in real time throughout the opening hours between 05:30 and 16:35. These transactions are often large and time-critical, and comprise the most relevant data for the analysis in this paper. Transactions relating to banks' liquidity management are settled gross and include unsecured interbank trading. Other large transactions, such as those on behalf of large corporate clients[5],

[2]See for example Akram and Findreng (2021) who provide empirical evidence that interbank activity increased significantly when a penalty for holding excess reserves above some individual quota was imposed by the Norwegian central bank.

[3]Bay Fevolden and Smith (2019) offers a detailed analysis of RTGS transactions in Norway.

[4]One day of settlements corresponded to about 8.5% of Norway's mainland gross domestic product the same year. See Statistics Norway - https://www.ssb.no/en

[5]These clients may also include other banks, such as foreign banks without access to Norges Bank or smaller banks using a larger bank as a correspondent bank.

are important drivers of bilateral payment flows, which is the main explanatory variable in the analysis below.

The total amount of reserves varies due to transactions over the government's account in Norges Bank and fluctuations in circulating notes and coins. Norges Bank aims to keep total reserves at a stable targeted level of NOK 35 $\pm$ 5 bn by using loan and deposit auctions with short maturities.[6] By again using the 2017 numbers from Bay Fevolden and Smith (2019), this would indicate that each unit of reserves changed hands almost seven times per day ($\frac{236}{35}$).

Norges Bank offers unlimited interest-free intraday borrowing of reserves against collateral. If the intraday loan is not paid back by the end of the day, the loan is converted into an overnight loan with an interest rate 100 basis points above the key policy rate. Banks can deposit unlimited reserves with Norges Bank overnight. The deposits are remunerated at the key policy rate up to a predefined quota. Reserves in excess of this quota are remunerated at the reserve rate, which is equal to 100 basis points below the key policy rate.[7]

The banks are divided into three quota groups based on the banks' total assets, where the quota within each group is the same with the exception of some settlement banks, which have supplemented quotas.[8] The total amount of quotas is set at NOK 45 bn, suggesting that if Norges Bank is successful in keeping total reserves at NOK 35 bn, each bank should on average have close to 78 % of their quota filled up.[9]

The high turnover of reserves, combined with the penalty for having a shortage or a surplus of reserves overnight, incentivize the banks to trade reserves with each other.

[6] For more details on Norges Bank's market operations, see https://www.norges-bank.no/en/topics/liquidity-and-markets/Market-operations/

[7] Norges Bank has no reserve requirement.

[8] See the following link for an example of how the quotas were set in 2017 https://www.norges-bank.no/en/news-events/news-publications/Circulars/2017/1-quotas-in-the-system-for-the-management-of-bank-reserves/

[9] https://www.norges-bank.no/en/topics/liquidity-and-markets/The-liquidity-management-system/The-management-of-bank-reserves-The-system-in-Norway/

Banks with a shortage of reserves can borrow from banks with a surplus of reserves. Similarly, banks with reserves in excess of their quotas can place their funds with banks with spare capacity in their quotas. Liquidity statistics from Norges Bank confirm that banks mostly avoid using the overnight standing facilities.[10] Over the period 2012-2015 (the data set used in this paper), total liquidity averaged NOK 33.1 bn and about NOK 1 bn of this liquidity was deposited at the reserve rate, 100 basis points below the key policy rate. Overnight borrowings from the central bank occurred on 50 days, with an average of NOK 176 million on those days at the overnight borrowing rate, 100 basis points above the key policy rate. Akram and Findreng (2021) analyze the Norwegian unsecured overnight interbank market and find that unsecured overnight interbank trading increased with the implementation of quotas and reduction in Norges Bank's target for total reserves in 2011. They also find that, while the overnight unsecured interest rate was normally above the key policy rate in the old system, where the banks could deposit unlimited reserves remunerated at the key policy rate, it is now usually a few basis points below the key policy rate. That is, the standing facilities in place from 2011 provide incentives for both borrowing and lending in the unsecured overnight interbank market.

There are multiple ways banks can trade reserves. See for example Di Filippo et al. (2021), who analyze how banks choose between secured and unsecured trading in the euro interbank market. Table 1 displays the results from a money market survey by Norges Bank in 2015.[11] The survey reveals aggregated information on borrowing and lending volumes for eleven anonymous banks in April 2015. These eleven banks are among the largest and most active banks in the Norwegian market, but as the survey does not contain the entire market, these banks reported higher borrowing than lending, indicating that the sub-sample is a net borrower. The daily volumes of borrowing and lending are about NOK 88 bn and NOK 86 bn across all maturities and types of trade. The banks report trading in the categories FX Swaps,

[10] Aggregate liquidity statistics are published by Norges Bank - https://www.norges-bank.no/en/topics/Statistics/Bank-liquidity/

[11] See Norges Bank (2015)

Table 1: *Trading of reserves in April 2015 - Norges Bank survey*

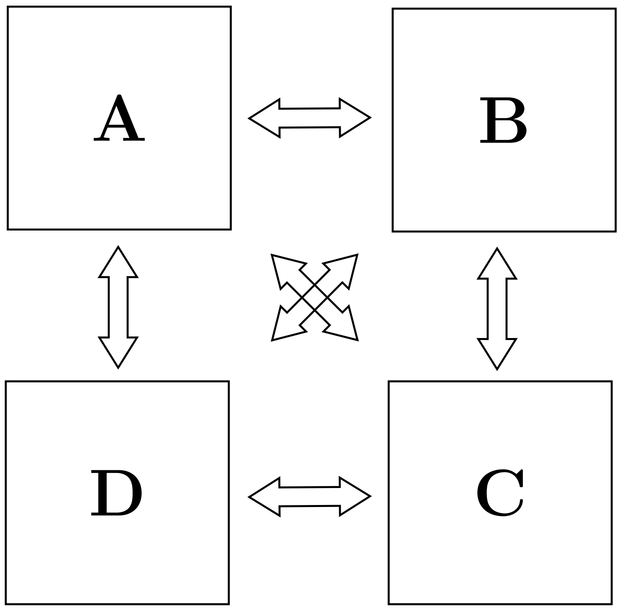
	Unsecured	Repo	FX Swaps	SUM (bn)
Borrowing	**32 %**	**1 %**	**66 %**	**88.3**
Overnight	72 %	0 %	28 %	34.2
Tomorrow-Next (T/N)	8 %	0 %	92 %	12.3
T/N-1 week	30 %	3 %	67 %	8.6
1 week - 1 month	4 %	7 %	89 %	9.1
1 month - 3 months	1 %	1 %	98 %	14.4
3 months - 6 months	1 %	0 %	99 %	7.7
6 months - 12 months	0 %	0 %	100 %	1.9
Lending	**21 %**	**2 %**	**76 %**	**85.8**
Overnight	65 %	0 %	35 %	26.4
Tomorrow-Next (T/N)	2 %	0 %	98 %	19.4
T/N-1 week	4 %	4 %	91 %	14.0
1 week - 1 month	0 %	12 %	88 %	11.2
1 month - 3 months	1 %	0 %	99 %	9.1
3 months - 6 months	0 %	1 %	99 %	4.4
6 months - 12 months	0 %	0 %	100 %	1.3

Note: Figures in this table are based on Table 1 in Norges Bank's money market survey 2015 (Norges Bank (2015)). Eleven banks report their lending and borrowing of central bank reserves for April 2015. All figures are aggregated daily averages. Columns 2 - 4 are the corresponding percentages of the total sum in column 5.

Repurchase Agreements and Unsecured. While FX swaps is the main channel for trading reserves with 66 % of borrowing and 76 % of lending in total, the unsecured market is the primary way of trading reserves overnight with 72 % of the overnight market. Repurchase agreements represents a negligible part of total trading and seem to be mostly used for maturities between a few days and a month.

Given the importance of unsecured interbank loans in the money market with the shortest maturities, it seems reasonable to use this market to analyze how payment flows affect banks' trading decisions when adjusting their daily liquidity positions. The very simplistic example illustrated in Figure 1 with four banks sending and receiving reserves may not be unrealistic in the Norwegian case as the number of active participants is rather limited. Theoretically, one can know about each bank's liquidity position by knowing all their transactions of reserves. Naturally, the banks only know about the transactions where they are themselves involved. Even though an outflow of reserves from for example bank A to bank B in isolation means that bank A will have lower liquidity, it is unclear to bank B whether bank A has a

Figure 1: *Illustration of bilateral flow of reserves between banks*



positive net payment flow with other banks or whether it for example has a positive payment flow with the government (which increases the total amount of reserves).

In the core analysis of this paper, I follow 17 banks over the period 2012-2015 (details on data selection are given in Section 4). Table 2 displays the distribution of gross and net liquidity at closing time for these banks. Gross liquidity is the banks' final holdings at end of day after trading reserves. Looking at gross liquidity, the 17 banks deposited reserves worth about 71% of their quota. Furthermore, they borrowed overnight from Norges Bank 0.25% of the times and deposited excess reserves 13% of the times.[12] The second row displays net liquidity at day-end, which is the banks' liquidity before unsecured overnight trading. We can see that before unsecured overnight trading, the banks had negative liquidity positions 18 % of the times and excess reserves almost 50 % of the times. The median time for when a loan was transferred was 58 minutes before closing time.[13] This observation confirms that the banks are using unsecured overnight loans to adjust their liquidity holdings before closing time.

[12]See Figure A1 in Appendix C in the appendix for the full distribution of gross liquidity.

[13]As this is an OTC market based on bilateral agreements over the phone or chat system, the exact time for when the banks agree on the trade is unknown.

Table 2: ***Liquidity to quota at end-day***

	Mean	St. Dev.	$X < 0$	$0 < X < 1$	$X > 1$
Gross Liquidity to Quota	0.709	0.378	0.25 %	86.83 %	12.92 %
Net Liquidity to Quota	0.782	1.113	17.89 %	33.20 %	48.91 %

Note: The table shows the average liquidity to quota ratio at closing time for a selection of 17 banks and 999 trading days over the period 2012-2015, resulting in 19 983 observations. The banks have individual quotas.

3 Identifying unsecured overnight interbank loans

In earlier papers, Akram and Findreng (2017, 2021) develop an algorithm to identify unsecured overnight interbank loans using data from the RTGS system. The algorithm is based on the work of Furfine (1999, 2000, 2001, 2002), but modified to increase accuracy and fit Norwegian data. The main goal is to distinguish interbank loan transactions from all other transaction in the RTGS system. The original procedure by Furfine (1999) classifies a pair of transactions between two banks on consecutive business days as an overnight loan if the amount transferred on day (V_t) is a plausible value and the amount returned on the subsequent day (V_{t+1}) equals the transferred amount plus an amount that may be considered a reasonable interest rate. This implied interest rate needs to be within a predefined bandwidth and the loan size is typically restricted to a round value.

In the analysis in this paper, I use a sub-sample of the data analysed in Akram and Findreng (2021) and follow their choice of restricting V_t to a round value in NOK millions and a bandwidth equal to the key policy rate $\pm$ 70 basis points. A drawback of using this algorithm is that it tends to wrongly identify a rather large number of transactions as overnight loans. A possible solution with an obvious drawback is to tighten the bandwidth for what one may consider a reasonable interest rate. In more recent versions of the algorithm, it is also considered that overnight interest rates are quoted in annual terms with a limited number of decimals. For example, if the market convention is to quote interest rates with two decimals, one could annualize the implied interest rate and round it to the nearest third decimal and require this to be zero or nine (see for example Demiralp et al. (2006) and Frutos et al. (2016)). Akram and Findreng (2017, 2021) took this approach one step further by calculating the highest rounding error that may occur for each loan. The smallest monetary unit in Norway is $\frac{1}{100}$ NOK, implying that the return value may be off by 0.005 NOK. Allowing for three decimals in the quoted annualized interest rates, they impose the following maximum error condition:

$$\frac{|\,(ii_t \times 100000) - round\,(ii_t \times 100000)\,|}{100000} \leq \left(\frac{0.005}{V_t}\right) \times \frac{365}{days}. \tag{1}$$

where ii_t is the implied interest rate and $days$ is the number of calendar days between the two consecutive business days. In Akram et al. (2019), a reliability assessment of the same algorithm is performed. In short, they collect real data on interbank loans for one month through a survey and are able to correctly identify the 223 loans reported by the banks. In the analysis in this paper, the algorithm identifies 14 684 overnight interbank loans out of 1 408 813 potential transactions in the RTGS system over the period 2012-2015.

4 Data and Methodology

The data set consists of bilateral payment flows taken directly from RTGS data and unsecured overnight trading estimated using RTGS data. The data is set up as a panel with daily observations for each directional banking relationship over the period 2012-2015. That is, each pair of banks consists of two directional banking relationships, as both banks can act as the lender and both banks can act as the borrower. Net flow of funds is then calculated as the net flow between the two banks excluding unsecured overnight interbank loans. I require each bank to have been involved in at least one unsecured overnight interbank loan (either as a lender or a borrower) over the period. As a second requirement, to avoid banks that have an account solely for contingency purposes, I limit the sample to banks that have a minimum of three general transactions in total with other banks on average per day (any transaction above NOK 100 or about EUR 10 counts).[14] After data cleaning, I am left with 17 banks over 999 business days.[15]

4.1 Unsecured Overnight Loans and Banking Relationships

Table 3 displays the number of days with unsecured overnight lending within each directional banking relationship over the period 2012-2015. For anonymity purposes, the actual numbers are replaced by a shading system. Light grey, grey and black indicate whether lending within the directional banking relationship occurred seldom, quite often or frequently. A substantial part of the "seldom" observations represent no activity at all. Looking at for example bank C and D, C borrowed quite often from D, and D has frequently borrowed from C. On more than half of the days, there was no lending in either direction within the pair of banks.[16] There are two main takeaways from Table 3. Firstly, there are strong banking relationships in the unsecured overnight market. Secondly, some banks tend to act mostly either as a lender or as a borrower. Take for example bank B, which has frequently borrowed from nine different lenders. Bank B is not a frequent lender to any other bank.

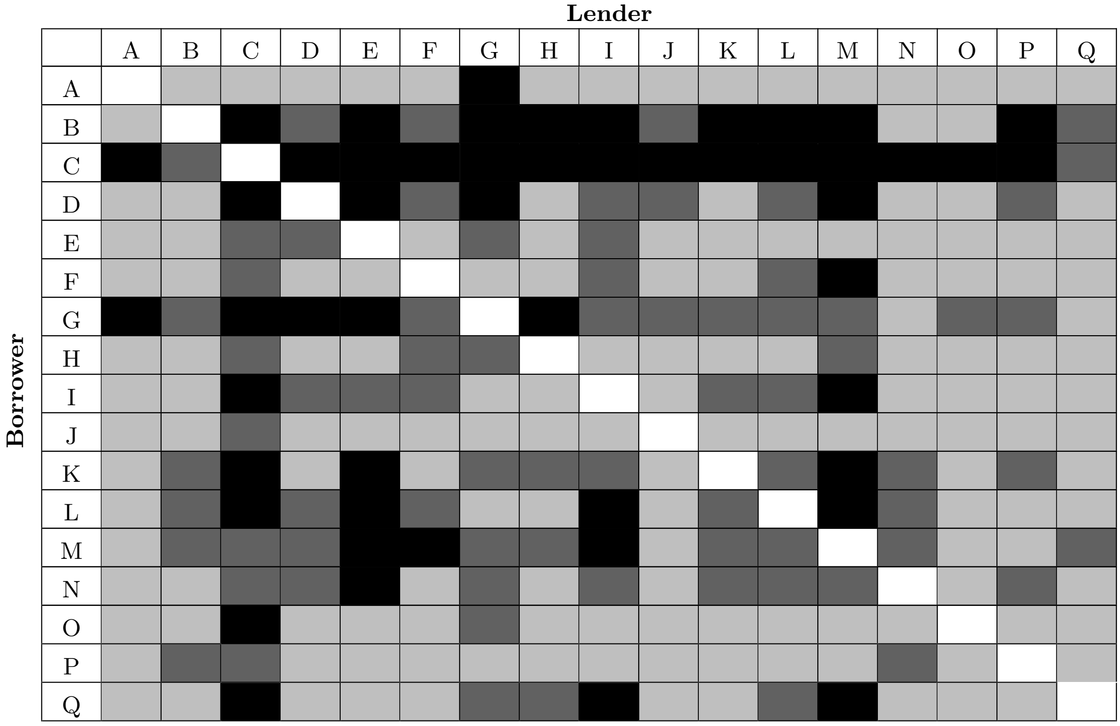
Table 4 shows the payment flow for the same directional banking relationships over the period 2012-2015. The cell values represent the number of days the net payment flow from the sender bank to the receiver bank was more than NOK 5 million. Also in this table, the numbers are categorized in a shading system for anonymity purposes. Looking again at bank C and D, we can see that both banks were frequent senders of a net flow of more than NOK 5 million to each other. This indicates that there are few days where there was a net flow of less than NOK 5 million in either direction. The table shows that the strong banking relationship is also present in the payment flow (bank A is again a strong example). For some pairs, the relationship

[14] Any transaction to or from any other bank within the sample counts. Transactions with the government, central counterparties or with Norges Bank, such as daily interest income, do not count.

[15] See Appendix A in the appendix for a sensitivity analysis on sample selection critera.

[16] There are a few occasions where the two banks within a pair borrow from each other on the same day. These observations are netted such that only one of the banks can be classified as the lender (borrower).

Table 3: ***Days with Overnight Interbank Loans by Directional Banking Relationship***

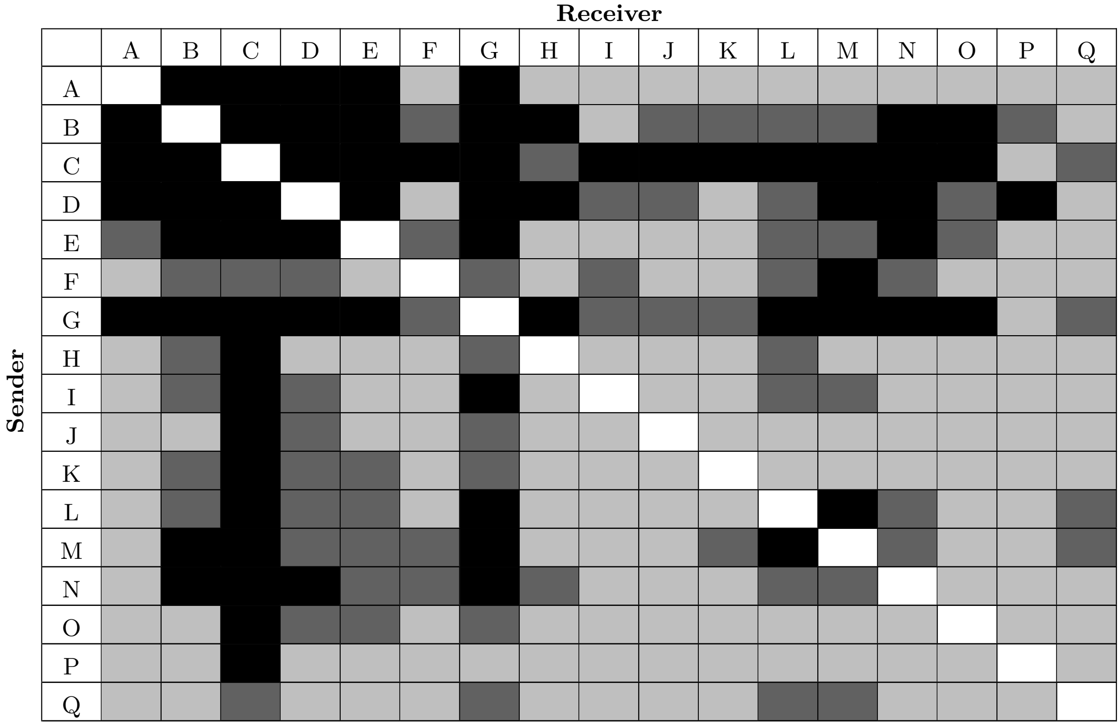


Note: Banks A and B constitute two banking relationships. One where bank A is the potential lender and bank B is the potential borrower, and another where the two banks have reverse roles. There are 999 trading dates and 17 banks that are deemed active in the interbank market and Real Time Gross Settlement System over the period 2012-2015. Light grey, grey and black indicate 0 to 5, 6 to 75 and more than 75 unsecured overnight interbank loans.

is skewed. Bank B, for example, was a frequent sender of more than NOK 5 million to bank O, while the reverse seldom happened. The table design is such that when the same cell in Table 3 and Table 4 are compared, the cell in Table 4 indicates how frequently there is a net flow from the potential borrower to the potential lender in Table 3. A strong link between these two numbers indicates that when funds is flowing in one direction, unsecured interbank loans are made in the opposite direction. The correlation coefficient between Table 3 and Table 4 is 0.46, showing that the relationship in unsecured lending is correlated with the number of incidents where the net flow of funds is more than NOK 5 million and in the opposite direction.

There are 14 directional relationships that are deemed completely inactive in this analysis as there are no transactions above NOK 100 and no interbank lending over the period. This leaves 257 752 observations for the regressions as opposed to the possible 271 728 observations ($17 \times 16 \times 999$).

Table 4: ***Days with Min. 5 million in net Transactions by Directional Banking Relationship***



Note: Banks A and B constitute two banking relationships. One where bank A is the potential sender of minimum NOK 5 million (excluding unsecured overnight interbank loans) and bank B is the potential receiver, and another where the two banks have reverse roles. There are 999 trading dates and 17 banks that are deemed active in the interbank market and Real Time Gross Settlement System over the period 2012-2015. Light grey, grey and black indicate 0 to 45, 46 to 250 and more than 250 qualifying transactions.

4.2 Unsecured Overnight Loans and Bilateral Payment Flows

The left-hand side of Table 5 shows how often an overnight interbank loan occurs for different levels of payment flows within the directional banking relationships. There are 8 406 cases in the sample where the potential borrower, within the directional banking relationship, transfers more than 0.3 of its quota to the potential lender (excluding unsecured overnight loans). In 15.1% of these cases, an unsecured overnight loan follows in the opposite direction. While this number is rather large and in favour of the hypothesis that banks use the payment flow to find a counterparty, this may well be an effect due to the direct effects on the two banks' liquidity positions.[17]

[17]Table A4 in Appendix D provides statistics on how often interbank lending occurs by different liquidity statuses within the directional banking relationships.

Table 5: ***Overnight Interbank Loans by Net Flow of Central Bank Reserves***

	Net Flow to Quota			Net Flow Others to Quota		
	Loans	Cases	%	Loans	Cases	%
$X < -0.3$	1 272	8 406	15.1	3 866	54 574	7.1
$-0.3 \leq X < 0$	3 782	48 405	7.8	2 649	69 014	3.8
$X = 0$	2 918	144 120	2.0	47	1 894	2.5
$0 < X \leq 0.3$	3 248	47 848	6.8	2 352	73 712	3.2
$0.3 < X$	854	8 963	9.5	3 160	58 548	5.4

Note: Under Net Flow to Quota, X represents the net flow of central bank reserves (excluding unsecured overnight loans) from the potential lender to the potential borrower relative to the potential borrower's liquidity ratio in Norges Bank. A negative value indicates that the potential borrower is the net sender of central bank reserves. Under Net Flow Others to Quota, X represents the net flow of central bank reserves from all other remaining banks, in the RTGS system, to the potential borrower in relations to its quota. There are 999 trading days and 17 banks resulting in 257 742 observations over the period 2012-2015.

Another explanation may be that banks with a strong relationship in terms of payment flow also have a strong relationship in the unsecured interbank market. The latter argument is supported by the rather high occurrence (9.5%) of unsecured interbank loans when the payment flow of the same size is in the opposite direction.

The right-hand side of Table 5 is structured in the same way as the left-hand side, but here the payment is to all other remaining banks outside the specific directional relationship. We can see that when the aggregate net payment flow to other banks is more than 0.3 of the potential borrower's quota, an unsecured overnight loan occurs within the relationship in 7.1% of the cases. This is about half compared to when the payment flow is directly to the potential lender. This may be because the potential lender receives excess funds from the other banks as a second-round effect and therefore has a placement need.

In Section 5, I show that when controlling for liquidity positions, relationship effects and payment flow to other banks, a bank with outflows is indeed more likely to borrow from the bank with corresponding inflows.

4.3 Are Payment Flows Informative for Liquidity Positions?

So far, I have implicitly assumed that there is a one to one relationship between bilateral payment flows and the respective liquidity positions at the two banks. Meaning that if bank A sends one unit of reserves to bank B, then bank B should on average hold one additional unit of reserves in net liquidity at end of day. However, this may not be trivial as there may be mechanisms in the banking system that affect the distribution of reserves. For example, if bank A sends bank B a large amount of reserves, could that mean that bank A also sends large amounts to other banks on that day? This could for example occur if bank A has a large corporate client that settles outstanding debt to several different creditors (with accounts at different banks) on the same date. In other words, what information can the counterparty obtain from the bilateral payment flow? In this subsection I test this assumption. Consider the following regression

$$\frac{Liquidity_{i,t}}{Quota_{i,t}} = a_i + \beta \frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} + \epsilon_{i,t} \tag{2}$$

where $\frac{Liquidity_{i,t}}{Quota_{i,t}}$ is bank i's net liquidity to quota at end of day and $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}}$ is the bilateral net payment flow of reserves from bank j to bank i, also as a ratio to bank i's quota. Both these variables are excluding unsecured overnight interbank loans. a_i are bank fixed effects to allow the banks to have individual liquidity preferences over time. If $\beta > 1$, it implies that when bank i is the net sender of flows to bank j, bank i is also a net sender on average to the other banks. If $\beta = 1$, it implies that the bilateral flow between bank i and j has no affect on bank i's net flow with the other banks. If $\beta < 1$, it implies that when bank i sends funds to bank j, bank i receives reserves on average from the remaining banks. If $\beta = 0$, then the bilateral payment flow has no information regarding the counterparty's liquidity position. While one may initially expect $\beta = 1$, banks are regularly offered short-term deposit and loan auctions by the central bank. In this case, one may expect $\beta < 1$.

Table 6 displays the result of regression (2). The coefficient for $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}}$ of 0.131

Table 6: *Liquidity and Flow of Reserves*

	$\frac{Liquidity_{i,t}}{Quota_{i,t}}$	$\frac{Liquidity_{i,t}}{Quota_{i,t}}$
$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$	0.131*** (0.023)	
$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} < -0.3$		0.096*** (0.011)
$-0.3 \leq \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} < 0$		0.329*** (0.053)
$0 \leq \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} < 0.3$		0.311*** (0.056)
$0.3 \leq \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$		0.152*** (0.022)
Cons.	0.769*** (0.002)	0.768*** (0.002)
Bank FE	YES	YES
Observations	257 742	257 742
No. of Banks	17	17
R-Squared	0.313	0.313
Within R-Squared	0.002	0.002

Notes: $\frac{Liquidity_{i,t}}{Quota_{i,t}}$ is bank i's net liquidity position relative to its quota in Norges Bank at the end of day t. $\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$ is the bilateral net flow of central bank funds from bank j to bank i. All values are net of overnight interbank loans. Robust standard errors in parentheses. Three asterisks indicate $p < 0.01$ while two indicate $p < 0.05$ and one indicates $p < 0.10$.

is significant and different from zero. This implies that if bank j sends (receives) reserves equivalent to one quota through the day to bank i, bank i's liquidity position is increased (reduced) by 0.131 quota at end of day. While the results confirm that payment flows are informative for liquidity positions, the coefficient is also about 38 standard errors away from 1. This may be explained by market operations by the central bank, the sample of banks being a net receiver or net sender of payment flow to or from smaller banks outside the sample, and by transactions to and from the government's account. The coefficient may also suffer from a negative bias. Even though net liquidity is net of interbank trading, I am not able to control for other types of reserve trading. In the Norwegian case, it is not unlikely that when a bank receives (sends) a large amount of reserves, it lends (borrows) the same amount through an FX swap. If the FX swap is made with a third party, then there will be a negative bias for the coefficient for $\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$.[18]

[18] If the FX swap is made within the relationship, the FX transaction will net out in

In the second column in Table 6, $\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$ is split into four groups based on size to allow for a non-linear relationship in the informativeness of payment flow. Net flows from bank j to bank i below -0.3 quotas, between -0.3 and 0 quotas, between 0 and 0.3 quotas and above 0.3 quotas are all significant at the 1% level. However, one unit of net flow between -0.3 and 0.3 quotas affects bank i's liquidity position by 0.31 to 0.33 units, more than twice the affect from the first model in Table 6. The coefficient for large negative flows from bank j to bank i has a lower value of about 0.10, and the coefficient for large positive flows from bank j to bank i has a value of about 0.15. I conclude that the bilateral payment flow is informative about the counterparty's liquidity position.

5 Main Results

Table 7 displays the results of panel regression 3. The dependent variable, $Loan(j \to i)_t$, is a binary variable equal to one if there is an unsecured overnight interbank loan from bank j to bank i on day t and zero otherwise. The panel is set up such that there is one potential observation for each directional banking relationship per day. Daily fixed effects, d_t, are included to control for varying market conditions, such as market turmoil, policy meetings, calendar effects and trading activity by the central bank. Quarterly directional banking relationship fixed effects, $a_{j,i,q}$, are included to account for directional banking relationships, but also to account for quarterly updated bank characteristics, such as accounting and performance statistics from the banks' quarterly reports.

$$Loan(j \to i)_t = a_{j,i,q} + d_t + \beta_1 \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} + \beta_2 \frac{Liquidity_{i,t}}{Quota_{i,t}} + \beta_3 \frac{Liquidity_{j,t}}{Quota_{j,t}} + \epsilon_{j,i,t} \qquad (3)$$

The emphasis in this analysis is on the variable $\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$, which is the daily net flow of funds from the potential lender, bank j, to the potential borrower, bank

$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$.

Table 7: *Overnight Interbank Loans on Net Flow and Liquidity*

	$Loan(j \rightarrow i)_t$	$Loan(j \rightarrow i)_t$	$Loan(j \rightarrow i)_t$
$\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}}$	-0.017***	-0.017***	0.003
	(0.002)	(0.002)	(0.002)
$\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} \times B_{i,t}$			-0.032***
			(0.007)
$\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} \times P_{j,t}$			-0.035***
			(0.006)
$\frac{\sum_{k \neq j} Net\ Flow(k \rightarrow i)_t}{Quota_{i,t}}$		0.002***	0.002***
		(0.001)	(0.001)
$\frac{Liquidity_{i,t}}{Quota_{i,t}}$	-0.033***	-0.034***	-0.034***
	(0.001)	(0.001)	(0.001)
$\frac{Liquidity_{j,t}}{Quota_{j,t}}$	0.041***	0.041***	0.041***
	(0.001)	(0.001)	(0.001)
Cons.	0.041***	0.041***	0.041***
	(0.001)	(0.001)	(0.001)
Relationship FE (quart.)	YES	YES	YES
Date FE	YES	YES	YES
Observations	257 742	257 742	257 742
No. of Banks	17	17	17
R-Squared	0.307	0.307	0.308
Within R-Squared	0.065	0.065	0.066

Note: $Loan(j \rightarrow i)_t$ is a binary variable equal to one if there is an unsecured overnight loan of central bank reserves from bank j to bank i on day t. $B_{i,t}$ is a binary variable equal to one if the potential borrower (bank i) has negative net liquidity and thus a borrowing need at day t. Similarly, $P_{j,t}$ is a binary variable equal to one if the potential lender (bank j) has more than one quota in net liquidity and thus a placement need at day t. Robust standard errors in parentheses. Three asterisks indicate $p < 0.01$ while two indicate $p < 0.05$ and one indicates $p < 0.10$.

i, normalized by the potential borrower's quota. The interesting observations are when the variable takes a negative value, meaning the net payment flow of funds is from bank i to bank j. The net flow of funds excludes unsecured overnight interbank loans. If bank j is reluctant to lend to bank i (or bank i is reluctant to borrow from bank j) following a flow of funds from bank i to bank j, the coefficient is expected to be positive, indicating a form of peer monitoring. If it is more likely that bank i borrows from bank j after transferring funds to bank j, the coefficient is expected to be negative and indicate that banks are minimizing search costs. The first regression in Table 7 shows that the coefficient on $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}}$ is -0.017 and significant at the 1% level. That is, if bank i is a net sender of an amount worth one quota to bank j, a loan is 1.7% more likely to occur in the opposite direction. I also control for the liquidity positions net of interbank loans for the potential borrower, $\frac{Liquidity_{i,t}}{Quota_{i,t}}$, and the potential lender, $\frac{Liquidity_{j,t}}{Quota_{j,t}}$, to their respective quotas. The results confirm that a bank with more liquidity is more likely to be a lender and a bank with less liquidity is more likely to be a borrower.

Turning to the second regression in Table 7, the variable $\frac{\sum_{k \neq j} Net\ Flow(k \rightarrow i)_t}{Quota_{i,t}}$ is introduced. This represents the net payment flow received by bank i from all other banks in the sample (all banks except bank j). We can see that when this variable is negative (an outflow from bank i), the probability that bank i will borrow from bank j is reduced. That is, if bank i is a net sender of one quota worth of funds to all other banks (except bank j), bank i is 0.2% less likely to borrow from bank j. This confirms the previous result indicating that the bank prefers borrowing from a bank to which it has sent reserves.

In the third regression in Table 7, $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} \times B_{i,t}$ and $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} \times P_{j,t}$ are introduced to differentiate between situations where the potential borrower has a real borrowing need and when the potential lender has a real placement need. $B_{i,t}$ and $P_{j,t}$ are binary variables equal to 1 if the potential borrower has a negative liquidity position and if the lender has a liquidity position above one quota, respectively. We can see that both these coefficients are highly significant, and with magnitudes about twice the size compared to the coefficient for $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}}$ in the first regression specification. A transfer from bank i to bank j worth one quota is associated with a 3.2-3.5% increased likelihood of a loan in the opposite direction if one of the banks has a real need to trade. We can also see that in the remaining situations, where none of the counterparties has an outright need to trade, the coefficient is no longer significant.

The results displayed in Table 7 show that banks use payment flow to choose a trading partner. When a bank analyze the bilateral payment flow with other banks, it can use this information to make an educated guess in finding a counterparty with the opposite liquidity need and thereby reduce search costs.[19] A model specification that allows for non-linearity in net flow variables and in net liquidity variables is offered in Section B.

6 Asymmetric Information and Pricing of Loans

The results presented above suggest that banks use bilateral payment flow to reduce search costs to find a counterparty in the unsecured overnight interbank market. The probability of bank j lending to bank i is higher following an outflow of reserves from bank i to bank j (after controlling for liquidity positions and directional banking relationship effects). This implies that bank i is not punished for "revealing" a negative signal about its liquidity position, but rather rewarded by an easier matching process in the search for a liquidity provider.

However, it may be that pricing of loans is sensitive to bilateral flow of funds. The benefit of reduced search costs may be lost in unfavourable pricing. It is possible that, due to asymmetric information, a bank with a liquidity shortage that has also revealed a negative signal (bank i) has limited options other than trading with the observer of the signal (bank j). The observer can analyze the size and nature of the bilateral flow of funds and thus have an informational advantage compared to all other potential lenders. All other potential lenders, who have not observed a signal, may then be unwilling to lend. An uniformed lender, pricing loans at average risk, will only get to lend if the borrowing bank doesn't have a better offer. This implies

[19] In the results displayed in Table 7, the dependent variable is a binary variable for whether a loan takes place within the directional relationship or not. However, while the banks may use net flow of funds to reduce search costs, they may at the same time reduce volumes to contain credit risk. In a similar regression, I regress $\frac{Volume(j \to i)}{Quota_{i,t}}$, which is the loan volume for those observations where there is an actual loan from bank j to bank i in relation to bank i's quota, on $\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$ and net liquidity positions for the two banks. I find that for every one quota sent from bank i to bank j, the loan from bank j to bank i increases by 0.014 quotas. The coefficient is significant at the ten percent level. When splitting $\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$ into groups based on size, I find that for large net flow of funds (higher than 0.5 quota), there is a stronger relationship between net flow and lending volume. For every one unit of NOK above 0.5 quota sent from bank i to bank j, the lending volume from bank j to bank i increases by 0.028 NOK. The relationship is significant at the five percent significance level. The relationship is, however, not significant for smaller payment flows.

Table 8: ***Overnight Interbank Premium on Net Flow and Liquidity***

	$ii_{i,j,t}$
$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$	0.574
	(0.379)
$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} \times B_{i,t}$	-0.420
	(0.311)
$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} \times P_{j,t}$	-0.130
	(0.303)
$\frac{\sum_{k \neq j} Net\ Flow(k \to i)_t}{Quota_{i,t}}$	0.049
	(0.051)
$\frac{Liquidity_{i,t}}{Quota_{i,t}}$	-0.559***
	(0.077)
$\frac{Liquidity_{j,t}}{Quota_{j,t}}$	-0.537***
	(0.053)
Cons.	-1.403***
	(0.123)
Relationship FE (quart.)	YES
Date FE	YES
Observations	11 922
No. of Banks	17
R-Squared	0.785
Within R-Squared	0.024

Note: $ii_{i,t}$ is the premium relative to the key policy rate paid by bank i, borrowing central bank reserves unsecured overnight from bank j, in basis points at day t. *Borr.* is a binary variable equal to one if the potential borrower (bank i) has negative net liquidity and thus a borrowing need. Similarly, *Place.* is a binary variable equal to one if the potential lender (bank j) has more than one quota in net liquidity and thus a placement need. Robust standard errors in parentheses. Three asterisks indicate $p < 0.01$ while two indicate $p < 0.05$ and one indicates $p < 0.10$.

a winning curse phenomena, and the uninformed lenders may be better off staying out of the market. In other words, the informed counterparty may have some market power and charge higher interest rates. This logic is inspired by models on asymmetric information such as the model on relationship banking and asymmetric information by Sharpe (1990) and von Thadden (2004).

While a net flow of funds from bank i to bank j increases the probability of a loan from bank j to bank i regardless of whether there is a borrowing need for bank i, a placement need for bank j, or both, the effect, if any, on pricing is more complex. If the counterparty makes use of the information advantage, a signal indicating a borrowing need should translate into a higher spread, while a signal indicating a placement need should translate into a lower spread. Table 8 displays results from a regression setup similar to the third regression in Table 7 in Section 5. The dependent variable is now the spread, $ii_{i,j,t}$, between the interest rate on a loan from bank j to bank i and Norges Bank's key policy rate at time t. The coefficients for the variables $\frac{Net\ Flow(j \to i)_t}{\text{Quota}_{i,t}}$, $\frac{Net\ Flow(j \to i)_t}{\text{Quota}_{i,t}} \times B_{i,t}$, $\frac{Net\ Flow(j \to i)_t}{\text{Quota}_{i,t}} \times P_{j,t}$ and $\frac{\sum_{k \neq j} Net\ Flow(k \to i)_t}{Quota_{i,t}}$ are not significant.

The coefficients for $\frac{Liquidity_{j,t}}{Quota_{j,t}}$ and $\frac{Liquidity_{i,t}}{Quota_{i,t}}$ are still significant and with the expected negative signs. An increase in liquidity by one quota, either by bank i or bank j, reduces the spread by 0.53 - 0.60 basis points.

The results in Table 8 indicate that the bilateral payment flow is not a driver of prices for unsecured overnight interbank loans. While it could be that banks were forced to trade with informed counterparties at unfavourable prices rather than reducing search costs, these results support the conclusion above that banks use the bilateral net flow of funds to reduce search costs and are not penalized when sending negative signals.[20]

7 Conclusion

This paper investigates whether banks use the payment flow of central bank reserves to conduct peer monitoring or rather to reduce search costs before making trading decisions in the unsecured overnight interbank market. The payment flow represents a signal about the banks' net liquidity positions (net of unsecured overnight interbank loans), and the banks use this signal to find a counterparty and thereby

[20] A potential drawback of the statistical method presented in Table 8 is that the decision to participate in an unsecured overnight interbank loan may not be independent of the spread. Participation is likely positively correlated with the spread for the lender and negatively correlated with the spread for the borrower. Furthermore, Table 7 provides evidence that the bilateral net flow of funds from bank j to bank i reduces the probability for each of the banks of participating in a loan from bank j to bank i. Thus, the lender's decision is likely to cause a downward bias on the coefficients for the variables related to the bilateral net flow of funds. On the other hand, the borrower's decision is likely to cause an upward bias on the same coefficients. The magnitudes of these biases and whether they cancel each other out are unclear. One could address the selection bias using the Heckman approach (see Heckman (1976) and Heckman (1979)), but it would be challenging to include the relationship fixed effects necessary in this analysis (see Table 3).

reduce search costs. The analysis disentangles the signalling effect and the direct liquidity effects of the payment flow. I have also opened up for the possibility that the bilateral payment flow affects the pricing of loans and that the banks are not reducing search costs, but are rather trapped within a banking relationship and face unfavourable pricing due to asymmetric information. In Section 6, I provide results indicating that this is not the case, and the conclusion is robust to the inclusion of pricing. Furthermore, the descriptive statistics provided in Section 4 shed some light on the high prevalence of banking relationships in the interbank market. If banks are mostly interested in reducing search costs, it makes sense that they prefer trading within existing relationships.

Overall, the results indicate that banks in a decentralized interbank market use the payment flow of central bank reserves to reduce search costs, rather than to assess counterparty risk. In isolation, this is an argument to reorganize the unsecured overnight interbank market into a centralized system with collateral and anonymous participants for a more effective distribution of liquidity.

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A Robustness Sample Size

The analysis above is sensitive to the chosen sample of banks. About 130 banks had an account with Norges Bank in the sample period. Several of these banks were inactive and held an account for contingency purposes. There were 29 banks that participated at least once, either as lender, borrower or both, in an unsecured overnight interbank loan. There are large disparities within the 29 banks when it comes to both participating in the unsecured overnight interbank market and in general transaction activity on their accounts with Norges Bank. Table A1 displays some activity measures for the 29 banks. The average bank had almost 60 transactions per day on their accounts over the period 2012 - 2015, while the 10th and 25th and 50th percentile only had 0.86, 1.87 and 7.35 transactions. The 90th percentile had more than 180.[21] There are similar skewed distributions in the daily number of unsecured overnight interbank market transactions. On average the banks participated in 0.46 loans per day. The 10th, 25th, 50th and 90th percentile lent 0.00, 0.04, 0.28 and 0.93 times per day. Similarly, the 10th, 25th, 50th and 90th percentile borrowed 0.00, 0.01, 0.10 and 1.54 times per day.

In the analysis above, all banks were required to have an average of at least three general transactions on their account per day to avoid including inactive banks. In Table A2, I mimic the third regression in Table 7 above, but with a larger sample without any lower criteria for general transactions and a smaller sample where each bank must have minimum of ten general transactions. The sample then consists of 29 and 13 in the two regressions. When allowing the sample to include more inactive banks, the coefficients for the net flow of funds variables are no longer significant.[22] Among the 29 banks, there are several relationships that are automatically excluded from the regression as there are no transactions or loans over the period. If no relationships were excluded, one would expect $29 \times (29-1) \times 999 = 811\ 188$ observations

[21] All transactions below NOK 100 (about EUR 10) are set to zero.

[22] I also test the added 12 banks in isolation and obtain similar insignificant results. This confirms that this new result is due to a larger sample with inactive participations rather than opposite behaviour by the added banks.

Table A1: ***Distribution Account Activity - Wide Sample***

		Percentiles				
	Mean	**10**	**25**	**50**	**75**	**90**
General Transactions	59.74	0.86	1.87	7.35	46.29	180.13
Borrowing Transactions	0.46	0.00	0.01	0.10	0.60	1.54
Lending Transactions	0.46	0.00	0.04	0.28	0.60	0.93

Note: General transactions are the daily average of all transactions worth at least NOK 100 (about EUR 10) registered on each bank's account with Norges Bank. Borrowing and lending transactions are the averages of how many times each bank has borrowed and lent in the unsecured overnight interbank market per day. The sample consists of the 29 banks that have at least been involved in one unsecured overnight interbank loan over the period 2012-2015.

as opposed to the 457 353 observations from the regression.[23] Similar results, both in magnitude and significance, as in Table 7, are obtained for the second regression with a smaller sample. There are also exactly as many observations in this regression as one would expect, meaning there are no inactive relationships.

By including banks that are nearly inactive, the results are no longer significant. However, the analysis is meant to measure how active banks behave in the Norwegian interbank market. The results are robust to reducing the sample size.

B Robustness Non-Linearity in Payment Flows

One could argue that the results obtained in Table 7 in Section 5 would be different if one allows for non-linearity in the variables. The second regression presented in Table 6 in Section 4.3 provides evidence that the information $\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}}$ reveals is depending on its size. While it is unclear to what extent the counterparty is aware of how much information payment flows provide, it is nevertheless useful to allow for non-linearity in payment flows on the probability for a loan to take place. Furthermore, while results presented above indicate that banks are using payment flow to reduce search cost, it may be that the lending bank (bank j) is more or less reluctant lending following a large payment. On one side, a large payment flow

[23]Some observations are also missing due to some days with missing liquidity reports from the smaller inactive banks.

Table A2: ***Overnight Interbank Loans on Net Flow and Liquidity***

	$Loan(j \rightarrow i)_t$	$Loan(j \rightarrow i)_t$
$\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,j}}$	-0.001	0.004*
	(0.002)	(0.002)
$\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} \times B_{i,t}$	0.007	-0.031***
	(0.006)	(0.006)
$\frac{Net\ Flow(j \rightarrow i)_t}{Quota_{i,t}} \times P_{j,t}$	-0.000	-0.032***
	(0.004)	(0.006)
$\frac{\sum_{k \neq j} Net\ Flow(k \rightarrow i)_t}{Quota_{i,t}}$	0.007***	0.002***
	(0.001)	(0.001)
$\frac{Liquidity_{i,t}}{Quota_{i,t}}$	-0.013***	-0.042***
	(0.001)	(0.001)
$\frac{Liquidity_{j,t}}{Quota_{j,t}}$	0.011***	0.050***
	(0.002)	(0.001)
Cons.	0.033***	0.031***
	(0.001)	(0.001)
Relationship FE (quart.)	YES	YES
Date FE	YES	YES
Observations	457 353	155 844
No. of Banks	29	13
R-Squared	0.282	0.326
Within R-Squared	0.019	0.081

Note: $Loan(j \rightarrow i)_t$ is a binary variable equal to one if there is an unsecured overnight loan of central bank reserves from bank j to bank i on day t. $B_{i,t}$ is a binary variable equal to one if the potential borrower (bank i) has negative net liquidity and thus a borrowing need at day t. Similarly, $P_{j,t}$ is a binary variable equal to one if the potential lender (bank j) has more than one quota in net liquidity and thus a placement need at day t. Robust standard errors in parentheses. Three asterisks indicate $p < 0.01$ while two indicate $p < 0.05$ and one indicates $p < 0.10$.

from bank i to bank j could be used as a strong signal reducing search costs for a counterpaty. On the other side, while bank j would normally use a payment from bank i to reduce search costs, it may, for larger sums, be reluctant to lend as a large payment flow may reveal a negative signal about bank i's riskiness. From Table A3, we can see that a net flow of funds from bank j to bank i of less than -0.3 quotas (positive flows bank i to bank j) indicates an increased probability of about 2.4% for each quota sent. The relationship is significant at the one percentage significance level. This is a stronger result than provided in the first model specification in Table 7 in Section 5 of 1.7%. Furthermore, net flows of size between -0.3 and 0 quotas of the same sum would increase the probability for a loan with about 2.9%. However, only significant at the ten percent level. Positive flows (when bank j is the sender) up to 0.3 quotas similarly reduces the probability by about 3.3%, significant at the five percent level. Large positive net flows above 0.3 quotas are associated with a 1% reduction in probability for a loan from bank j to bank i for each amount worth one quota, significant at the one percent level. Net flows to all other banks are significant for levels below -0.3 quotas and above 0.3 quotas. The net liquidity to quota variables at day-end for bank i and bank j are also grouped by size. Bank i's net liquidity to quota is significant at the one percentage level for all groups of liquidity. However, the negative relationship between liquidity and the probability of borrowing from bank j is increasing in the borrowing need for bank i. Bank j's net liquidity to quota is strong and significant when bank j has excess liquidity, and thereby a placement need. Bank j's liquidity is less important, although strongly significant for lower levels. Im sum, allowing for net flow and net liquidity variables to affect the probability for a loan from bank j to bank i in a non-linear relationship does not alter the results above.[24]

C Distribution Gross Liquidity at Close

The histogram in figure A1 displays the distribution of net liquidity at end-of-day for the 17 banks in the sample over the 999 trading days resulting in 16 983 observations. Each bar represents the percentage of total observations that are within brackets of 0.25 quotas. There are 17 extreme observations between 6.0 and 15.5 quotas not shown in the graph for readability. In 48.9 % of the cases, the banks have net liquidity worth between 0 and 1 quota, indicating that no action is required to avoid using the standing facilities with Norges Bank. 33.2 % of the observations are above one quota (15.1 % between 1 and 1.5) and 17.9 % below the quota.

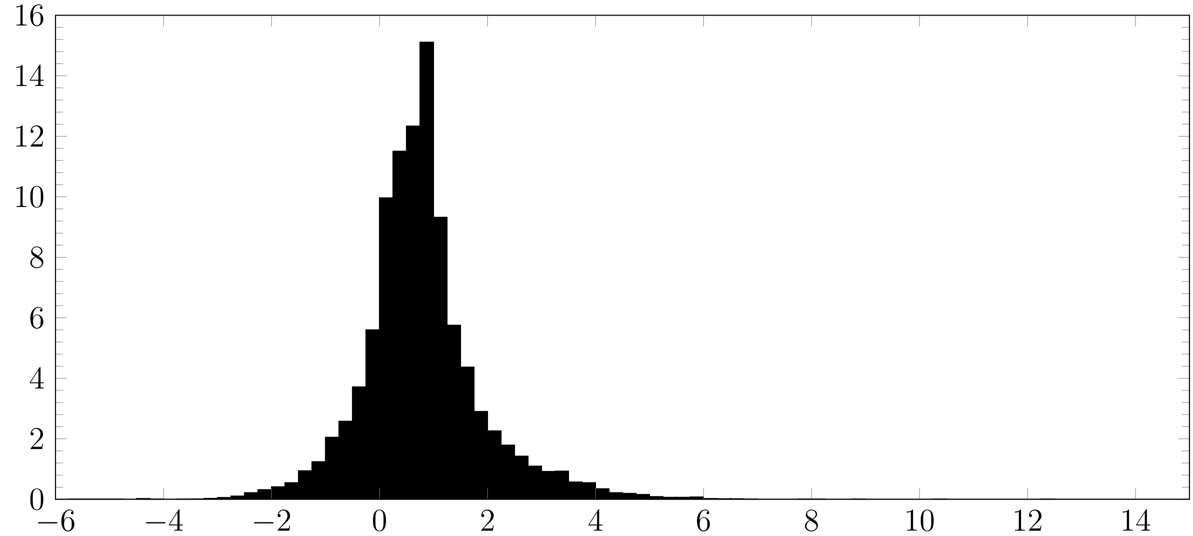
[24] A model specification without relationship fixed effects is also tested, but due to the clear relationship between banks with high occurrence of payment flows and between banks with high occurrence of unsecured interbank loans (see Section 4.1), those results suffer from an omitted variable bias and inflate the results. Similarly, a model without testing for liquidity with the sender and with the receiver produce inflated coefficients.

Table A3: ***Overnight Interbank Loans on Net Flow and Liquidity***

	$Loan(j \to i)_t$
$\frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} < -0.3$	-0.024*** (0.004)
$-0.3 \leq \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} < 0$	-0.029* (0.015)
$0 \leq \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}} < 0.3$	-0.033** (0.015)
$0.3 \leq \frac{Net\ Flow(j \to i)_t}{Quota_{i,t}}$	-0.010*** (0.003)
$\frac{\sum_{k \neq j} Net\ Flow(k \to i)_t}{Quota_{i,t}} < -0.3$	0.002*** (0.001)
$-0.3 \leq \frac{\sum_{k \neq j} Net\ Flow(k \to i)_t}{Quota_{i,t}} < 0$	-0.000 (0.006)
$0 \leq \frac{\sum_{k \neq j} Net\ Flow(k \to i)_t}{Quota_{i,t}} < 0.3$	0.004 (0.005)
$0.3 \leq \frac{\sum_{k \neq j} Net\ Flow(k \to i)_t}{Quota_{i,t}}$	0.002** (0.001)
$\frac{Liquidity_{i,t}}{Quota_{i,t}} < 0$	-0.070*** (0.002)
$0 \leq \frac{Liquidity_{i,t}}{Quota_{i,t}} < 0.5$	-0.063*** (0.004)
$0.5 \leq \frac{Liquidity_{i,t}}{Quota_{i,t}} < 1.0$	-0.048*** (0.002)
$1.0 \leq \frac{Liquidity_{i,t}}{Quota_{i,t}} < 1.5$	-0.045*** (0.001)
$1.5 \leq \frac{Liquidity_{i,t}}{Quota_{i,t}}$	-0.021*** (0.001)
$\frac{Liquidity_{j,t}}{Quota_{j,t}} < 0$	0.007*** (0.001)
$0 \leq \frac{Liquidity_{j,t}}{Quota_{j,t}} < 0.5$	0.002 (0.003)
$0.5 \leq \frac{Liquidity_{j,t}}{Quota_{j,t}} < 1.0$	0.005*** (0.001)
$1.0 \leq \frac{Liquidity_{j,t}}{Quota_{j,t}} < 1.5$	0.049*** (0.001)
$1.5 \leq \frac{Liquidity_{j,t}}{Quota_{j,t}}$	0.051*** (0.001)
Cons.	0.038*** (0.002)
Relationship FE (quart.)	YES
Date FE	YES
Observations	257 742
No. of Banks	17
R-Squared	0.321
Within R-Squared	0.084

Notes: $Loan(j \to i)_t$ is a binary variable equal to one if there is an unsecured overnight loan of central bank reserves from bank j to bank i on day t. Robust standard errors in parentheses. Three asterisks indicate $p < 0.01$ while two indicate $p < 0.05$ and one indicates $p < 0.10$.

Figure A1: ***Distribution of net Liquidity to Quota at End of Day***



Note: There are 17 banks and 999 trading days over the period 2012-2015 resulting in 16 983 observations. Each bar is 0.25 quota wide and the y axis is the total percentage of observations that falls within this quota interval.

D Unsecured Overnight Loans and Liquidity Positions

Table A4: ***Overnight Interbank Loans by Liquidity Status***

	Potential Lender					
Potential Borrower	$X < 0$	$0 \leq X < 0.5$	$0.5 \leq X < 1$	$1 \leq X < 1.5$	$1.5 \leq X$	Total
$X < 0$	4.4	4.3	5.1	21.4	44.6	14.8
$0 \leq X < 0.5$	0.8	0.6	0.9	7.6	18.5	4.8
$0.5 \leq X < 1$	0.5	0.4	0.5	4.0	9.2	2.5
$1 \leq X < 1.5$	0.2	0.2	0.4	1.6	2.4	0.9
$1.5 \leq X$	0.1	0.2	0.2	2.0	2.1	0.8
Total	1.1	1.1	1.3	7.2	15.9	

Note: All numbers are percentages and represent how often overnight interbank loans occur grouped by different liquidity combinations between the potential lender and borrower. Potential lenders in first row and potential borrowers in first column. X represents total net reserves excluding overnight interbank loans as a ratio to the bank's liquidity quota at Norges Bank. One pair of banks constitutes two directional banking relationships where each bank takes the role as either the borrower or the lender. There are 17 individual banks and 999 trading days resulting in 257 742 observations over the period 2012-2015 after excluding 14 directional relationships without any activity in the period.