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Research Paper

Networks and lending conditions: empirical evidence from the Swiss franc money markets

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ABSTRACT

This paper provides an empirical analysis of the network characteristics of two interrelated interbank money markets and their effect on overall market conditions. Based on transaction data from the unsecured and secured Swiss franc money markets, the trading network structures are assessed before, during and after the financial market crisis. It can be shown that banks in the unsecured market are connected to a lower number of counterparties but rely heavily on reciprocal and clustered trading relationships. The corresponding network structure likely favored the exchange of liquidity prior to the financial market crisis but may have also led to a lower resilience of the unsecured market. There is empirical evidence that conditions in both sub-markets were significantly driven by the individual network position of banks. The network topology likely affected the shift observed from unsecured to secured lending and the increase in risk premiums for unsecured lending during the financial market crisis. This paper therefore provides further evidence of the functioning of interbank money markets, especially the impact of market participants' interconnectedness.

Keywords: repo transaction; unsecured interbank money market; financial market turmoil; financial stability; Switzerland.

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1 INTRODUCTION

Interbank money markets are a key factor in the efficient allocation of liquidity within the banking system. Broadly speaking, banks exchange central bank reserve balances through interbank money markets. That is, banks with excess liquidity transfer reserves to banks with a liquidity shortage (see, for example, Heider *et al* 2015; Mancini *et al* 2016). A failing interbank market can lead to an inefficient allocation of money and, consequently, impair the whole financial system as well as the real economy. If the liquidity is, for example, not where it can be used most efficiently, the financial intermediation to households and firms can be impaired (see, for example, Acharya and Merrouche 2010). Disruptions in the interbank money market can, at an extreme, even lead to bank runs (see, for example, Afonso *et al* 2011). Interbank money markets can therefore be seen as an important ingredient in the proper functioning of financial markets.

Banks typically exchange liquidity either on a secured basis (in the so-called secured or repurchase agreement (repo) market) or on an unsecured basis (in the so-called unsecured market). In the unsecured market, no collateral is involved, while in the secured market, liquidity is exchanged against high-quality securities as collateral. In contrast to secured transactions, unsecured money market transactions do not involve the opportunity cost for the cash taker of the securities involved. That is, the unsecured money market serves as an actual funding source for banks, as no initial endowment is required. However, an unsecured transaction is only concluded if the cash provider has faith in the cash taker that the liquidity will be returned. With increasing risk perception, the price for unsecured borrowing can rise. Secured transactions, in contrast, are considered safer, as the collateral obtained can be liquidated by the cash provider if the cash taker defaults. However, to conclude a repo transaction, the cash taker needs to be endowed with unencumbered securities.

It is of particular interest to understand how shocks in the interbank market evolve and whether the interbank market mitigates or amplifies shocks to individual banks or the banking sector as a whole. Likewise, it is important to gain a comprehensive understanding of the drivers of the ability and willingness of market participants to fund themselves in the unsecured or secured market. A comprehensive understanding of interbank money markets is crucial for central bankers, as a well-functioning money market is essential for the effectiveness of the monetary transmission mechanism.

During the financial market crisis of 2007–9, several interbank money markets across the global financial system were indeed impaired. At the height of the crisis, a strong increase in the risk premiums for unsecured loans and, in some jurisdictions, even a freeze in market activity was observed (see, for example, Hördahl and King 2008). The US repo market experienced a so-called run on repo, which was characterized by heavily increasing haircuts on repo transactions and, accordingly, the inability to use certain asset classes as collateral (see, for example, Gorton and Metrick 2011). Turbulence in the Swiss franc money market was not as severe as in other money markets. However, a significant shift in market activity from the unsecured to the secured money market was observed; this was accompanied by increased risk premiums for unsecured money market transactions.

Presumably, the lack of trust in counterparties led to decreased market activity in the unsecured Swiss franc money market and increasing risk premiums for unsecured loans during the financial market crisis (Guggenheim *et al* 2011). The interconnectedness of market participants was apparently an important driver for the dispersion of such market tensions. If interconnectedness indeed plays an important role in lending conditions in money markets, the significance of a single market participant cannot be discerned solely by examining an institution in isolation. Instead, it is its position in a web of relationships that has to be considered, especially in times of high uncertainty and lack of counterparty confidence (Gabrieli 2012). An analysis of network characteristics, therefore, can entail important information on the functioning of relationship patterns within different markets, which in turn can provide information on the dispersion of shocks in the according markets.

The economic literature has shown that trading relationships and the interconnectedness of banks can influence the functioning of interbank money markets. Furfine (1999b), for example, finds that banking relationships affect the pricing of federal funds transactions, especially for small market participants. Cocco *et al* (2009) find evidence that in the Portuguese interbank money market, banks with large imbalances in liquidity reserves, small banks, banks with poor performance and banks with high volatility in liquidity shocks are more likely to borrow funds from banks with which they share a relationship. Further, Kraenzlin and von Scarpatetti (2011) find evidence for price differentiation in the Swiss franc repo market due to differences in the centrality scores and bargaining power of market participants as well as private information. Similarly, Bräuning and Fecht (2012) find that relationship lending can significantly affect the access to liquidity by improving private information about counterparties. Hence, failed relationships can lead to a loss of valuable information and thus hinder access to liquidity for borrowers. Allen *et al* (2012) find that market participants in the Canadian dollar market continued to support counterparties with high credit risk during the financial market crisis due to the tight interconnectedness of, and, hence, high contagion risk among, Canadian banks. Finally, Gabrieli (2012) examines the Italian unsecured interbank money market and finds evidence that measures of interconnectedness can capture part of the cross-sectional variance in interbank rates.

The aim of this paper is to examine interconnectedness in two different interbank sub-markets. It thus adds to the literature by providing empirical evidence of the influence of market participants' interconnectedness across sub-markets by conducting a thorough analysis of the networks in the two interrelated markets and estimating their effect on overall market conditions. In the first step, based on a comprehensive data set consisting of transactions of both the secured and unsecured Swiss franc money market, the network topology of two sub-markets that share a large number of market participants and common institutional features are simultaneously assessed and compared. The characteristics of the networks should tell us, how, according to the theoretical literature, shocks affect the market. In the second step, the impact of network characteristics on market activity and interest rates is analyzed. By running panel regression models, we can test whether network characteristics indeed affected the well-functioning of the money markets. Because the data set ranges from January 2005 to December 2012, the analysis is conducted before, during and after the financial market crisis and, therefore, also allows assessing the impact of the networks' structures during various time periods. Moreover, a comprehensive data set from the Swiss payment system and individual bank bond yield spreads allows us to account for the liquidity position and credit risk of each market participant. Therefore, drivers of money market tensions, which previously had not been evaluated, can be assessed.

This analysis provides evidence that banks in the unsecured market are connected to a small share of potential market participants but rely heavily on a few clustered trading relationships. Through this type of trading relationship, market participants in the unsecured market may have been able to build a so-called social collateral that favored liquidity provision prior to the crisis. According to theoretical models, this type of link pattern can lead to a lower network resilience, as shocks can propagate easily. The econometric analysis reveals that the activity in the two sub-markets is driven by the individual network positions of market participants. The diversification of a bank, measured by its degree centrality, positively drove turnover and led to lower interest rates for unsecured lending and borrowing. Further, prior to the financial market crisis, the clustering of banks supported turnover in the interbank money markets and led to a reduction in interest rate premiums. The reduction in clustered trading relationships accompanied by the increasing credit risk of banks likely supported the shift in activity from an unsecured to a secured money market.

This paper is structured as follows. Section 2 introduces the institutional setup of the Swiss franc money market, provides information on its network topology and draws implications for funding conditions. In Section 3, the econometrical analysis is presented. Finally, Section 3 offers conclusions.

2 THE SWISS FRANC MONEY MARKETS

2.1 Setup

Repo transactions in Swiss francs are predominantly traded on an electronic trading platform. During the time period analyzed, these transactions were conducted on the Eurex Repo trading platform, which was also used by the Swiss National Bank (SNB) for the implementation of its monetary policy operations.[1] For the collateralization of cash, only high-quality securities are accepted. The automatic settlement of securities is performed in the Swiss security settlement system, SECOM, while the cash leg is simultaneously settled in the Swiss real-time gross settlement (RTGS) system, Swiss Interbank Clearing (SIC). For a detailed description of the Swiss franc repo market, see, for example, Fuhrer *et al* (2016).

In the unsecured market, transactions are traded on an over-the-counter (OTC) basis and are predominantly settled in the SIC system. For more information about the unsecured Swiss franc money market, see Guggenheim *et al* (2011).

The main motivation for a cash provider to trade cash against securities as collateral is to lend without counterparty risk. The cash taker, on the other hand, might take advantage of relatively low interest rates compared with unsecured transactions, but they may also require the availability of (high-quality) securities. Hence, only in the unsecured market can cash takers obtain liquidity without an initial endowment. This might also be a reason why the turnover in the unsecured Swiss franc money market was higher than in the secured market prior to the financial market crisis.

Between January 2005 and autumn 2007, the average daily turnover in the unsecured money market was approximately CHF 8 billion, whereas in the secured market it oscillated at approximately CHF 5 billion (see Figure 1 in the online appendix). With the outbreak of the financial market crisis, the turnover in the unsecured market decreased to a level of CHF 5 billion, while the secured market increased significantly. At the height of the crisis (autumn 2008), the activity in the unsecured market collapsed to a level below CHF 1 billion a day, while in the repo market the daily turnover reached a high of approximately CHF 15 billion. Thereafter, the activity in the repo market decreased again but remained at a level above CHF 5 billion, and thus far above the level in the unsecured market. Market activity in both markets only dropped significantly after autumn 2011 due to the substantial liquidity provision by the SNB. Overall, a shift in turnover can be observed from the unsecured to the secured interbank money market during the crisis (Guggenheim *et al* 2011).

In addition, a large increase in the spread between unsecured and secured interbank interest rates during the financial market crisis was observed (see Figure 2 in the online

[1] As of May 1, 2014 the SNB conducts its monetary policy operations on the SIX Repo trading platform. In addition, interbank money market transactions can be conducted on this new platform.

appendix). The spread reflects the risk premium for unsecured lending and can be seen as a measure for stress in the unsecured money market. This measure remained at a relatively low and constant level for a long time. However, it suddenly increased in August 2007 and reached a high in autumn 2008. After mid-2009, the spread reached low levels again but remained quite volatile. These facts indicate that, like unsecured money markets in other currencies, the unsecured money market for the Swiss franc exhibited significant stress during the height of the financial market crisis.

2.2 The data

The network structures in the Swiss franc money markets are estimated by analyzing transaction data that stems from two different sources. The first data set consists of repo transactions between commercial banks concluded on the Eurex Repo trading platform. Between January 2005 and December 2012, approximately 180 000 transactions from 161 banks were settled in the Swiss franc repo market. The second data set is based on the transaction data from the SIC system. Guggenheim *et al* (2011) introduced an augmented Furfine (1999a) algorithm to identify unsecured money market transactions from SIC data. The second data set contains this transformed data between January 2005 and December 2012 and approximately 365 000 transactions stemming from 241 market participants. In both data sets, information about the cash taker, the cash provider, the interest rate, the maturity and the cash volume is included. Because data from the unsecured market only contains transactions of a maturity of up to ninety days, both data sets are limited to transactions with a maturity of up to ninety days.[2]

The transaction data for the purpose of this analysis is favored over the data on interbank exposures collected by the SNB – which is used, for example, in Mueller (2006) – for several reasons. First, in contrast to data that provides balance sheet positions on specific days, the transaction data tracks every single transaction on every single business day and, therefore, allows a dynamic analysis of the network characteristics. Second, the transaction data provides information on the linkages among all market participants in the SIC system and, accordingly, in the Eurex Repo trading platform. Due to the open-access policy of the SNB, foreign banks, which do not need to report their exposure to the SNB, are included in the data set.[3] Therefore,

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[2] Robustness checks revealed that the algorithm only allows us to reliably estimate transactions with a maturity of up to ninety days.

[3] In international terms, the access policy of the SNB is relatively liberal, such that foreign banks are also able to participate in SIC and, therefore, in the Swiss franc money markets (see Kraenzlin and Nellen 2015).

the coverage of the market is assumed to be much broader. Third, the data set allows us to study not only the exposure among banks but also the prevailing market prices.

Guggenheim *et al* (2011) highlight potential drawbacks of the algorithm when used to identify unsecured money market transactions. One important drawback is the missing identification of correspondent banking transactions, as only transactions settled on SIC can be identified by the algorithm. However, it can be shown that the misspecification of network measures due to correspondent banking is expected to be small, and that its negative influence on the analysis is limited (see the online appendix).

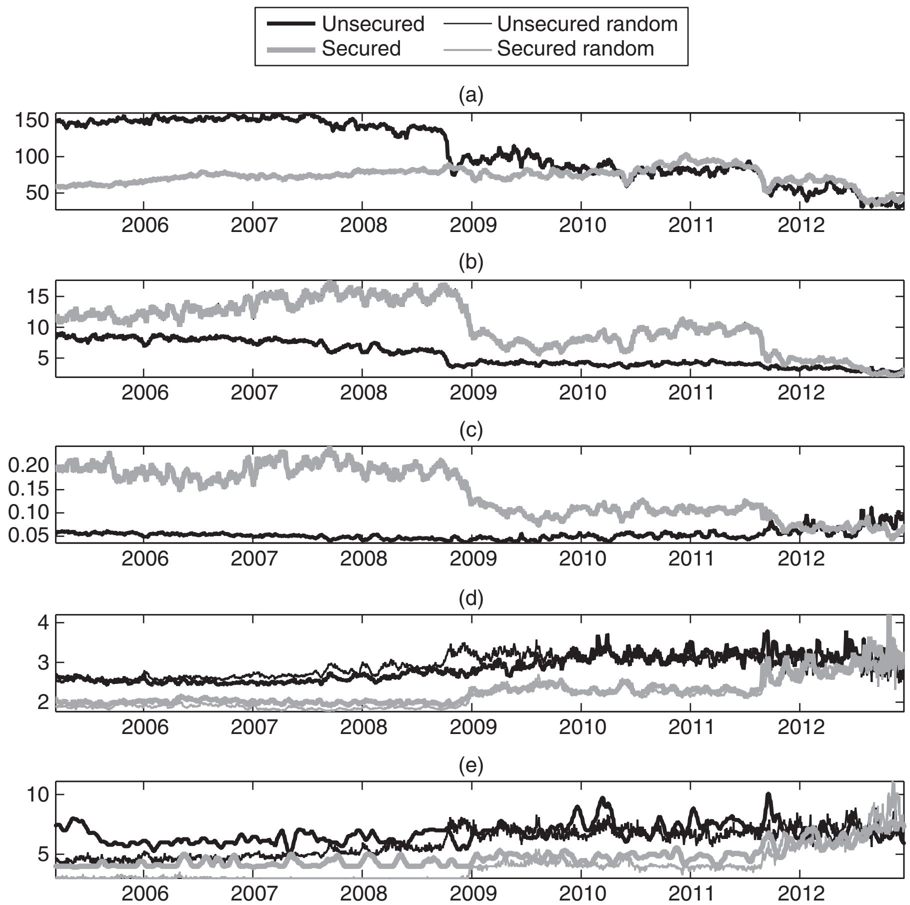
The average time to maturity of the relevant contracts in the two markets is roughly twenty-five days, ie, a contract will mature, on average, twenty-five days from today. Hence, on average, the relationships a bank has formed during the past twenty-five days decide whether it is able to renew a contract. In other words, it is reasonable to presume that a bank's network position is determined within the next twenty-five days before a contract expires and might have to be renewed. To analyze the network structures of the two markets, daily networks, each consisting of transactions from the past twenty-five days, are computed. Compared with networks that only contain transactions from a single day, network statistics are less volatile, and more banks can be related to the different network statistics. Further, it seems reasonable that the network position of a bank is not as volatile as networks based on a single day would suggest.

2.3 Network topology

In the following, the network characteristics of the Swiss franc money markets are illustrated by making use of network theory (also called graph theory in the mathematical literature). Some basic concepts and the measures used in the analysis are explained in the online appendix. In addition to the graphs based on actual data (actual networks), so-called random networks are computed that are determined by the densities, ie, the unconditional probabilities that two nodes in a network are connected, and the number of nodes of the actual networks.[4] The random networks serve as a basis for comparison, as the number of banks, the degree and the density are identical to the actual network, but links are formed randomly. The difference from the random network illustrates the special aspect of the actual networks, which can be explained by the formation of trading relationships. The network characteristics of the actual networks and their random counterparts can be illustrated by the distribution of individual measures at certain points in time as well as by the development

[4] For each day and market, the overall network statistics of the random networks are determined by the mean of one hundred random networks.

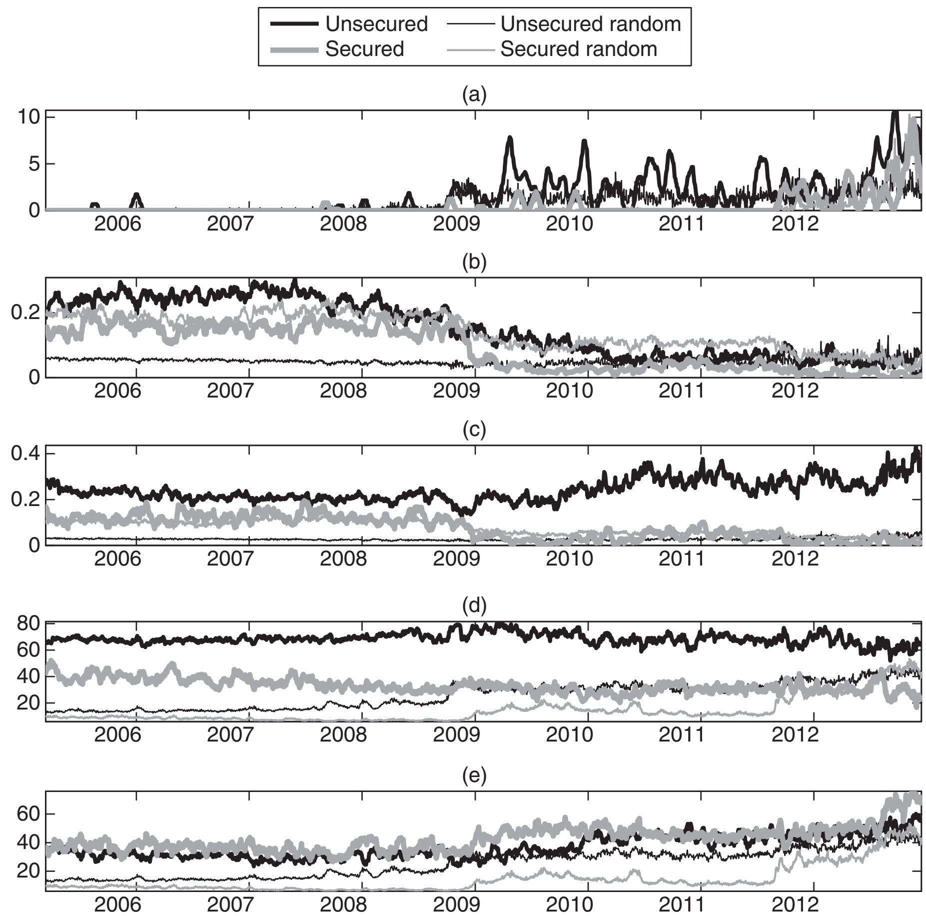
FIGURE 1 Network characteristics of Swiss franc money markets, January 2005 to December 2012.



(a) Number of banks. (b) Average degree. (c) Density. (d) Average path length. (e) Diameter (fifteen-day moving average). The illustrations show the development of selected network characteristics of the unsecured and secured Swiss franc money markets as well as their random counterparts. The network measures are computed on a daily basis. Random networks are computed based on the number of nodes and the density of the actual networks. For each day and market, the network statistics of the random networks are determined by the mean of one hundred random networks.

of overall network measures over time. Figures 1 and 2 illustrate the overall network statistics of the unsecured and secured money markets and their random counterparts for the period from January 2005 to December 2012. Additionally, Figures 5 to 8 in the online appendix show particular distributions of individual network measures for selected days and months.

FIGURE 2 Network characteristics of Swiss franc money markets, January 2005–December 2012.



(a) Number of disconnected banks (fifteen-day moving average). (b) Average clustering coefficient. (c) Reciprocity. (d) Average maximum borrowing preference index. (e) Average maximum lending preference index. The illustrations show the development of selected network characteristics of the unsecured and secured Swiss franc money markets as well as their random counterparts. The network measures are computed on a daily basis. Random networks are computed based on the number of nodes and the density of the actual networks. For each day and market, the network statistics of the random networks are determined by the mean of one hundred random networks.

Stylized facts

There are several network measures indicating that banks in the unsecured market are not as well connected to each other as those in the repo market. First, although there are more participating banks in the unsecured market, the average degree (ie, average number of counterparties) in the repo market is significantly higher. Accordingly, the density in the repo market is much higher, ie, banks in the repo market trade with a larger share of potential counterparties. Before the collapse of Lehman Brothers, approximately 20% of the possible links are used in the repo market, whereas only approximately 5% are used in the unsecured market. Although the density in the repo market decreases at the end of 2008 to a level of roughly 10%, it remains significantly above the level of that in the unsecured market of 5%. The degree distributions for selected months also reveal that the market participants' degrees in the repo market are much more uniformly distributed. In the unsecured market, we can observe a large mass at very low levels and a few outliers with a very high degree. Thus, a large proportion of the market participants in the unsecured market trade with very few counterparties.

Second, in absolute terms, market participants in the repo market are closer to each other. The average path length in the secured market is approximately half of a link shorter than in the unsecured market. However, this is also due to the higher number of market participants in the unsecured market. Between mid-2006 and autumn 2009, the unsecured market even shows a lower average path length than its random counterpart, indicating a short average path length relative to the size of the network. The repo market, on the other hand, exhibits a higher average path length than the random network. Further, the diameter, ie, the path in the graph that connects the two most distant nodes, is approximately two links longer in the unsecured market. The diameter in the repo market only increases at the end of the observation period, when the market activity in the repo market decreases. Hence, figuratively speaking, market participants in the repo market are more closely connected to each other through links to other banks.

Third, the number of disconnected banks, ie, banks not connected to the giant component, is very low in both markets until the end of 2008. Afterwards, the average number of disconnected banks in the unsecured market increases greatly, to a level far above that in its random counterpart. The number of disconnected banks in the repo market, on the other hand, remains at a level slightly above zero until autumn 2011. Thus, after 2008, an increasing number of banks in the unsecured market cannot be linked, by transactions, to a large part of the network.

There is evidence that in the unsecured market, in contrast to the repo market, trading relationships with specific counterparties matter greatly. First, banks in the unsecured market rely heavily on clustered trading relationships. The average clustering coefficient (ie, the probability that two market participants with a common neighbor share a link as well) in the unsecured market lies far above that in its random counterpart, at least until mid-2010. Clustering in the repo market is at a very low level compared with the level in its random network. The levels remain constant in the repo market until the end of 2008, whereas in the unsecured market they decrease heavily after August 2007. Moreover, the clustering in the unsecured market is very pronounced at banks with low degrees. Clustering coefficients in the repo market are distributed much more uniformly over the degree. Thus, until August 2007 (and, to a lesser extent, until mid-2010) it is quite common in the unsecured market for two trading partners to have a trading relationship with a mutual trading partner. Further, many of these market participants only rely on a few specific counterparties.

Second, reciprocity is much higher in the unsecured market than in the repo market. Whereas the share of reciprocal lending in the repo market corresponds to the random network, in the unsecured market it is ten times as high as in the random equivalent. Thus, for trading on an unsecured basis, market participants more often rely on reciprocal trading relationships. In the unsecured market, 20–30% of the transactions are based on reciprocal lending; however, in the secured market, only 5–10% are based on reciprocal transactions. Moreover, reciprocal borrowing and lending become more important with the evolvement of the financial market crisis. After 2009, banks in the unsecured market increase reciprocal lending and borrowing from roughly 20% to 30%.

Third, banks in the unsecured market depend more heavily on just a few trading partners. The average maximum borrower preference index lies at almost 70%, ie, banks, on average, borrow 70% of their funds from the same counterparty. In the repo market, this share lies at around 40% before the start of the crisis, declining to approximately 30% afterwards. In both markets, the indexes are much higher than in the random counterparts.

Overall, the illustrations reveal that the networks in the repo and unsecured markets significantly differ from their equivalent random networks and are thus determined by the formation of specific trading relationships. While network measures such as clustering and reciprocity in the unsecured market lie far above the measures of the random network, the respective measures in the repo market do not reach the levels in the random network. This further highlights the importance of the establishment of specific trading relationships in the unsecured market compared with the repo market.

Implications

Market participants in the unsecured market make use of so-called social collateral in order to increase trust and thus facilitate access to liquidity. In contrast to the secured market, in the unsecured money market no physical collateral is involved to reduce counterparty risk. Thus, trust must be an important factor for the conclusion of transactions, which in turn can be ameliorated by the maintenance of trading relationships. According to the theoretical literature, the establishment of reciprocal and clustered trading relationships can increase trust and thus facilitate access to liquidity. Mobius and Szeidl (2007) and Karlan *et al* (2009) propose a game-theoretic model in which a valuable friendship can secure a transaction in a manner similar to physical collateral. They find that "the level of trust equals the sum of the weakest link values over all disjoint paths connecting borrower and lender"; thus, it positively depends on the number of common friends of two agents, or, put differently, on the clustering coefficient. In other words, the network position may serve as social collateral for tomorrow's borrowing and lending activities. The model further reveals that a change in the network structure or social collateral today may affect the lending conditions of subsequent periods. Because the dissolution of a trading relationship today can lead to the breakup of additional relationships tomorrow, a small variation in today's network might have a significant impact on conditions tomorrow. The illustrations of the network characteristics above underline the important role social collateral can play in the unsecured market. Market participants in the unsecured market do not trade with many different trading partners; instead, they rely on relationships with specific counterparties as well as clustered and reciprocal trading relationships. This may in turn foster trust between market participants and thus foster the exchange of liquidity in the unsecured market. Because the maintenance of such trading relationships is likely to be costly, market participants may optimize the number of links and therefore only trade with a few counterparties.

In the repo market, market participants do not need to rely as heavily on specific counterparties, as trust plays a minor role due to the inclusion of physical collateral. In contrast to the unsecured market, the diversification of repo market participants is much higher.

The resulting network structure makes the unsecured market more prone to shocks than the secured market. The related literature suggests that a network structure such as that found in the unsecured market, characterized by the importance of specific trading relationships and low diversification, makes a market less resilient. Relative to the total number of market participants, banks are relatively close to each other in the unsecured market, which, according to Cohen-Cole *et al* (2012), favors a fast spread of shocks. The network of the unsecured market, with its low density, high local clustering and short average path length, resembles a so-called small-world network, as introduced by Watts (1999). According to Georg (2011) and Haldane (2009), such networks are relatively prone to contagion. Also, Allen and Gale (2000) find that financial contagion is favored by chains of overlapping liabilities that allow the losses to move through the network. Consequently, the impact of a liquidity shock is strongest in an incomplete butconnected market with a high degree of interconnectedness.[5]

[5] For descriptions of this, see the online appendix. Both secured and unsecured markets can be classified as incomplete but connected.

Consequently, there are reasons to presume that the network in the unsecured market exhibits a lower resilience to shocks than the secured market. A typical market participant in the unsecured market has a very low degree and a high clustering coefficient, and it usually trades the majority of its liquidity with a few counterparties on a reciprocal basis. These facts indicate a risk for such banks in the sense that shocks can easily flow through overlapping liabilities (high clustering), but the risk of being hit cannot be diversified (low degree). A shock, such as banks starting to hoard liquidity, can spread rapidly within a cluster of banks. Because these banks are not diversified, they are unable to obtain liquidity elsewhere in the network. Clustering is not as evident in the repo market as in the unsecured market, and market participants are diversified to a higher degree. Thus, repo market participants are more likely to be able to connect with alternative trading partners in case a shock hits them. Therefore, due to their network structures, one would expect the repo market to be more resilient to shocks than the unsecured market.

The related literature finds that a tipping point can be reached such that the network structure no longer supports access to liquidity but rather favors the dispersion of shocks. Georg (2011) finds that a high degree of interconnectedness in a financial network can amplify access to liquidity in normal times but may intensify shocks and destabilize the system in times of high market stress. Haldane (2009) calls this the "robust-yet-fragile" or "knife-edge" property of financial networks. The network can thus serve as a shock absorber up to a certain tipping point, but afterwards it tends to support the spread of shocks.

The combination of the important role of social collateral and the low resilience of the network structure could have rapidly exacerbated lending conditions in the unsecured market. Due to the existing network structure in the unsecured market, a shock, such as evolving mistrust in other participants, could have spread rapidly through the market after the emergence of critical events at the beginning of the financial market crisis.[6] Accordingly, increasing mistrust may have led to a lower willingness of market participants to lend on an unsecured basis. This in turn likely induced a decline in the level of social collateral, which, according to Karlan *et al* (2009), again worsened subsequent lending conditions.[7] Therefore, the unsecured Swiss franc money market might have exhibited the robust-yet-fragile or knife-edge property, according to Haldane (2009), favoring a stable exchange of liquidity

[6] Note that shocks do not need to be equated with the default of a market participant. As Cohen-Cole *et al* (2012) show, uncertainty, risk or specific behavior can also spread through a network, even without a default.

[7] As proposed by Karlan *et al* (2009), a change in today's social collateral can have a significant effect on conditions tomorrow, as a reduction in trading relationships can induce a negative effect on others' social collateral and the dissolution of further trading relationships.

in normal times but also a sudden deterioration in lending conditions in times of stress.

Thus, aside from the fact that unsecured lending is riskier due to the absence of physical collateral, the network structure of the unsecured market tends to be less resilient. Overall, one can expect that shocks in the unsecured market instead have a more contagious effect than would be the case in the repo market.

3 ECONOMETRIC ANALYSIS

The econometric analysis aims at assessing whether network characteristics can affect the conditions in the Swiss franc money market. The market turmoil during the financial market crisis provides the opportunity to evaluate the impact of the network characteristics on the activity in the market in times of market stress. Because a comprehensive data set of transactions in the secured and unsecured money market is available, the network position of each market participant can be assessed. Therefore, it can be tested whether the individual network position affected the individual market activity as well as the interest rates paid before, during and after the market turmoil took place. To test for the impact of network characteristics on conditions in the money market, an econometric analysis is conducted. In the following paragraphs, the choice of potential determinants (ie, variables) is motivated, the models are specified and the regression results are stated.

3.1 Determinants of money market conditions

Network variables

The individual network measures that presumably had a major impact on lending conditions, as mentioned above, are taken into account to determine their effect on money market conditions.

The degree centrality, defined as the degree of a market participant divided by the total number of market participants in the network, is included in the regressions to account for the relative importance of the number of counterparties of a cash taker and a cash provider. As already noted, if a market participant has a higher degree centrality, it is connected to a larger share of the network, is better diversified and is thus able to conduct a money market transaction in case a shock hits the market. The degree centrality should therefore have a positive effect on money market conditions. Hence, the degree centrality is expected to have a positive effect on turnover in the money markets. Moreover, a better-diversified market participant should be able to receive a larger set of offers, place its price quotations at more banks and, therefore, pay or receive an advantageous interest rate. Thus, the degree centrality should have a negative effect on the interest rates paid in the money markets. As seen above, market participants in the secured market seem to be better diversified. Hence, the effect is expected to be more pronounced in the secured market.

The clustering coefficient, defined as the probability that two trading partners of a market participant are connected to each other as well, is included in the regression to account for the interconnectedness of a market participant. As argued above, clustering, or having a common "friend", can increase trust between two market participants. As in the unsecured money market, no collateral is involved. A certain level of trust may even be essential so that a transaction takes place between two market participants. Clustering is therefore expected to have a positive effect on funding conditions. Hence, a cash provider with a high clustering coefficient is more willing to provide cash, or a cash taker with a high clustering coefficient is more able to take cash. The same argument holds for the interest rates. A market participant with a high clustering coefficient is able to establish social collateral with trading partners and is therefore able to receive or is willing to provide better interest rates. The effect of clustering should be more pronounced in the unsecured market due to the lack of physical collateral. As shown above, clustering, that is, having a common trading partner, can serve as social collateral and foster trust between market participants. In contrast, due to the involvement of physical collateral, trust should play a minor role in the secured market.

Reciprocity, defined as the number of reciprocal links divided by the total number of links established by a market participant, is included in the regression to account for the impact of reciprocal trading relationships on money market conditions. Reciprocity tends to increase trust between two market participants and, thus, to foster a trade relationship. Therefore, specifically in the unsecured market, reciprocity should have a positive effect on funding conditions. Hence, cash providers with many reciprocal trading relationships are expected to be more willing to provide cash or more able to take cash. Analogously, interest rates offered or received by a market participant with a high reciprocity level should be lower than average. Due to the missing physical collateral, the effect of reciprocity should be more pronounced in the unsecured market than in the repo market.

Strength, defined as the net flow of transactions of a market participant, ie, the value lent net the value borrowed, is included in the regressions to account for the importance of a cash provider and cash taker in the money market during the past observation period. On the one hand, a high measure of strength indicates that a market participant has conducted a large number of money market transactions as a cash provider. It can be assumed that a strong market participant is generally cash long and a typical cash lender. However, a low (negative) strength value indicates that a market participant has conducted a large number of money market transactions as cash taker. Strength is thus expected to have a positive effect on cash provision and a negative effect on borrowing.

Control variables

It has been widely recognized in the literature that increasing credit and liquidity risk can lead to disruptions and thus drive the funding conditions in interbank money markets. Several theoretical models suggest that increasing liquidity risk and liquidity hoarding can lead to lending disruptions (see, for example, Allen *et al* 2009; Caballero and Krishnamurthy 2008; Diamond and Rajan 2009; Eisenschmidt and Tapking 2009). Therefore, three variables are incorporated to control for the liquidity risk of market participants. First, the net excess reserves according to Fecht *et al* (2011) are used. This variable accounts for the balances at the central bank relative to the minimum reserve requirements of a bank and is a measure of the liquidity position of bank i at time t (at the beginning of the settlement day).[8] Excess reserves have increased since the global financial market crisis due to the SNB's unconventional monetary policy (see above). A bank with higher excess reserves in general has a lower need to obtain liquidity in the interbank money market. Therefore, the overall need for the redistribution of liquidity in the system may have been decreasing due to the higher liquidity available in the system. It can further be seen as a proxy variable for the size of a market participant. Second, current transactions in the Swiss RTGS system (SIC) are considered as a proxy for current liquidity shocks by including the net value (incoming minus outgoing transactions, excluding money market transactions) of bank i on settlement day t. The variable indicates the size of the liquidity shocks that banks have on a specific settlement day. For both liquidity variables, it holds that the higher the value, the better the liquidity position of a participant. Third, the overall value of balances at the central bank is included in the interest rate regressions as a variable for the market liquidity.[9] According to Schwarz (2010), the overall level of liquidity in the market significantly influences the prices in the market.

Moreover, several models emphasize asymmetric information and the increasing level of credit risk. In such a situation, market participants are unable to distinguish between banks with low and high credit risk, and banks start to ration cash provision (see, for example, Freixas and Jorge 2008; Heider *et al* 2015). A measure to control for credit risk is included in the regression analysis. Because CDS spreads are only available for a fraction of the participants in the Swiss franc money markets, bond yield spreads are used as a proxy variable for the credit risk of a bank.[10] Bond yield

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[8] Banks domiciled outside Switzerland do not need to hold minimum reserves at the SNB. Therefore, a value of zero is assumed for their lower bounds.
[9] The variable is not included in the turnover regression due to the potential endogeneity problem.
[10] Special thanks goes to Adrian Bruhin and the Financial Stability division of the SNB, who provided the codes in R for the calculation of the bond yield spreads.

spreads are defined by the volume-weighted yield spread between a set of bonds denominated in Swiss franc with a time to maturity of between two and five years and the according yield for Swiss confederation bonds, which is assumed to be risk free. The related literature suggests the bond yield and CDS spreads move together in the long run (see Eisenschmidt and Tapking 2009; Zhu 2004). The premium on a specific bond compared with the risk-free bond can therefore be seen as a proxy for the credit risk of the according issuer. Data on bonds denominated in Swiss francs are available for approximately sixty-five banks, allowing their yield spreads to be computed. They account for approximately 85% of the turnover and outstanding volume in the market. In addition, bond spreads for different groups belonging to the same geographical regions and types of bank are computed.[11] Banks without an individual bond spread are assigned to these artificial group bond spreads.

As Eisenschmidt and Tapking (2009) argue, the credit risk of both lender and borrower determines the risk premium. Consequently, in the interest rate regression, the credit risks of both the cash taker and cash provider are included. The collateral basket is included in the interest rate regression.

3.2 Models

To examine the effect of network characteristics on funding conditions in the Swiss franc money markets, two regression models are applied. First, variables accounting for the activity of cash takers and cash providers in the unsecured and secured Swiss franc money markets are regressed on a set of variables considering the individual network measures as well as individual liquidity risk and credit risk (turnover regression). Second, variables accounting for interest rate premiums in the money markets are regressed on the same set of variable rates (interest rate regression). To account for the unobservable individual specific characteristics of the banks, panel and least-square dummy variable (LSDV) regression models are applied.

Turnover regression

In the turnover regression, the determinants of the difference between the individual turnover in the unsecured and secured markets are evaluated, and thereby the relative

[11] The following groups are computed: Swiss cantonal banks, Swiss insurances, small banks from Switzerland and banks from Liechtenstein, Belgium, France, Luxembourg, the Netherlands, Great Britain, Scandinavia, Austria, Germany, southern Europe, eastern Europe/Russia, Asia and North America. The majority of banks without an individual bond spread are small, domestic-private and regional banks as well as small, private and regional banks from neighboring countries such as Austria, Germany and Liechtenstein. The bond spreads of these groups are also computed based on bonds of rather small private or regional banks. Therefore, it can be argued that the risk profile of these banks should approximately correspond to the credit risk based on the group bond spreads.

importance of the secured and unsecured markets is assessed. The following fixed effects model is estimated:

$$y_{it} = X'_{it}\beta + \alpha_i + \varepsilon_{it}, \tag{3.1}$$

with

$$X'_{it}\beta = \sum_{n=1}^{N} \beta_n \mathrm{NW}^n_{it-1} + \sum_{l=1}^{L} \gamma_l \mathrm{LR}^l_{it} + \sum_{c=1}^{C} \delta_c \mathrm{CR}^c_{it}, \tag{3.2}$$

where NW^n_{it-1} denotes the network measure n at date $t-1$, LR^l_{it} are the liquidity risk variables l and CR^c_{it} is the credit risk component c of market participant i at day t.

In the baseline regression, the dependent variable y_{it} is defined as the spread between the log value (in million CHF) of the turnover in the unsecured market TU_{it} and the log value (in million CHF) of the turnover in the secured market TS_{it} of cash provider i on day t:

$$y_{it} = \log(\max\{1, \mathrm{TU}_{it}\}) - \log(\max\{1, \mathrm{TS}_{it}\}). \tag{3.3}$$

Regressing the ratio of unsecured and secured turnover on the potential drivers will provide information as to whether market participants are traded in the unsecured or secured market due to their network position. The turnovers of market participants as lenders and borrowers are both assessed, and therefore TU (TS) can be denoted as either the amount of liquidity lending or borrowing of market participant i at time t in the unsecured (secured) market. Hence, the relative importance of lending as well as borrowing in the unsecured and secured markets is analyzed. Note that the very few transactions with a value between zero and CHF 1 million are replaced by a value of zero.[12]

As a robustness check, further assessments will be made as to whether the potential drivers affected the turnover in the two sub-markets. Therefore, the individual turnover of market participants – as lender and borrower – in the two sub-markets are regressed on the same set of variables:

$$y_{it} = \log(\max\{1, \mathrm{TU}_{it}\}), \tag{3.4}$$

$$y_{it} = \log(\max\{1, \mathrm{TS}_{it}\}). \tag{3.5}$$

[12] Specifically, 0.1% of the transactions worth 0.001% of the total turnover in the unsecured market, and none in the secured market.

Interest rate regression

The determinants of the interest rate premiums in the unsecured money market are evaluated by means of an LSDV regression[13]

$$
\begin{aligned}
\hat{r}_{i,t} = {} & \sum_{n=1}^{N} \beta_n \mathrm{NW}^{n}_{\mathrm{CTUnsec},i,t-1} + \sum_{n=1}^{N} \gamma_n \mathrm{NW}^{n}_{\mathrm{CPUnsec},i,t-1} \\
& + \sum_{n=1}^{N} \eta_n \mathrm{NW}^{n}_{\mathrm{CTSec},i,t-1} + \sum_{n=1}^{N} \theta_n \mathrm{NW}^{n}_{\mathrm{CPSec},i,t-1} \\
& + \sum_{l=1}^{L} \delta_l \mathrm{LR}^{l}_{\mathrm{CT},i,t} + \sum_{l=1}^{L} \kappa_l \mathrm{LR}^{l}_{\mathrm{CP},i,t} \\
& + \sum_{c=1}^{C} \zeta_c \mathrm{CR}^{c}_{\mathrm{CT},i,t} + \sum_{c=1}^{C} \lambda_c \mathrm{CR}^{c}_{\mathrm{CP},i,t} \\
& + \sum_{d=2}^{D} \mu_d \mathrm{CT}_{i,t} + \sum_{s=2}^{S} \nu_s \mathrm{CP}_{i,t} + \alpha_i + \varepsilon_i,
\end{aligned}
\tag{3.6}
$$

where $\hat{r}_{i,t}$ denotes the difference between the interest rate of the unsecured transaction iu_i and the Swiss Average Rate for secured contracts S_t in basis points (bps):[14]

$$
\hat{r}_{i,t} = iu_i - S_t. \tag{3.7}
$$

The regressions are run separately for transactions with maturities of one day (ON), one week (1W), one month (1M) and three months (3M). $\mathrm{NW}^{n}_{\mathrm{CT(CP)Unsec(Sec)},i,t-1}$ denotes the network characteristic n of the cash taker (or provider) of transaction i in the unsecured (secured) market at $t-1$. $\mathrm{LR}^{l}_{\mathrm{CT(CP)},i,t}$ stands for the liquidity risk measure l of the cash taker (provider) and $\mathrm{CR}^{c}_{\mathrm{CT(CP)},i,t}$ stands for the credit risk component c of the cash taker (provider) of transaction i on day t. In addition, the indicator variables $\mathrm{CT(CP)}_{i,t}$, which equal one if the cash taker (provider) $d(s)$ was involved in transaction i, are included. To account for the direct reciprocal relationship of the two market participants involved, an indicator variable RP(D) is included; this is equal to one if the two participants conducted a transaction within the past twenty-five days in the opposite direction.

[13] Standard panel models cannot be applied due to the highly unbalanced data set. In contrast to turnover regression, missing values cannot be replaced by zeros. Due to the low number of observations for longer maturities, only overnight transactions are considered.
[14] Swiss Average Rates are based on the transactions and quotes concluded or posted on the Eurex Repo trading platform.

3.3 Data issues

As outlined in Section 2, the levels of interest rate premiums and turnover change significantly during the observation period 2005–12. To account for different time periods and levels in turnover and interest rates, the sample is split into four sub-periods. The first period starts in 2005 and lasts until August 8, 2007, when market turmoil first occurred and unsecured interest rates started to hike.[15] The subsequent period lasts from August 9, 2007 until September 14, 2008: the day before the investment bank Lehman Brothers collapsed. The third period ranges from September 15, 2008 until April 22, 2010, when the European sovereign debt crisis started to emerge.[16] The subsequent and final period lasts from April 23, 2010 until August 2, 2011. Afterwards, SNB began a major increase in liquidity provision, and activity in both markets nearly came to a halt.

Transactions concluded on the last working day of a minimum reserve requirement period and on the last working day of a month are excluded due to the high volatility in interest rates on such days, as proposed by Kraenzlin (2009) and Mancini *et al* (2016). Table 1 in the online appendix provides summary statistics for the dependent variables for different time periods.

In the panel regressions, only banks participating in both markets are included. Overall, there are 113 banks participating in both markets between January 2005 and December 2012. However, a number of banks do not participate, either on a daily basis or during the whole sample period, which leads to attrition and, consequently, to a potential bias of the estimates in panel regression models (see, for example, Baltagi 2005). Nevertheless, it can be argued that attrition should not lead to a self-selection problem and should not bias the results. In the specifications stated above, the goal is actually to evaluate the difference in total turnover in the unsecured and repo markets, which by definition is only determined by actual transactions. Moreover, missing values can be replaced by zeros, which leads to a perfectly balanced panel data set.

To measure the market activity, the turnover or the outstanding volume in the according market could be measured. As mentioned above, the goal of the regressions is to determine the drivers for funding conditions on a specific day by accounting for individual network positions as well as liquidity and credit risk characteristics. Therefore, turnover is favored over the outstanding volume of market participant i at

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[15] On August 8, 2007 BNP Paribas had to suspend three funds exposed to the US subprime mortgage market. This event is seen by many economists as the outbreak of the financial market crisis (see, for example, Acharya *et al* 2009).

[16] During April 2010, Greek government bond yields increased heavily, which revealed the unsustainability of Greek fiscal policy. In May 2010, European countries had to agree on the provision of bilateral loans totalling €80 billion (Minka and de Haan 2013).

time t, as its turnover reveals the ability to conclude a new transaction on a specific day. When using the outstanding volume, concluded transactions in the past are considered as well. Depending on the maturities of the trades a market participant has completed, the conclusion of trades a long time ago can influence the outstanding volume. Hence, there can be situations in which the model would try to explain activity in the money markets a long time ago based on the current network position of a market participant. Moreover, an endogeneity problem may arise, as simultaneity in the outstanding volume and past network measures may occur through past transactions.

As independent variables, the lagged individual network measures are used, which are based on the network positions between $t - 26$ and $t - 1$. The dependent variable is based on the current market situation, ie, the turnover at time t. By regressing current turnover values on past network measures, simultaneity in the dependent and independent variables, and therefore endogeneity, can be ruled out, as proposed in Cocco *et al* (2009).

The daily network measures are partially correlated. Specifically, the strength and degree centrality show a relatively high correlation exceeding 0.5. To avoid multicollinearity, the degree centrality (DC) in the secured (unsecured) market is orthogonalized with respect to the strength (ST) in the secured (unsecured) market:

$$\mathrm{DC}_{i,t} = \beta_1 + \beta_1 \mathrm{ST}_{i,t} + \nu_{i,t}. \tag{3.8}$$

Thus, the variation in the degree centrality, which is not driven by the strength ($\nu_{i,t}$), is used as an independent variable in the regression model. Due to the orthogonalization of the two variables, the correlation between the degree centrality and the reciprocity can be reduced as well.

Several panel regression tests are computed. Tests for spatial (cross-sectional) and serial correlation are conducted. Höchle (2007) introduces a panel data model with standard errors according to Discroll and Kraay (1989) that are robust to serial and spatial correlation, specifically for panels with a large number of T. If the tests cannot be rejected, these robust standard errors are used. Moreover, a Hausman test is computed to check for random effects. These, however, can always be rejected. Finally, in the LSDV regression, heteroscedasticity-robust standard errors are applied.

3.4 Results: turnover regression

The turnover regressions show the impact of a market participant's network position on its market activity in the unsecured and secured markets while controlling for its liquidity and credit risk. The regression results can be found in Tables 1 to 3. In the baseline regression, a positive sign indicates a positive effect on unsecured lending and a negative effect on secured lending, and vice versa. Coefficients in the robustness check regressions with the dependent variables specified in (3.4) and (3.5) can be interpreted one-to-one, ie, a positive sign indicates a positive effect on the turnover in the market in question.

The majority of the coefficients are consistent for different specifications, ie, the signs of the coefficients on the robustness check regression are in line with those in the baseline regressions. The regressions show a goodness-of-fit of between 0.12 and 0.60. The robustness check regressions as well as the regressions with the cash provision as a dependent variable generally show a higher goodness-of-fit. The majority of the coefficients are statistically significant at least at the 5% level. Hausman tests all indicate fixed effects. Therefore, the results of the fixed effects regressions are reported. Serial and cross-sectional correlation cannot be rejected in all cases. For this reason, robust standard errors according to Höchle (2007) are used in such cases.

The hypothesis regarding the degree centrality stated above can be confirmed: the degree centrality, which is measured by the network position during the previous twenty-five business days, has a statistically and economically significant positive effect on borrowing and lending in the unsecured and secured Swiss franc money markets. The baseline regression reveals that the degree centrality in the secured market positively affects turnover in the secured market. Turnover in the unsecured market is affected to a much lower extent. For instance, lending in the unsecured market is only positively influenced by the degree centrality in the unsecured market in the first and last periods. It is likely that diversification in the unsecured market was not high enough to ensure stable market activity. Robustness check regression reveals that the coefficients for the degree centrality are significantly positive in almost all cases. Note that diversification seems to be a more important factor for borrowers than for lenders. Also, the effect on the activity in the secured market is more pronounced.

The hypothesis regarding the clustering of market participants can only partly be confirmed. The baseline regression reveals that the lender's willingness to provide cash is increasing in the clustering coefficients of the corresponding market. The impact tends to decrease over time, especially in the unsecured market. The effect in the secured market is economically stronger and remains significant until the last period. Robustness checks confirm the results from the baseline regression, but they also reveal that clustering entails a (economically lower) negative effect on borrowing, especially in the repo market. Only in the third period does clustering in the repo market show a slightly positive effect on cash taking in the unsecured market. Thus, the establishment of clustered trading relationships apparently leads to a higher probability of cash lending, whereas it reduces the probability for cash borrowing. These results lead to the conjecture that typical lenders, ie, cash-long market participants, often maintain clustered trading relationships, which might help them increase trust in the counterparties. For typical borrowers, ie, cash-short market participants, trust is less important, as they typically do not rely on clustered trading relationships.

TABLE 1 Turnover regression (y_{it} based on (3.3)).

	Lending				Borrowing			
	P1	**P2**	**P3**	**P4**	**P1**	**P2**	**P3**	**P4**
NW unsecured market								
DC	0.15***	0.075	0.04	0.11*	0.035	−0.015	−0.15***	−0.019
CL	0.063***	0.031***	0.028**	−0.019	−0.033***	−0.020*	0.0025	−0.013
RP	−0.0062	−0.0037	0.00055	−0.0068	0.0019	0.007	−0.012	−0.017
ST	−0.19***	−0.027	−0.077***	−0.058**	0.11**	0.043	−0.046*	0.081**
NW secured market								
DC	−0.14***	−0.046	−0.27***	−0.15***	−0.28***	−0.28***	−0.40***	−0.24***
CL	−0.13***	−0.12***	−0.13***	−0.053***	0.039***	0.048***	0.054***	0.018***
RP	−0.014**	−0.01	−0.00066	0.0048	0.0064	0.0019	−0.0039	0.01
ST	0.21***	0.062***	0.20***	0.22***	−0.015	−0.077***	−0.22***	−0.25***
LR								
NE	−0.092***	−0.13***	−0.0081	−0.0047	0.11***	0.18***	0.024***	0.023**
PS	−0.11***	−0.11***	−0.061***	−0.072***	0.11***	0.13***	0.082***	0.10***
CR								
BS	0.041***	−0.031**	0.0014	0.028*	0.023***	−0.065***	−0.026**	−0.0098
Const.	0.21***	0.068	−0.090***	−0.18***	−0.026	−0.11**	−0.18***	−0.20***
R^2	0.37	0.35	0.35	0.36	0.22	0.33	0.15	0.24
No. obs.	67 687	30 510	44 183	35 482	67 687	30 510	44 183	35 482

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; coefficients are standardized. DC, degree centrality; CL, clustering coefficient; RP, reciprocity; ST, strength; NE, net excess reserves; PS, liquidity position payment system; BS, bond spreads; No. obs., number of observations; P1 = 3/1/05–8/7/07; P2 = 8/8/07–9/15/08; P3 = 9/16/08–4/22/10; P4 = 4/23/10–7/31/11.

TABLE 2 Turnover regression unsecured market (y_{it} based on (3.4)).

	Lending				Borrowing			
	P1	**P2**	**P3**	**P4**	**P1**	**P2**	**P3**	**P4**
NW unsecured market								
DC	0.30***	0.093*	0.22***	0.23***	0.33***	0.28***	0.18***	0.28***
CL	0.096***	0.043***	0.056***	0.0041	–0.042***	–0.038***	–0.018***	–0.027***
RP	0.0046	0.012	0.024**	0.013	0.0036	–0.003	0.020*	–0.016
ST	–0.019	–0.069	–0.062***	–0.097***	0.41***	0.36***	0.12***	0.033**
NW secured market								
DC	0.091***	0.067*	0.050*	0.16***	0.21***	0.12***	–0.038*	0.19***
CL	0.0059	0.014	0.0038	0.011	–0.010*	–0.016**	0.012***	–0.0091*
RP	–0.005	–0.0056	–0.0089	–0.0095	–0.0014	–0.013*	–0.016*	–0.0052
ST	0.11***	–0.01	–0.011	0.038***	0.094***	–0.029***	0.011*	0.017*
LR								
NE	0.13***	0.17***	0.023**	–0.00015	–0.12***	–0.17***	–0.027***	–0.033***
PS	0.13***	0.13***	0.060***	0.068***	–0.11***	–0.13***	–0.095***	–0.11***
CR								
BS	0.028***	–0.012	–0.0032	0.004	0.0068	–0.028**	–0.035***	–0.024**
Const.	0.60***	0.49***	0.26***	0.20***	0.36***	0.32***	0.21***	0.26***
R^2	0.45	0.12	0.39	0.52	0.60	0.60	0.47	0.54
No. obs.	67 687	30 510	44 183	35 482	67 687	30 510	44 183	35 482

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; coefficients are standardized. DC, degree centrality; CL, clustering coefficient; RP, reciprocity; ST, strength; NE, net excess reserves; PS, liquidity position payment system; BS, bond spreads; No. obs., number of observations; P1 = 3/1/05–8/7/07; P2 = 8/8/07–9/15/08; P3 = 9/16/08–4/22/10; P4 = 4/23/10–7/31/11.

TABLE 3 Turnover regression secured market (y_{it} based on (3.5)).

	Lending				Borrowing			
	P1	**P2**	**P3**	**P4**	**P1**	**P2**	**P3**	**P4**
NW unsecured market								
DC	0.12***	−0.007	0.12**	0.054	0.30***	0.22***	0.30***	0.22***
CL	0.017***	0.00085	0.01	0.024*	−0.010*	−0.01	−0.015*	−0.006
RP	0.013**	0.014***	0.018***	0.017*	0.0017	−0.0087	0.028**	0.0071
ST	0.24***	−0.029	0.041*	−0.0071	0.31***	0.24***	0.13***	−0.064**
NW secured market								
DC	0.29***	0.11**	0.35***	0.29***	0.48***	0.35***	0.43***	0.40***
CL	0.19***	0.15***	0.15***	0.066***	−0.049***	−0.056***	−0.053***	−0.026***
RP	0.014**	0.0069	−0.006	−0.012	−0.0077	−0.011*	−0.0072	−0.015
ST	−0.17***	−0.082***	−0.24***	−0.22***	0.11***	0.049**	0.26***	0.29***
LR								
NE	0.13***	0.17***	0.023**	−0.00015	−0.12***	−0.17***	−0.027***	−0.033***
PS	0.13***	0.13***	0.060***	0.068***	−0.11***	−0.13***	−0.095***	−0.11***
CR								
BS	−0.027***	0.026***	−0.004	−0.028*	−0.016***	0.038***	0.005	−0.0064
Const.	0.40***	0.42***	0.35***	0.38***	0.39***	0.43***	0.39***	0.45***
R^2	0.54	0.48	0.53	0.43	0.52	0.57	0.36	0.39
No. obs.	67 687	30 510	44 183	35 482	67 687	30 510	44 183	35 482

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; coefficients are standardized. DC, degree centrality; CL, clustering coefficient; RP, reciprocity; ST, strength; NE, net excess reserves; PS, liquidity position payment system; BS, bond spreads; No. obs., number of observations; P1 = 3/1/05–8/7/07; P2 = 8/8/07–9/15/08; P3 = 9/16/08–4/22/10; P4 = 4/23/10–7/31/11.

Reciprocity hardly exhibits any effect in the baseline regression. The hypothesis, however, cannot be rejected, because in the robustness check regressions, the coefficients reveal a statistically significant, although economically weak, effect. In the unsecured market, a statistically significant effect on both cash provision and cash taking in the third period can be observed. In addition, reciprocity in the unsecured market exhibits a positive effect on secured borrowing in the third period. Hence, at the height of the crisis, market participants in the unsecured market seem increasingly to have maintained reciprocal trading relationships to conclude money market transactions. Therefore, in addition to maintaining clustered trading relationships, reciprocity may have supported the access to liquidity by fostering trading relationships.

The strength of a market participant, especially in the unsecured market, significantly influenced the borrowing in the secured and unsecured market. Secured borrowing is increasing in the strength of the market participants in the unsecured market. That is, net cash lenders in the unsecured market also borrow funds in the secured market. The coefficients are statistically and economically significant in the first two periods. The effect diminishes afterwards. Further, the borrowing in the secured market is increasingly influenced by the strength of the repo market in the third and fourth periods. Hence, market participants seem to have borrowed cash on a secured basis and lent it on an unsecured basis in the first two periods, which is potentially associated with earning a spread. With the evolvement of the crisis, these trade patterns changed, and market participants instead traded as cash takers and providers only within the repo market. Thus, there is evidence that market making across the two sub-markets was reduced by strong market participants.

The effects of the control variables are in line with expectations. On the one hand, banks experiencing positive cash shocks preferably provide cash on a secured basis. On the other hand, banks with a negative liquidity shock are more able to obtain liquidity in the secured market. The credit risk has an ambiguous effect on turnover in the two markets. Market participants with a higher credit risk are more likely to lend and borrow cash in the unsecured market at the beginning of the sample period. After the first period, however, market activity in the unsecured market is significantly decreasing in the credit risk. Further, in the second period, the market activity in the secured market is significantly increasing in the credit risk. This switch can be ascribed to the fact that market participants with a high credit risk were able to borrow on a secured basis, and cash providers became more risk averse due to precautionary reasons and lent cash in the secured market.

3.5 Results: interest rate regressions

The interest rate regression shows the impact of a market participant's network position on the interest rate premiums paid in the unsecured money market, while controlling for its liquidity and credit risk. A positive sign indicates a positive effect on the premiums or an increasing unsecured rate. Put differently, a positive sign indicates that a cash taker is worse off and a cash provider is better off than average.

Most coefficients, including those for bank-specific dummy variables, are statistically significant at least at the 5% level. The goodness-of-fit varies between 0.14 and 0.48 and is the highest in the third period, when the interest rate premiums increased heavily. The regression results for overnight transactions can be found in Table 4. The rest of the tables can be found in the online appendix.

As in the turnover regression, the economic impact of the degree centrality is the highest among all regressors. The degree centrality seems to be the most important driver of price differentiations, as the economic and statistical significance is the highest among all independent variables. The hypothesis regarding the degree centrality can partly be confirmed. Interest rate premiums generally decrease with the degree centrality of cash takers and cash providers. In some instances during the second and third periods, interest rate spreads increase in the degree centrality of cash takers. Moreover, during the second and third periods (especially in the overnight and one-week segment), cash providers with a high degree centrality were able to take advantage of higher interest rates. Therefore, with a few exceptions during the financial market crisis, diversification seems to have reduced the risk premiums in the unsecured market.

The hypothesis regarding the clustering of market participants cannot be rejected either. The interest rate premiums in the unsecured market are in most cases decreasing in the clustering coefficients of market participants. However, compared with the degree centrality, the economic effect is less pronounced. Generally speaking, interest rate premiums are decreasing in the clustering coefficient of cash takers. Moreover, there is evidence that cash providers who established clustered trading relationships granted rebates in the overnight market during the second and third periods. Thus, cash providers with a high clustering coefficient in the unsecured market not only provided more liquidity but also offered better interest rates to their counterparties.

The hypothesis regarding the impact of reciprocity only holds during the second period. Hence, reciprocity entails a significant negative impact on the interest rate premiums in the overnight unsecured market during the crisis. So, reciprocal relationships can lead to a reduction in interest rate premiums in times when market participants increasingly rely on trust to conclude a transaction. Note, however, that the results also reveal that interest rates are often increasing in the reciprocity of market participants. This may be for two reasons. First, cash takers with high reciprocity rely heavily on a specific counterparty, which may increase the bargaining power of the cash provider. Moreover, if the counterparty is unable to provide funds, it may be more difficult to find an alternative counterparty to conclude a transaction.

TABLE 4 Interest rate regression (ON).

	P1	P2	P3	P4
NW unsecured market				
DC (CT)	−0.19***	0.32***	−0.15***	−0.21***
DC (CP)	−0.19***	0.083	−0.036	0.034
CL (CT)	−0.018***	−0.02	−0.00	−0.00
CL (CP)	−0.01	−0.043**	−0.069***	0.02
RP (CT)	0.016**	−0.090***	−0.01	−0.00
RP (CP)	−0.01	−0.065***	−0.01	0.052***
RP (D)	0.00	0.02	0.02	−0.00
ST (CT)	−0.36***	0.18***	0.11***	0.062*
ST (CP)	−0.33***	0.05	0.16***	−0.013
NW secured market				
DC (CT)	−0.14***	0.27***	0.29***	−0.13**
DC (CP)	−0.12***	0.17***	0.14***	0.073
CL (CT)	−0.01	0.02	0.027***	−0.00
CL (CP)	−0.0100*	−0.01	0.02	0.01
RP (CT)	0.027***	−0.042***	0.079***	0.0027
RP (CP)	0.025***	−0.026*	0.045***	0.017
RP (D)	−0.018**	−0.037***	0.085***	−0.018
ST (CT)	0.054**	0.15***	0.22***	0.060*
ST (CP)	0.082***	0.12***	0.049***	−0.014
LR				
NE (CT)	0.13***	−0.00011	0.0047	0.029**
NE (CP)	0.12***	−0.013	−0.0048	0.026*
PS (CT)	0.045***	−0.035***	−0.023*	0.061***
PS (CP)	0.045***	−0.020*	−0.018*	0.058***
ML	0.17***	0.32***	−0.0066	−0.0074
CR				
BS (CT)	−0.029***	0.11***	0.11***	0.0087
BS (CP)	−0.044***	0.050***	0.082***	−0.086***
R^2	0.151	0.221	0.486	0.143
No. obs.	68 278	23 470	17 802	12 268

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; coefficients are standardized. DC, degree centrality; CL, clustering coefficient; RP, reciprocity; ST, strength; NE, net excess reserves; PS, liquidity position payment system; ML, market liquidity; BS, bond spreads; CP, cash provider; CT, cash taker; RP (D) is a dummy variable indicating reciprocal relationships; No. obs., number of observations; P1 = 3/1/05–8/7/07; P2 = 8/8/07–9/15/08; P3 = 9/16/08–4/22/10; P4 = 4/23/10–7/31/11.

The strength of a market participant has an ambiguous effect on interest rate premiums. Interest rates increase in proportion to the strength of the cash provider. This is likely due to the fact that strong cash providers (ie, net lenders) have a higher bargaining power and can thus demand higher interest rates. On the other hand, interest rates are also increasing in the strength of cash takers, especially after the first period and in short-term contracts. Strong cash takers had previously provided a relatively large amount of liquidity, making them sensitive to unexpected liquidity shocks. In the case of such shocks, they would have to fund themselves again in the interbank market, which is likely to be done on a short-term basis. As they may be in immediate need of cash, their interest rates are likely to increase. The regression results indicate that such unexpected shocks with a price impact likely occurred with the evolvement of the financial market crisis.

The effect of liquidity risk is ambiguous and, in most cases, has low economic explanatory power. Credit risk, however, exhibits a statistically and especially economically significant positive impact on interest rate premiums in the second and third periods. While even in the first period a slight negative effect is observed, during the financial market crisis premiums are increasing in the credit risk of both cash takers and cash providers. Moreover, the positive effect increases with the maturity of the contract. This finding is in line with the reasoning of Eisenschmidt and Tapking (2009), who argue that the credit risk of cash providers negatively affects unsecured lending due to high uncertainty with regard to refunding conditions.

4 CONCLUSION

The network topology of the secured and unsecured Swiss franc money markets significantly differs from so-called random graphs and is thus determined by the formation of specific trading relationships. The network topology reveals that market participants in the unsecured market are less diversified but locally more interconnected than in the secured market, ie, banks trade with only a small fraction of potential counterparties and rely heavily on a few reciprocal and clustered trading relationships. There is an indication that market participants in the unsecured market establish social collateral in order to increase trust and facilitate the exchange of liquidity.

The regression results indicate that the interconnectedness or network position of market participants influences their ability to obtain and their willingness to provide liquidity in the interbank market. Further, interest rates are affected by individual network positions. It can be shown that the turnover in the interbank markets is increasing in the degree centrality, especially in the repo market, where diversification by market participants is much higher. The degree centrality accordingly reduces interest rate premiums. Clustering fosters the trading relationship of two banks and can thus support – to an economically lesser extent than the degree centrality – the exchange of liquidity and the reduction of interest rate premiums. Although clustering in the secured market is lower than in the unsecured market, the effect on turnover is more pronounced in the former, especially after the first period. However, this may also be due to a reduction in the number of clustered trading relationships in the unsecured market during the crisis. Instead, market participants in the unsecured market seem to have increasingly maintained reciprocal trading relationships to conclude money market transactions at reduced risk premiums. This, in turn, may have reduced the social collateral between market participants and increased dependency on specific counterparties. In contrast, in the repo market, the effect of the network position remained quite stable and seems to have continued supporting the exchange of liquidity. Finally, regression results indicate that strong market participants reduced cross-market market making, which may have reduced turnover in the unsecured market.

Another important finding of the regressions is that the network positions in both sub-markets influenced the conditions. This result can certainly be ascribed to the fact that the markets are closely related. It nonetheless gives rise to the interpretation that even the interconnectedness of market participants in other market segments can affect market functioning.

In addition to network characteristics, credit risk affected money market conditions. After the outbreak of the financial crisis, turnover in the unsecured market was decreasing and interest rate premiums were increasing in the credit risk of market participants. The increasing credit risk likely contributed to the shift of turnover toward the secured market and the increased risk premiums for unsecured lending at the height of the crisis.

Network theory has proven to be a useful tool for analyzing the effects of interconnectedness in financial markets. This network analysis reveals that interconnectedness in unsecured money markets can be accentuated by heavy local clustering and reciprocity, which supports access to liquidity through social collateral. By their nature, markets such as the unsecured money market have to rely on trust or on social collateral. Ordinarily, such behavior is certainly favorable, both for an individual bank and for the system as a whole, as it supports access to liquidity. In times of high market stress, it turns out that the resulting network structure can make the market prone to shocks, which may lead to reduced market activity and increased interest rate premiums.

Although the perception of credit risk has decreased during the last couple of years, activity in the unsecured market has not yet picked up. This is certainly also due to the vast liquidity available in the market, which makes a redistribution of liquidity less necessary. Moreover, with the new regulatory initiatives, it is doubtful whether the market activity in the unsecured Swiss franc money market will start to increase again in times of lower overall liquidity in the system. Finally, it may also be uncertain whether a network structure that allows for a stable level of market activity in the unsecured Swiss franc money market can be reached again. In this respect, a nearly nonexistent unsecured money market may be a probable scenario in the future. What this might mean for the well-functioning of the financial system will be left for further research.

DECLARATION OF INTEREST

The views expressed in this paper are those of the author and do not necessarily represent those of the Swiss National Bank.

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