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Abstract

The dissertation consists of three chapters. Chapter 1 ("Can Interbank Lending Markets Self-Regulate? Quasi-Experiment from the Clock Synchronization of 1883") insists on the ability of interbank market to withstand systemic risk during the panic of 1883. To establish causal relationship between the bank's counterparty exposure and its solvency we instrument for the former with the discrepancy between the bank's city local time (solar time) and railroad time, which occurred thanks to clock synchronization of 1883.

Chapter 2 ("Implied Maturity Mismatches and Investor Disagreement", written with S. Bar-Yosef and I. Venezia) studies the relationship between implied maturity mismatches and investor disagreement, concluding that interest rate risk of banks is positively associated with trading volume, and the role of return in this relationship is minimal or even non-existent.

Chapter 3 ("Discount Windows, Equity Runs and Market Revelation") draws a channel through which information on bank illiquidity, which is kept secret as a preventive measure against bank runs, can be inferred from the publicly observable equity trading by uninformed investors.

Can Interbank Lending Markets Self-Regulate? Quasi-Experiment from the Clock Synchronization of 1883

October 13, 2016

Abstract

How does an access to the interbank lending market affect the bank's stability in the presence of systemic risk? We turn to history to address this question empirically, thereby avoiding modern sources of omitted variable bias (such as anonymous liquidity provision by a central bank, undetectable derivative cross-holdings, deposit insurance, etc.). Assembling a unique dataset on national banks in New England, we test the self-sufficiency of interbank network in withstanding systemic risk during the panic of 1893. To deal with endogeneity between the bank's insolvency and its counterparty exposure, we instrument for the latter with the discrepancy between the bank's city local time (solar time) and railroad time. Such discrepancy occurred subsequently to the clock synchronization of 1883 – the transition of all railways from operations under the heterogeneous (solar) time of their cities to standard time, as defined by the time zones. Given the importance of railroad connections for the 19th century interbank communications, we hypothesize that the occurred time discrepancy introduced search frictions and transaction costs in signing and serving bilateral contracts among network counterparties, with banks for which local time deviated from the standard time the most turning more isolated. Employing a structural model, we find that in the competitive banking with minimal regulation: (a) network centrality mitigated insolvency; (b) interbank exposure was welfare improving for lenders and borrowers; but (c) increasing exposure had diminishing marginal returns.

JEL Classification: G01, G21, G33, N21

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1. INTRODUCTION

It is hard to downplay the role of interbank lending market in the stability of financial institutions. It serves as a source of short-term funding; it is used to support fractional reserve banking; it transmits monetary policy; it smooths and reallocates liquidity risk, etc. As a result, the ability of the interbank market to self-regulate in turbulent times is a top-notch priority of policy enforcement. Nonetheless, researchers have come to mixed conclusions concerning the resilience of interbank market. Some authors stress on the malfunctioning of interbank market in the absence of a central bank[1], some point to its self-regulating and self-stabilizing nature[2] and some insist that both scenarios are highly situational[3].

The difficulty of correct inference is largely due to the simultaneity between the bank's activity in the interbank market and its solvency rate. The liquidity position of each bank (and so its solvency) is both a consequence and a cause of the extent to which the bank is connected to its counterparties. In the modern setting, causality is difficult to document because valid instruments are rarely available and modern interbank markets are complex.[4] In this paper, we overcome the above two obstacles to the causal inference by providing a quasi-experimental solution in the historical set-up. More specifically, we study how simple borrowing-lending relationships in the *unregulated* interbank lending market affected the survival rates of individual banks during the panic of 1893 – a period in the banking history characterized by the absence of a central bank, deposit insurance and sophisticated modern-like derivatives.[5]

[1] See Bhattacharya and Gale (1987), Giavazzi and Giovannini (2011), Acharya et al. (2012)
[2] See Goodfriend and King (1988), Calomiris and Kahn (1996), Iori et al. (2006), Gorton and Huang (2006)
[3] See Allen and Gale (2000), Freixas et al. (2004), Nier et al. (2007)
[4] The complexity of modern financial markets – due to multiplicity of interbank relationships, over-complicated derivative linkages, anonymous discount window borrowing, widely mentioned "too-big-to-fail" concern, other safety nets such as deposit insurance and active hedging with off-balance sheet derivatives, etc. – is highly inconvenient for the test, since it poses countless sources of omitted variable bias.
[5] The panic of 1893, which started with the failure of large railroad companies and was followed by the subsequent run on hard currency, is remembered in the U.S. history as the deepest trough forgoing the Great

Amidst the wide variety of explanations behind the banking disorder during the panic of 1893, contemporary and modern accounts highlight the interbank contagion as an important source of bank insolvencies.[6] Yet, the formal testing of the contagion hypothesis is limited and, if undertaken, it has been suffering from severe methodological setbacks plaguing the correct inference. One of the most common threats to validity is strict endogeneity between the banks' exposure to interbank market and its odds of being liquidated. As opposed to its predecessors, this paper puts to test the profitability of participation in the interbank lending market by providing an explicit solution for the endogeneity problem. Contrary to the prevalent view, we find that the interbank market was an efficient self-regulatory mechanism which significantly contributed to the stability of individual institutions in the years surrounding the panic.

Before we continue, let us cast a brief look at how we implement a quasi-experimental design to address the endogeneity concern. Throughout the 19th century railroad connections played a vital role in the interbank lending market, which is traditionally viewed as the decentralized over-the-counter market where terms of bilateral contracts are discussed on a case by case basis.[7] In such an environment, railroads served as an important means of interbank communications by providing the necessary infrastructure for mail correspondence, cash-in-transit, hard currency transportation, private travelling of bank representatives, etc.

Depression. The series of events that unwrapped in a matter of months had devastating consequences in a long term. Over the first year of the crisis the industrial production decreased by 2.6% (Romer 1994), the total unemployment soared to 11.68% (Romer 1986) and the money supply of specie, Treasury bonds and bank notes fell by 6.3% (Rothbard 2002). Just in a matter of one year more than fifteen thousand businesses went bankrupt and failures of financial institutions numbered to over five hundred (OCC 1893). The recovery had to wait for over three years until the total production reached its pre-crisis levels in 1897.

[6] Comparing the U.S. and Canadian banking systems of the time, Bordo et al. (1996) expressed the opinion that the absence of branching and "pyramiding of reserves" in the U.S. explicitly contributed to the contagion of system-wide shocks. In the presence of contagion, absence of deposit insurance and a credit crunch that followed were mentioned as forces aggravating the financial system disruption (Gorton 2009). Some authors claim that unregulated interbank market unable to withstand systemic shocks was one of the reasons stipulating the creation of the Federal Reserve System (Lockhart 1921, Calomiris and Gorton 1991).

[7] Cocco et al. (2009, p. 25) writes: "The interbank market is fragmented in nature. For direct loans, which account for most of the market volume, the loan's terms are agreed on a one-to-one basis between borrower and lender. Other banks do not have access to the same terms."

Nevertheless, for the most part of the 19th century, railroads were governed by the local (usually solar) time of their cities, and the multiplicity of time that existed led to frequent communication disruptions and delays. To deal with the reverse causality vastly overlooked in the relationship under study (i.e. operations in the interbank market determined bank's stability, but it was also easier for stable banks to find business partners), we resort to the policy intervention that directly addressed the multiplicity of railroad time but had an indirect effect on the composition of interbank connections.

On November 18, 1883, all railroad stations in the U.S. transited from using the heterogeneous time set by their cities to using the standard time established by the predefined time zones. Meanwhile, each city preserved and continued operating under its local (solar) time. Given that banks continued utilizing the time of their home cities, we predict that such clock synchronization artificially and unintentionally redistributed interbank assets by moving them away from banks for which local urban time deviated from the standard time the most. In other words, banks originating from cities with the larger time disparities became subject to (a) higher *search frictions* at the ex-ante stage of looking for counterparties, and (b) larger *transaction costs* at the ex-post stage of maintaining relationships with counterparties.

To proceed with the empirical analysis, we create a unique dataset by manually assembling the balance sheet information on all national banks that existed in New England – the homogeneous U.S. region with mature and competitive banking system, where the panic of 1893 originated but bank failures were minimal. The main blocks of data come from the annual reports filed by the Office of the Comptroller of the Currency (OCC) in 1883 and 1884. These reports contain snap-shots of financial situations of individual banks in the third quarters of the corresponding years. The historic incidences and particular circumstances of bank liquidations are further obtained from the OCC (1897) and supplemented by similar data from the OCC (1900). To calculate time difference between the bank's city local time and railroad time, we retrieve the necessary data from two complementary sources. First, we obtain solar noon time (as of November 18, 1883) for each location in the sample from the NOAA Solar Calculator available at the web-site of Earth System Research Laboratory. Second, because the boundaries of railway time zones established in 1883 were different from those used today, we consult the vintage 19th century maps to precisely define their boundaries. Finally, we complement these data with the county specific controls reported in the decennial U.S. Census of 1880. We also use Google maps to compute air distances (a) between cities and their state capitals and (b) between cities and the only reserve city in the sample, Boston.

We begin by testing the relevance of our instrument. As a starting point, we utilize the cross-section of banks in 1884, just one year after the adoption of the railway time. We find that the time discrepancy between the bank's city local time and the standard time is strongly negatively correlated with the bank's centrality in the interbank market, i.e. the total sum of amounts borrowed to and lent from other banks scaled by total assets. After controlling for bank-, city-, county-specific controls and state effects, this finding is supported by t-statistics significant at less than 1% confidence level and F-statistics on the excluded instrument uniformly larger than 10. To verify that this effect is driven by the time mismatch following the clock synchronization and not by the unobservable variation, we employ the placebo test on the cross-section of banks in 1883, just a month before the adoption of the railway time. In all specifications, we find that the corresponding coefficients are three-six times smaller than those estimated in 1884, very close to zero, and the instrument weakness is supported by both insignificant t-statistics and F-statistics uniformly smaller than 10.

We begin the analysis of the effect of bank's total exposure to interbank market (centrality) on the probability of its failure by employing the reduced form probit estimation. We define bank failure as forced or voluntary liquidation not followed by reorganization in the interval between 1884 (just one year after the adoption of the time zones) and 1897 (the end of the main course of the panic).[8] We control for bank-, city-, county-specific variables and state effects. Independently of specification, the coefficient at the bank's centrality is found to be uniformly negative but statistically insignificant.

Nonetheless, the presence of the above mentioned endogeneity is neglected in the simplistic reduced form model. The potentially biased coefficients motivate us using structural probit technique with the time discrepancy between the bank's city local time and the railroad time as an exogenous instrument. We employ conditional maximum likelihood estimation to the structural model and calculate parameters of interest in one step from a system of simultaneous equations. Controlling for bank-, city-, county-specific covariates and state effects, we are able to detect a highly negative and significant effect of the bank's centrality on the probability of its closure. We interpret this finding in line with the extant literature on the usefulness of interbank portfolio diversification in tackling systemic risk (e.g. Allen and Gale 2000), enhanced efficiency from peer screening and monitoring (e.g. Rochet and Tirole 1996) and the multiplier effect stemming from the capability of systemically important banks to establish new connections easier and cheaper (Craig et al. 2015).

We test for the necessity of using structural probit by applying the Wald test, i.e. computing the correlation coefficient between the disturbances from the reduced form and structural probit equations. As expected, the errors are found to be highly positively correlated

[8] Studies found that banks build relationship lending in the interbank markets by repeatedly interacting with the same counterparties and that such relationships are long lasting (see Cocco et al. 2009, Affinito 2012, Afonso et al. 2014). For example, Afonso et al. (2014), studying relationship lending in the Fed Funds market, writes: "a majority of banks in the interbank market form long-term, stable and concentrated lending relationships". Theoretical motivation for such cooperation is provided by Carlin et al. (2007).

and statistically significant, strongly emphasizing on the selection of unobservables in the reduced form probit. Though it does not serve as a formal proof for the presence of endogeneity, it does shed some light on the behaviour of omitted covariation in the model.

Two influential strands of literature disagree on whether interbank market serves as a contagion diffuser or as a risk sharing cushion, and our results are indicative of the latter. To further ascertain this finding and deepen into the analysis of channels of causality, we divide sample banks into net lenders and net borrowers, two subsets of banks with the contrasting liquidity needs. To minimize distance related costs in the absence of branching, bank-lenders (deposit banks) had revenue incentives to reach distant capital markets by investing their liquidity surplus in the correspondent banks. On the other hand, bank-borrowers (investment banks), backed by such inflows, transformed into sophisticated intermediaries diversifying funding options and reducing their chances of running out of funds. Therefore, we study whether the interbank market performs its designated functions of liquidity reallocation among lenders and borrowers in the presence of systemic risk.

We replicate structural probit estimation separately for each class of banks with an endogenous regressor being interbank borrowing (gross and net) for net borrowers and interbank lending (gross and net) for net lenders. According to our results, both subpopulations of banks substantially benefitted from the interbank market participation. While lenders profited from the investment opportunity for their liquidity surplus, borrowers enjoyed the efficiency gain from financing of their liquidity shortfall. On the other hand, the extracted benefits (probabilities of survival) are found to be economically larger for lenders. This might be an allusion to lenders extracting rent at the expense of borrowers, or lenders discriminating against illiquid borrowers by refusing to lend (see Donaldson 1992, Diamond and Rajan 2011, Acharya et al 2012). But even in the potential presence of such market inefficiency, borrowers are found to be not severely harmed, since the coefficient at borrowing for them is still economically and statistically significant.

In the robustness check, we corroborate our finding that the interbank market improved the stability of individual institutions. All of our results are robust to (a) a two stage least square (2SLS) estimation with the linear probability model in the second stage; (b) a sample without small banks (less than $100,000, $200,000 and $300,000 in total assets); (c) a sample without undercapitalized banks (less than 15%, 20% and 25% in equity to assets ratio); (d) a model when time mismatch is measured as a natural logarithm; (e) a sample of only country banks (banks in the reserve city Boston are excluded); (f) a sample of banks with non-zero exposure (only connected banks); (g) a model with the universal definition of failure (reorganizations and bank charter expirations are added to the definition of failure); (h) a model when the definition of total exposure (centrality) accounts for “bills of other banks”, “due from approved reserve agents”, “national bank notes outstanding” and “state bank notes outstanding”; and (i) a model in which failure is re-defined as forced or voluntary liquidation not followed by reorganization (1) from 1884 till 1900 inclusive; (2) from 1893 till 1900 inclusive; and (3) from 1893 till 1897 inclusive (over the main course of the panic).

As a last step, we test for the non-linearity of the detected negative effect of interbank exposure on the bank’s insolvency. Given the relatively small sample and the highly positively skewed distribution of all measures of exposure (total exposure, gross borrowing and gross lending), we cannot use traditional tests (e.g. splitting the sample into quartiles based on exposure and tracking how the effect varies as we move from quartile to quartile). Instead we truncate the distribution of the exposure at the right tail and estimate the effect on the truncated sample. By gradually moving a cut-off value from right to left, we study how the effect changes. Based on such an analysis, we manage to detect a strictly monotonous increase in the negative effect of interbank exposure on the probability of insolvency, as we move from the least to the most truncated sample. Such a result is robust to all measures of exposure (total exposure, gross borrowing and gross lending) and all subsamples (all banks with non-zero exposure, only net lenders and only net borrowers). We conclude that the negative effect of interbank exposure on the insolvency is larger at lower levels of exposure, and therefore increasing interbank activity has diminishing marginal returns.

The contribution of this paper is fourfold. First, despite its historical content, the convenience of the set-up (e.g. absence of anonymous discount window borrowing, "too-big-to-fail" concern, deposit insurance, postal savings system, over-complicated derivative cross-holdings, etc.) allows us contributing to the vast modern literature on the net benefits of the interbank lending market during the financial crisis. Second, we also contribute to the literature on the relevance of interbank topology for the resilience of the interbank lending market. Namely, we highlight the facts that in the presence of systemic risk in the competitive banking with minimal regulation (a) higher interconnectedness of the network leads to its higher stability, (b) the interbank lending market fulfils its designated function of liquidity reallocation among lenders and borrowers, (c) but increasing interbank exposure has diminishing marginal returns and therefore is the most beneficial at lower levels of exposure. Third, highlighting the risk sharing role of the counterparty exposures in the interbank lending market, we partially refute the widespread view that such exposures led to sequential insolvencies of individual banks by scattering negative shocks during the panic of 1893. Finally, by utilizing the time standardization of 1883 as an exogenous shock to search frictions and transaction costs in signing and serving bilateral contracts among network counterparties, we provide explanation to the formation of interbank networks on the eve of the panic.

The following chapters are organized as follows. Section 2 describes the historical background and reviews the existent literature. Section 3 communicates the identification strategy. Section 4 describes the data and the sample construction methods. Section 5 discusses the empirical results, and Section 6 provides the concluding remarks.

2. HISTORICAL BACKGROUND

In this chapter we lay out the historical context of the study. We start with the discussion of interbank relationships existing in the National Banking Era (NBE). Then we move to communicating the logic behind the clock synchronization of 1883 and its contribution to the organization of the interbank network. We proceed to discussing the panic of 1893 and the empirical evidence on the shock propagation during the panic. The chapter is concluded with the revision of the existent literature on the interbank market functioning.

2.1 Interbank Networks during the National Banking Era

NBE starts with the adoption of National Banking Acts of 1863, 1864 and 1865. These acts establish U.S. dollar as a national currency, introduce federal chartering for banks, create the Office of the Comptroller of the Currency (OCC) responsible for bank examinations and enact stricter compliance requirements for national bank activity. Despite the selected course to improve solvency and resilience, a central bank has not been established yet and the supervisory device has been largely put on the shoulders of national banks themselves.

Some of the regulatory features directly defined the way in which banks were connected. In particular, National Banking Acts were first in the U.S. history to introduce reserve requirements but the function of reserve collection and storage was imposed onto the interbank network itself. A reserve system that existed had a three-tier pyramid-like structure and divided all banks onto central reserve city banks (banks in New York, Chicago and St.

Louis), reserve city banks (banks in 16 smaller cities) and country banks (banks in all other places). Country banks (3rd tier) were required to keep 15% of their capital as reserves (in specie and/or tender notes): 6% of it had to be in the vault and 9% could be deposited in reserve city banks (2nd tier). In turn, reserve city banks (2nd tier) were required to keep 25% of their capital as reserves: half of it had to be in the vault and half of it could be deposited in central reserve city banks (1st tier). Finally, central reserve city banks (1st tier) were required to sustain the entire 25% of capital as reserves in their vault.

Notwithstanding such positive policy innovation, the liquidity drain that could occur during the panic of 1893 is frequently attributed to the pyramidal structure of interbank reserves. If a country bank (3rd tier) had to withdraw money from its correspondent bank in the reserve city (2nd tier), this was viable only conditional on the reserve city bank having sufficient funds on its accounts. Of course, to meet its obligation, the 2nd tier bank could withdraw cash from its correspondent in the central reserve city (1st tier) but likewise this was doable provisional on the central city bank being sufficiently liquid. Proponents of contagion point out that, given such "deposit stacking", bank-specific shocks could be easily disseminated to other banks and become a cause for payment suspensions and insolvencies.

Apart from reserve requirements, prohibition of bank branching in the U.S. directly contributed to the shape and organization of interbank networks. It gave birth to thousands of unit banks with single offices existing all throughout the country. To aid transactions between these unit banks and their geographically remote customers in presence of large distances, banks could establish connections with each other by embracing the functions of financial intermediaries on behalf of other banks.[9]

[9] In particular, Calomiris and Carlson (2015) observe that alongside with the vertical integration, i.e. bank linkages *between* the tiers, banks were also linked horizontally by issuing loans and deposits *within* the tier. This means that interbank market served not only as a reserve system but also as a lender-borrower net in the context of a modern Fed Funds or repo market.

Banks also tended to form clearing house associations uniting banks within city limits (White 2011). Absence of a central bank in the US stimulated the growth in a number of clearing houses and functions that were delegated to them (Dowd 1994). The tasks carried out by them varied from clearing cash payments to monitoring bank-members. Gorton (2009) writes: "Banks themselves developed increasingly sophisticated ways to respond to panics […] centred on private banks clearinghouses. […] In response to a panic, banks would jointly suspend convertibility of deposits into currency. […] The clearing house would also cease the publication of individual bank accounting information […] and would instead only publish the aggregate information of all its members. Finally banks issued loan certificates […] a kind of deposit insurance." In New England, the earliest clearing house association was established in Boston in 1856 (Gatch 2013).[10]

Another crucial distinction of the banks during the NBE from their modern successors roots in the fact that interbank linkages were refined from the over-complicated derivative usage, often in the form of off-balance sheet items.[11] According to modern authors (e.g. Mishkin 2006), derivatives were invented in the 1970s as a response to increased volatility of financial markets and urgent need for non-trivial risk hedging. Though it is not entirely true, as options and futures circulated in the 19th century to some extent, precisely novel advances in financial engineering (such as credit default swaps) typically contribute to the interbank connections nowadays. Given the imperfection of accounting reporting and multiplicity of maturities and exposures, these derivatives considerably perplex the modern analysis of

[10] It is important to note though, that we do not study the interbank linkages arising as the bailouts of bank coalitions (such as clearing houses) to more fragile banks *during* the crisis. We rather attempt to answer the question how the existing interbank connections *on the eve* of the crisis contributed to the solvency of the linked banks. Such linkages could in principle occur as a result of bilateral agreements within the clearing houses, but they were by no means settled in a response to the crisis unfoldment.

[11] Today non-dealers financial institutions hold 3 times more of foreign exchange derivatives, 25 times more of interest rate derivatives and 6 times more of equity linked derivatives than non-financial firms, as measured by notional amounts outstanding. For credit default swaps, this number is 6 times larger for banks and securities firms and for non-financial customers (BIS 2015).

interbank market. This poses even a bigger problem if the analysis is combined with external but unobservable interventions such as anonymous liquidity provision by a central bank (e.g. term auction facility or discount window borrowing). On the other hand, naivety of interbank linkages during the NBE (and absence of opaque liquidity provision by a central bank) provides a perfect laboratory for the examination of interbank market effectiveness.

2.2 Clock Synchronization of 1883 and Interbank Network Formation

In the first half of the 19th century cities were different in the local time they were using. Each city had its own time, usually solar time, measured by some observatory of local importance (Zerubavel 1982). Therefore, majority of railroad stations managed departures and arrivals each maintaining their own clocks, anchored to some neighbouring city hall clock. O'Malley (1990) mentions: "A traveller on a westbound train, setting his watch at departure, might find after less than half an hour's travel that his watch and the local time no longer agreed. To make matters worse, individual railroad and steamship lines each ran by their own standards of time–usually the time of the city the line originated in. When two lines met, or shared a track, or terminated at a steamship landing, it threw differences in timekeeping into high relief". Needless to say, such large array of railroad time became a frequent matter of errors. Holbrook (1947) writes: "In every city and town the multiplicity of time standards confused and bewildered passengers, shippers, and railway employees. Too often, errors and mistakes turned out disastrously, for railroads were now running fast trains on tight schedules; a minute or two might mean the difference between smooth operation and a collision".

The confusion of travellers caused by frequent clock adjustments made it imperative to adopt radical innovations. The assembly of General Time Convention which took place in Chicago on October 11, 1883 issued a proposal to make all railroads in the U.S. and Canada transit to uniform standard time. The transition effectively happened on November 18, 1883 when the railroad companies started to settle time under the dominion of five time zones, each with one hour offset: Intercolonial, Eastern, Valley (later renamed into Central), Mountain and Pacific. This day became known as "a day of two noons".

Despite the reception of standard time by railroad companies, the initiative to convert cities to new time was met with fierce opposition. Even though some of the largest cities conceded to the transition simultaneously with their railways (for example, Boston (The New York Times 1884)), other locales were much less welcoming. But independently of the adoption of new time by cities, conservative circles both in the largest cities and in the country became parties of long lasting resistance.[12] Political, civil, religious and even scientific matters were frequently raised to support such resistance. [13] So, although more and more cities had been adopting the railroad time as years passed by, the solar time was still preserved by many locales. It was not until March 19, 1918 that the U.S. Congress legally implemented the standard time zones nationally by issuing the Standard Time Act.

The 19th century interbank lending relied heavily on railroad connections, because to reach their destinations both labour and capital had to be transported physically.[14] Given difficulties frequent time adjustments were causing for traveling and mail correspondence, we insist that time standardization artificially and unintentionally contributed to asset reallocation

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[12] The civil and political pressure from the emerged opposition to rewinding clocks forced some cities (e.g. Detroit) to change time on several occasions from local to standard time and back.

[13] Some of the verbatim excerpts from the discontented go as follows. The Louisville Courier Journal called time standardization "monstrous fraud", "a compulsory lie" and "a swindle". Editor C. D. Warner wrote: "The chopping up of time into rigid periods is an invasion of individual freedom and makes no allowances for differences in temperament and feeling". (Levine 2008). Clergy insisted that "the local time of their region was God's time and that the new time was a falsehood – not based directly on the earth's rotation and the locale's meridian" (Bartky 2000, p 144).

[14] Unfortunately, all the studies that we are aware of on the railroad importance for banks are based on the Free Banking Era. For example, Atack et al. (2014) highlight the fact that the bank proximity to a railroad increased information dissemination about the bank, which in turn might have increased its visibility and transparency and made them a more attractive target to sign a contract with. The railroad proximity could also provide banks with the comparative advantages in storing and transporting specie during the gold standard that prevailed, thus increasing odds of integrating such banks into the financial network. On the other hand, during the NBE almost all New England cities had a railroad access (refer to figure 4 in Atack (2013) and figure 5 in Atack et al. (2007) for growth in railroad constructions). In particular many consider the panics of 1893, which we will further discuss, to be caused by the overinvestment into the railroad industry.

in the interbank network. We claim that banks in cities, which local time was less deviant from the standard time, were more likely to embrace functions of intermediaries in the interbank lending. All else equal, their advantageous geographic location made it relatively simpler for other banks in the network to sign a contract with them and then transact, given that the interbank contracts were settled through decentralized over-the-counter bilateral arrangements. In presence of multiple counterparties, all with different local time, signing and serving contracts could become increasingly painful, especially if time variations were significant.

So, given a need for frequent correspondence, other banks would find it much easier to negotiate the contract terms with banks in cities with small or no time discrepancy. In this case we may speak about *lower search frictions* at the stage of *contract signing* for banks with smaller time disparity. By the same token, time standardization simplified processes of peer monitoring and debt serving for banks located in cities with smaller time mismatch. In this case we may speak about *lower transaction costs* at the stage of *contract serving* for banks with smaller time disparity.

2.3 Panic of 1893 and Empirical Evidence on Contagion

The panic of 1893 is considered to be the largest financial depression in the 19th century (Sprague 1910, Kemmerer 1910). The panic of 1893 is thought to have started with Philadelphia and Reading Railroad filing for bankruptcy on February 26, 1893. In a matter of months it was followed by the failures of the Northern Pacific Railway, the Union Pacific Railroad and the Atchison, and the Topeka & Santa Fe Railroad. Only in 1893, more than 15,000 companies seized to exist (Lauck 1907, p. 105) and more than 500 banks were closed (Gorton 2009).

Among few factors that led to the crisis, overinvestment in railroad construction is the most widely cited.[15] The railway network expanded to catch up with the rapid exploration of the West. Railroad companies laid miles of superfluous railroad track into “uninhabited wilderness merely to insure that another road would not claim the territory first” (Faulkner 1959, p.145).[16] Between 1887 and 1890 industrial plants, involved in railroad construction, gas and electric lighting, grouped into joint stock companies and issued more than half a billion U.S. dollars in stocks and bonds (Lauck 1907, p. 10). Overconfidence in the industry doubled the value of NYSE listed bonds (most of which issued by railroad companies) from 1885 to 1890 (Lauck 1907, p. 10). As a matter of fact, overvaluation of railroad securities gave birth to overleverage of financial sector and loss of confidence in banks (Carlson 2005). Seasonal stringency led to bank panics (Miron 1986).

Some authors argue that the deposit withdrawals originating locally were later spread through interbank contagion (see Calomiris and Gorton 1991). Nonetheless, its empirical testing is limited. Carlson (2005) finds that the correspondent banking could be a medium of contagion for banks in Colorado, as evidenced by the suspension of payments in the beginning of the crisis. Ramirez and Zandbergen (2013) find the indication of contagion for four banks in Helena, Montana. They find that publication of newspaper articles about bank runs elsewhere in the country led to reduction in time certificate deposits held by the Helena banks. Calomiris and Carlson (2015) study the existing connections among reserve city banks in the Southern and Western states during the NBE. They detect positive relationship between

[15] To a lesser degree, these factors were depreciation of silver and the monetary shock from abroad. The comprehensive review of the causes of the panic and its timeline are presented in Lauck (1907).

[16] One can draw parallels between failures of large railroad companies, highly connected institutions with some of the bank functions (e.g. the 19th century railroads were allowed to issue notes just like banks did (see Wright 1949, p.371)), with the failure of Lehman Brothers during the financial crisis of 2008. The comparison is even more pertinent given the underlying factors which steered both crises. While in the former case it was overinvestment in the railway construction which caused the panic, in the latter case it was driven by a real estate bubble.

bank closures and the amount of interbank assets held in central reserve cities during the panic of 1893.

Unfortunately, these papers provide no or poor solution for the endogeneity problem. Moreover, despite detection of contagion for more connected banks, these papers suffer from a stark sample selection bias. The crisis originated in the East, but the authors deliberately overlook banks in New England and Mid-Atlantic states and concentrate on banks in the South and in the West, where the number of bank failures was the largest (Lauck 1907). The banking system of the South and the West was younger and therefore less mature. In such an environment the increased number of bank insolvencies could be at least partially explained by poor interbank oversight that led to agency conflicts and management inefficiencies once it came to the system-wide liquidity drain.[17]

2.4 Literature Review on the Interbank Market Functioning

There are ambiguous views on the importance of the interbank market for stability of individual banks and for the whole financial system. A large pool of research deals with modelling propagation of shocks within direct interbank linkages which brings down a series of banks and suspends cash payments (see Allen and Gale 2000, Freixas et al. 2000, Lagunoff and Schreft 2001, etc.). According to some, interbank network itself may act as a source of bank failures. Rochet and Vives (2004) model a situation when a solvent bank cannot obtain financing in the interbank market as a result of coordination failure. Flannery (1996) models a market breakdown at times of uncertainty (e.g. financial crisis) when a lending bank, uninformed about the portfolio composition of individual borrowers, abstains from lending to them.

[17] Grier (2007, p. 123) writes: "self-regulation works well in mature, advanced financial markets, where strong market discipline is the norm, built up through long traditions of integrity and experience".

Other papers are more positive about the role of interbank market, at least if some conditions are met. Rochet and Tirole (1996) establish that interbank market reduces probability of systemic distress by enforcing peer monitoring, i.e. introducing incentives for lenders to monitor their borrowers. Leitner (2005) builds a model in which banks insure each other against adverse liquidity shocks by providing loans to each other, but shows that highly interconnected networks are especially susceptible to systematic risk. In contrast, Allen and Gale (2000) show that the complete markets may provide interbank participants with the buffer against liquidity shocks, whereas incomplete structure serves as a shock transmitter.[18] Some empirical papers posit that the "domino effect" of bank failures is unlikely, since there are only a small number of sufficiently large banks that can trigger contagion (see Angelini et al. 1996, Furfine 2003, Boss et al. 2004).

Even if the papers converge in their opinion on the interbank market usefulness, they may still diverge regarding the practicality of central bank interventions. Goodfriend and King (1988) argue that in presence of developed financial markets policy interventions from a central bank are redundant, i.e. interbank market is self-sufficient in providing its members with liquidity. Kaufman (1991) and Schwartz (1992) posit that even if the illiquid banks do not obtain financing in the interbank market (like in Flannery (1996)) and subsequently go bankrupt, this is an efficient equilibrium. Their conclusions are that central bank intervention should be rare, and if it has to take place, it should be done through open market operations and not discount window lending since market participants are the most informed parties. Freixas et al. (2004) distinguish between loan screening at the ex-ante stage of interbank loan granting (screening moral hazard) and ex-post borrower monitoring (monitoring moral

[18] See Hüser (2015) for the detailed literature review on the relationship between network topology and its stability.

hazard). The authors argue that a central bank should interfere only in the presence of a former moral hazard, but not the latter.

The interaction between lenders and borrowers was also heavily studied. Furfine (2001) and King (2008) document the market discipline in the interbank market: the interest payable on interbank loans is increasing in the credit risk of a borrowing bank. On the other hand, it was also found that cash-rich banks exploit cash-needy banks by lending to them at higher interest rates (Donaldson 1992). It was also found that liquid banks seek rent by making windfall profits at the expense of illiquid banks. For example, studies documented cases of liquid banks refusing lending to their illiquid counterparties and forcing them to fire sale their assets in order to meet liquidity needs. These assets can be later acquired below market prices by liquid banks themselves (see Diamond and Rajan 2011, Acharya et al 2012, Gale and Yorulmazer 2013).

3. METHODOLOGY

To estimate the effect of interbank exposure on the bank's probability of failure, we use a structural probit model with an endogenous regressor. The full model can be represented by a system of three simultaneous equations (we omit bank subscripts i for simplicity):

$$y_1^* = x_1\beta_1 + y_2\beta_2 + \epsilon_1 \qquad (1)$$

$$y_1 = \begin{cases} 1 \; if \; y_1^* \geq 0 \\ 0 \; if \; y_1^* < 0 \end{cases} \qquad (2)$$

$$y_2 = x_1\theta_1 + x_2\theta_2 + \epsilon_2 \qquad (3)$$

Equation (1) assumes that the latent propensity of bank to fail y_1^* is a function of a vector of observable bank characteristics x_1, our scalar measure of bank's connectedness to interbank network y_2[19] and an unobservable error term ϵ_1. Equation (2) just postulates that the bank fails[20] if the latent function y_1^* takes on positive values and survives if negative. Finally, equation (3) is needed to represent y_2 as a linear function of exogenous variables x_1 and our scalar instrument x_2, a time mismatch between bank city local time and railroad time. We further assume that ϵ_1 and ϵ_2 have a bivariate normal distribution with zero mean and covariance matrix $\Sigma = \begin{pmatrix} 1 & \rho\sigma_2 \\ \rho\sigma_2 & \sigma_2^2 \end{pmatrix}$.

To estimate a structural model jointly described by equations (1), (2) and (3), we use conditional maximum likelihood estimation. The log-likelihood function (derived for this purpose in the Appendix B) is given by:

$$l = y_1 ln\Phi(\omega) + (1 - y_1)ln(1 - \Phi(\omega)) - 0.5ln(2\pi\sigma_2^2) - \qquad (4)$$

$$-0.5(y_2 - x_1\theta_1 + x_2\theta_2)^2/\sigma_2^2$$

with

$$\omega = \frac{x_1\beta_1 + y_2\beta_2 + (y_2 - x_1\theta_1 - x_2\theta_2)\rho/\sigma_2}{(1 - \rho^2)^{0.5}}$$

By maximizing (4) we recover the coefficient β_2 which is a consistent, asymptotically normal and efficient estimate of the effect of bank's exposure to interbank network on probability of its failure.

The vector of control variables x_1 is chosen to filter out the effect of other confounding factors, unrelated to the bank's interconnectedness, on the bank's probability of failure. It includes bank-specific variables (size, deposit growth, capitalization, liquidity, and market power), city-specific variables (a number of banks in the city, the bank's physical

[19] Depending on the context, y_2 can be a total exposure to the interbank network CON, gross interbank borrowing BOR, net borrowing (BOR minus LEND), gross interbank lending LEND or net lending (LEND minus BOR). Please refer to Table A6 in the Appendix A for the variable definitions.
[20] In the next chapter we explicitly define the term "failure".

distance to Boston, the bank's physical distance to its state capital), and county-specific variables (population, manufacturing capital, and farming land in the bank's county).

Larger banks are often considered to be safer due to their funding cost advantage. As a rule, such banks have higher loan portfolio diversification, easier access to external funding and more liquid debt issues (Kroszner 2013). On the other hand, deposit growth is used as a measure of bank expansion, and therefore we expect it to have a negative effect on the probability of failure. In addition, smaller (especially negative) deposit growth could be a symptom of an early bank run.

The role of capital ratio as a buffer to secure creditors and depositors against losses has been mentioned in the extant literature[21], and that is why larger capitalization is expected to be negatively linked to the probability of failure. High asset liquidity may play a similar role of a buffer, but it may also signal inefficient management as a result of agency problems and therefore the loss of profitable investment opportunities (Jensen 1986). Therefore, we make no predictions about the sign of its effect. Specie to assets ratio is used to proxy for liquidity[22] because all banks, independently of their state regulation, were required to keep specie as a part of reserve requirements in the era of the golden standard (Carlson 2014).

The bank's market power in its state[23] is used to proxy for the degree of interbank competition. According to the charter value theory, competition is expected to increase risk taking decisions of banks by driving down their franchise values and therefore profits (Keeley 1990). On the other hand, the risk shifting hypothesis predicts that competition improves stability of individual institutions by improving credit conditions for borrowers (Boyd and De

[21] See Santos (2001), Calomiris and Powell (2001), Calomiris and Mason (2003), Calomiris and Wilson (2004), Kim, Kristiansen and Vale (2005), Freixas and Rochet (2008), Acharya, Mehran and Thakor (2016), Allen, Carletti and Marquez (2011), Mehran and Thakor (2011), Thakor (2012)

[22] We also repeated all estimations with the alternative measure of liquidity which added "checks and other cash items", "tender notes", "fractional currency" and "bills of other banks" to "specie" but none of the results changed.

[23] In alternative specifications, we also controlled for the bank's market power *in its county*. The results are identical to those reported below.

Nicolo 2005). Another proxy for the degree of local competition is the number of banks in the city (additionally, cities with more saturated banking industry may naturally dwell more connected banks).

Next, we control for the distances of each bank's city to the capital of its state and to Boston – the largest city, the home of the famous clearing house association and the only reserve city in the region. Controlling for physical distances is necessary because of the clear dependence of the 19th century intermediation on geography. Moreover, in the absence of branching, banks located remotely from financial centres were forced to find correspondent banks in such centres to clear and collect checks from their clients, acquire access to capital markets and improve transparency and visibility of their brands and operations.

Population of the county affected the capital requirement for banks as well. The National Banking Act of 1864 introduced a minimum capital requirement equal to $200,000 for national banks in cities with population more than 50,000 people, $50,000 for cities with less than 6,000 people, and $100,000 for all other cities (Jaremski 2013). Larger population could also directly affect the demand for banking services from individual consumers.

Farming land is used to control for agricultural intensity of the region which was found to be a decisive factor in cash flow movement during the harvest seasons (Kemmerer 1910, Miron 1986, Hanes and Rhode 2013). On the other hand, manufacturing capital is included to account for the industrial concentration in the county and therefore the demand for banking services for purposes of trade and commerce (Calomiris and Carlson 2015).

We also include state effects to capture possible judicial discrepancies across states. Even though we attempted to pick a region as homogeneous as possible, i.e. New England, reserve requirements were still highly complicated during the NBE and could differ across states. For instance, the interstate disagreement existed whether to keep reserve requirements against demand deposits, against time deposits or against both (Carlson 2014). There were also the disparities in lawful allowances concerning the items to be included into reserve requirements: specie, short term loans, U.S. Treasuries or clearing house certificates (Bordo and Roberds 2013, Carlson 2014). The frequency of onsite inspections and the quality of financial reports could also vary from state to state (Granja 2014).

4. DATA AND SAMPLE CONSTRUCTION

As a primary source of data, we use the balance sheet information on New England banks which is collected manually from OCC (1883) and OCC (1884). These reports are available in print and online at the digital library of the economic, financial and banking history of the US, run by the Federal Reserve Bank of St. Louis (FRASER). They contain the snapshots of balance sheet items of all national banks in the US for the 3rd quarter of 1883 and 1884. To compute deposit growth for 1883, one of our controls, we also refer to OCC (1882). Table A2 in the Appendix A illustrates the breakdown of a typical balance sheet of the time based on its mean item values.

In our study, we focus on New England, the north-eastern part of the US encompassing six states: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut. We choose New England for several reasons. To begin with, the data on the dates when each city transited to the railroad time (time zones) is unavailable to us and might not even exist in practice. To solve this problem, we choose 1884 as our reference year (just year after the railroad time implementation), which is done to minimize probabilities that cities had actually sufficient time to transit to railroad time. On top of that, the opposition to transit to new time was naturally more intense at places where the time disparity between the old and the new time was larger (Bartky 1989). As one may note in Table 1, the average time mismatch for New England cities constituted almost 14 minutes (and not less than 5 minutes) which is significant enough to trigger local disapproval. In other words, we assume that cities in New England were unlikely to adopt time changes immediately after the clock synchronization of 1883.

Another reason to study New England is its multidimensional homogeneity. It was almost uniformly located within the Eastern Time, which significantly simplifies the analysis. This area had similar political, constitutional and legal systems and therefore was not a subject of regulatory competition. Being among the original Thirteen Colonies which were ones of the earliest to enter the Union, this region was characterized by the most developed banking system with the early adoption of reporting requirements and periodic onsite examinations (Granja 2014, Figure 1). It also had the most competitive banking systems of the time, with saturated concentration of banking sector on a small piece of land[24], in which all the banks were characterized by little or no market power (see Table 1). As a matter of fact, it was less likely for New England banks to induce bargaining power in the interbank market from a source other than their geographical location or liquidity supply (their lending role).

National banks coexisted with state banks and small private banks. In this study, we concentrate only on national banks to reduce wide regulatory gaps between national banks (monitored by the OCC), state banks (subject to state supervision) and private banks (unregulated enterprises mostly originating from rural areas).[25] Closer to the end of the 19th

[24] Table A8 in the Appendix A depicts the geographic distribution of the bank assets across the US regions. It can be seen that New England had the largest number of banks per square mile. Apart from being more competitive, this region was characterized by banks being on average much safer than banks in the West and South, as indicated by the larger capitalization and U.S. bonds on deposits.

[25] For example, national banks were subject to higher capital requirements but also to tax exceptions on issuing bank notes. They were also prohibited to extend loans based on real estate collateral in fear of maturity mismatch between such loans and demand deposits (White 1911, Granja 2014). Finally, double liability principle, to be further discussed, applied to national banks but not necessarily to state banks.

century the U. S. financial system has expanded to include other financial institutions such as mutual saving funds, savings and loan association and life insurance companies. Yet, total assets of commercial banks constituted 62.6% of all total assets possessed by financial institutions and remained dominant intermediaries in capital markets (White 1998).

The data on bank liquidations comes from OCC (1897). We include bank failures between 1884 and 1897 inclusive. 1897 is considered to be the year when the panic of 1893 was over (Lauck 1907). Choosing 1893 as the end year also resolves the trade-off between choosing a too early and a too late end year. Had the end year been chosen too early, we would have not enough incidences of bank failures. Had it been too late, our proxy for interbank activity measured in 1884 could become irrelevant for bank failures that occur in a very distant future. The latter could be especially valid for bank failures in a post-crisis period, when interbank linkages get structurally transformed, e.g. broken and rearisen with new counterparties on the nodes.

Table A3 in the Appendix A provides the distribution of bank liquidations by year and type of exit between (a) December 1, 1884 (the date when OCC (1884) was issued) and December 6, 1897 (the date when OCC (1897) was issued), and (b) between December 6, 1897 and December 3, 1900 (the date when OCC (1900) was issued). As expected, there was a sudden jump in a number of bank liquidations in the first two years of the panic of 1893. Jointly, in 1893 and 1894, the number of bank exits totalled to 11, which represented 25% of all bank exits in the sample.

In the main analysis, we define failures as voluntary and forced liquidations provided they are not followed by reorganization (i.e. succession by associations with the same or a different title).[26] Voluntary liquidations are included because they were also signs of poor financial standing thanks to the double liability principle: "if a bank failed, shareholders at the time of failure could be forced to pay an assessment up to the par value of the stock in order to compensate depositors and other creditors" (White 2011). So, in order to avoid paying the fee, owners often chose to liquidate the bank while it was still solvent. Table A3 in the Appendix A shows that the number of voluntary liquidations considerably exceeded the number of forced liquidations being indicative of prudent behaviour of managers who optimally chose to close a bank timely.[27] Table A4 in the Appendix A provides the complete list of all bank failures (voluntary and forced liquidations not followed by reorganization) between December 1, 1884 and December 6, 1897. Table A5 in the Appendix A extends the list by including all bank failures up till December 3, 1900.

We supplement these data with solar time prevailing in locales on November 18, 1883 (the date of the transition to railroad time) using National Oceanic and Atmospheric Administration (NOAA) Solar Calculator. It is available online at the web-site of Earth System Research Laboratory. Even though it is literally impossible to know the exact time in use across locales before the establishment of time zones, we assume that the local time did not significantly deviate from the time observed thanks to astronomically observed sun movement. In principle, cities could use the time different from their solar time if they were located near the larger and more economically significant city. Nonetheless, such deviations were small given their geographical proximity, and so we assume that the solar time is a good approximation of the local time.

[26] Therefore, we exclude reorganizations and charter expirations which may had a qualitatively different rationale behind bank closure. However, at the later stage we confirm that our results are also robust to the inclusion of reorganizations and charter expirations into the definition of failure.

[27] Double liability principle did not necessarily apply to *state* banks, as it was the matter of states under jurisdictions of which they operated. In 1870, only eighteen states had the double-liability principle in place. In 1900, the number of such states increased to thirty two. As a consequence, state banks were less likely to voluntarily liquidate the bank while it was still solvent, and so the number of such liquidations (relatively to forced liquidations) was much smaller for state banks (White 2011).

Another complication comes from finding the locale indicated in the OCC reports. Some of the towns were renamed and others became parts of the larger metropolises. Fortunately for us, such cases were extremely rare (only 15 instances[28]). So, when we are unable to identify the indicated locale on the map, we search for facts of its renaming or merger with a bigger city in the Internet.

The boundaries of time zones of 1883 were different from those used today. To define the boundaries, we inspect the collections for the vintage maps depicting the partition of the US territory into time zones. One can refer to Figure A4 in the Appendix A to see the examples of such maps. As one sees, almost all sample locales conveniently rest within the Eastern Time Zone but with two exceptions. They are Houlton, ME and Calais, ME. These cities belong to the realm of the Intercolonial Time Zone.[29] Eastern Time was based on the 75th meridian, and it was one hour slower than Intercolonial Time based on the 60th meridian.[30]

To collect such variables as population, amount of farming land and value of manufacturing capital in each of New England counties, we refer to the decennial U.S. Census published in 1880. Using Google maps, we also compute air distances between each locale in the sample and their state capitals and between each locale in the sample and Boston. In both, NOAA Solar Calculator and Google maps, we use map markers as identifiers of the locations.

Panel A of Table 1 provides the descriptive statistics of the variables estimated for 1884.[31] First, banks were heavily capitalized in 1884 relatively to modern banks. On average, they kept 34% of assets in paid in capital, with not less than 6.4% and not more than 65.8%.

[28] See Table A7 in the Appendix A for the list of locations that were renamed.
[29] While according to modern time zones, all New England states belong to the Eastern Time.
[30] All estimations below are conducted with the inclusion of Houlton, ME and Calais, ME, since their exclusion does not affect the results.
[31] Table A1 in the Appendix A delivers summary statistics when Boston banks are excluded.

Second, banks were not heavily concentrated with average market power (ratio of deposits to all deposit in the state) equal to 1.1%. The bank with the largest market power kept as little as 11.7% of all deposits in the county. Thirdly, banks kept relatively small amount of interbank assets, with average CON equal to 4.5% and heavy positive skewness. In addition, the number of banks varied by city. While most of the cities in New England had only one bank, Boston had fifty nine.

Panel B of Table 1 compares the difference in bank characteristics between net lenders and net borrowers. One can see that net borrowers were larger, more connected, less capitalized, slower growing, and located in cities closer to Boston, with larger population and industrial concentration.[32] Such characteristics of borrowers might be symptomatic of them being intermediaries who accumulated funds to transact on behalf of lenders located in less economically developed and more geographically remote regions.[33] Speaking in modern terms, bank-borrowers can be thought as investment banks, whereas bank-lenders can be thought as commercial or deposit banks.

Table 2 shows the Pearson's and Spearman's rank correlation matrix for transformed variables which explicitly enter our equations. Apart from size and capitalization, all other variables have surprisingly small (less than 10%) correlations with the dummy FAIL. It is also surprising that such preliminary analysis of the data reflects the positive and therefore counterintuitive correlation between capitalization and FAIL.

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[32] Contemporary studies have found similar characteristics of borrowers in the modern Fed Funds market, i.e. net borrowers are larger and slower growing (see Ho and Saunders 1985, Furfine 1999).

[33] Figures A2 and A3 in the Appendix A depict the geographic distribution of CON and net lending (LEND minus BOR). These figures illustrate that on average banks located closer to Boston had higher interbank exposure and borrowed more than lent. Additionally, Figure A1 shows that in the area around Boston a high number of financial institutions were domiciled. Altogether, this visual representation supports the evidence that borrowers played a role of correspondent banks which accumulated funds to conduct operations on the behalf of lenders, with lenders being normally located in rural areas, remotely from important commercial and industrial centres.

5. ESTIMATION AND RESULTS

5.1 Instrument Relevance: Time Mismatch and Interbank Exposure

We test the relevance of our instrument by estimating the equation (3) with OLS. We predict that after the implementation of time zones banks with larger difference between their city local time and railroad time became more isolated because of search frictions and transaction costs that such time standardization had brought.

Table 3 shows the results of OLS estimation of CON on time mismatch. Seven specifications depicted are different only in the control variables used. In all specifications, heteroscedasticity robust standard errors are clustered by county. To alleviate the possible bias caused by outliers, all continuous variables are winsorized at 1%. Consistent with the prediction, the coefficient at time mismatch is highly significant (less than 1% confidence level) and negative all throughout the specifications. Note that equation (3) can be treated as a first stage estimation of the 2SLS procedure. Therefore, we also provide F-statistics on the excluded instrument (time mismatch) to test for its strength where the null hypothesis is "the instrument is weak". As expected, F-statistics are sufficiently large (uniformly above 10) to reject the null. Interestingly, the R-squared is also high. In the specification (5), which we call our full model, it reaches 47.65%, meaning that almost half of variation in interbank activity is explained by our model.

To make sure that the result is driven by time standardization and not by omitted unobservable, we execute a placebo test. That is, we repeat the cross-sectional estimation of equation (3) exactly as before but in 1883, just before the actual time standardization. Under the given scenario, we anticipate the coefficients to be much smaller and statistically insignificant.

The results of such a falsification test are represented in Table 4. As expected, the coefficients at time mismatch in the placebo test are from three to six times smaller than the corresponding coefficients in the original regressions in Table 3. In four out of seven models, they are significant at less than 10%. Note that marginal significance of coefficients in the full model can be explained by the expectations of time standardization.[34] This seems especially correct given that the data for 1883 comes from the OCC report published on October 2, 1883, just nine days before the decision to standardize time was made during the Chicago meeting (October 11, 1883) and month and a half before the actual time standardization (November 18, 1883). In addition, many railroad companies adopted time standardization along some of their railroad lines well before "the day of two noons". Kern (1983) writes: "Around 1870, if a traveller from Washington to San Francisco set his watch in every town he passed through, he would set it over two hundred time. The railroads attempted to deal with this problem by using a separate time for each region. Thus cities along the Pennsylvania Railroad were put on Philadelphia time, which ran five minutes behind New York time." So time standardization occurred in 1883 was not immediate, as one could mistakenly think, but forgone by occasional standardizations put into action by the railroads themselves (Fox 2015).

5.2 Reduced Form Probit vs. Structural Probit

We start with estimating the reduced form probit on the cross-section of banks where total exposure to interbank market is treated as an exogenous variable. This model can be summarized by the equations (1) and (2). Table 5 presents the coefficients of such a model (partial effects on the response probabilities) estimated using conditional maximum likelihood algorithm. In all specifications, standard errors are clustered by county and all continuous variables are winsorized at 1%. State effects are included. As seen, all the coefficients at

[34] For example, it is well-known that months before the actual clock synchronization, jewellers who anticipated the transition, started producing custom-designed clocks with two dials, showing standard and railroad time respectively (McCrossen 2013, p.94).

interbank activity are negative but highly insignificant (standard errors are larger than coefficients).

The results however are not reliable in the presence of endogeneity. As a matter of fact, we re-estimate the effect of interbank activity on probability of failure using structural probit, as described by the equations (1), (2) and (3). We treat time mismatch between bank city local time and railroad time as an exogenous variable in our system of simultaneous equations. In all specifications, standard errors are clustered by county and all continuous variables are winsorized at 1%. State effects are included.

The results are illustrated in Table 6. As opposed to the reduced form estimation, the coefficients at CON jump in value drastically and become significant at less than 1% level. Such a result, robust to all specifications, emphasizes the fact that the upsides of operating in the interbank market greatly exceeded its downsides. This result also supports the view that the interbank market served as a risk sharing cushion rather than a contagion diffuser during the panic.

The two bottom rows of Table 6 test for the significance of correlation ρ between the errors from structural and reduced form probit equations in the covariance matrix Σ. This is a Wald test for exogeneity of CON (null hypothesis is "no endogeneity in the reduced form probit"). The first row shows the estimated parameter ρ, and the second row shows the Chi-square statistic of its significance. As seen, both ρ and Chi-square statistics are sufficiently high to econometrically motivate rejecting the null hypothesis and using the structural model instead of the reduced.

Finally, we execute a number of robustness checks. First, we employ the 2SLS estimation with the linear probability model in the second stage. Second, we restrict our sample only to medium and large banks by dropping banks with assets smaller than $200,000.

Third, we cut our sample only to well-capitalized banks with paid in capital not less than 20%.[35] Fourth, we re-define time mismatch as a natural logarithm.[36] Fifth, we exclude banks in the reserve city Boston, and so execute our study only on country banks. Sixth, we shrink our sample to only connected banks with non-zero exposure to interbank market. Seventh, we re-define failure to include charter expirations and reorganizations. Eighth, we run a model when the definition of total exposure (CON) also accounts for "bills of other banks", "due from approved reserve agents", "national bank notes outstanding" and "state bank notes outstanding".

The results of alternate specifications are shown in Table 7. We control for bank-, city-, county-specific variables and include state effects exactly as in our reference (full) model. Standard errors clustered by county are provided in brackets. All continuous data are winsorized at 1%. As it is seen, the consistently negative and highly significant effect of interbank activity on the probability of failure is preserved across all specifications.

We also conduct a robustness test with respect to in what time intervals we consider bank failures. We re-define failure as forced and voluntary liquidation not followed by reorganization (a) from 1884 till 1900 inclusive (over the full length of the sample period)[37]; (b) from 1893 till 1900 inclusive; and (c) from 1893 till 1897 inclusive (over the main course of the panic). [38] [39] Table 8, which shows the results, asserts that the negative effect of

[35] The selection of thresholds on total assets and a capital ratio was made randomly but in unreported regressions we confirm that our results in this and the upcoming sections are also robust to the following thresholds: (a) $100,000 and $300,000 for total assets, and (b) 15% and 25% for a capital ratio.

[36] In unreported regressions, we also tried to re-define interbank activity as a natural logarithm of the sum of three items: "Due from other banks and bankers", "Due to other national banks" and "Due to State banks and bankers". The results are robust to such specification.

[37] Table A5 lists all forced and voluntary liquidations not followed by reorganization between December 6, 1897 (date when OCC (1897) was published) and December 3, 1900 (date when OCC (1900) was published). Surprisingly, over these three years the total number of such exits is roughly equal to the number of similar exits over the entire thirteen years in the main analysis (from 1884 to 1897). This suggests that even though many banks officially filed for liquidation after the main course of the panic, they might have experienced structural problems much earlier. That is why we conduct a robustness check including the period from 1897 to 1900.

[38] In the main analysis, we include bank failures which begin from 1884 – almost immediately after the time standardization of 1884 but few years before the start of the main course of the panic of 1893. This is done to

interbank activity on the probability of failure is robust to alternative time horizons over which the failure is measured.

5.3 Borrowers vs. Lenders

To deeper study the beneficial effect of liquidity reallocation, we split our sample into net borrowers and net lenders. Such separation is done to divide all interbank agents into liquidity demanders (illiquid banks), which use interbank credit to finance their liquidity shortfall, and liquidity suppliers (liquid banks), which make investments of their excess liquidity. We attempt to answer the question whether interbank market continues to fulfil its goal of a risk sharing cushion in the presence of systemic risk through effective liquidity reallocation, i.e. it benefits borrowers by covering their liquidity gaps and lenders by giving them an investment opportunity for their liquidity surplus.

As before, we estimate the structural probit model of bank failures where CON is substituted with gross borrowing (if the sample consists of net borrowers) and with gross lending (if the sample consists of net lenders). Table 9 presents the results. Again, we use time mismatch as an instrument for gross borrowing and gross lending. We use seven specifications different only in control variables used, which correspond to their equivalent specifications in Table 6. Panel A (Panel B) concentrates on the case when BOR (LEND) is an instrumented variable and the sample is net borrowers (net lenders). Standard errors are clustered by county. All continuous variables are winsorized at 1%. State effects are included.

Panel A (Panel B) shows that interbank borrowing (lending) benefitted net borrowers (net lenders) by reducing the probability of their failure. Moreover, the coefficients at gross

account for the early precursors of the crisis (such as panic of 1884 and rate wars among railroad companies in 1884-1885) that had long-term consequences for the railroad industry (Lauck 1907, p.2)). On the example of the NBE, Gorton (1988) argues that panics can be predicted from the dynamics of business cycles, and this result is theoretically described in the literature on the fundamentals-driven bank runs (see Chari and Jagannathan 1988, Jacklin and Bhattacharya 1988, Allen and Gale 1998, etc.). By choosing 1884 as a starting point of the bank liquidations, we also maximize a number of observations on bank failures. Nonetheless, later we show that our results are unbiased to the choice of the starting year.

[39] In specifications in which we start counting failures from 1893, we drop banks that failed before this year.

borrowing for net borrowers are found to be always economically larger than the corresponding coefficients at gross lending for net lenders. This result accentuates that lenders are more likely to survive conditional on their participation in the interbank market. One explanation for this difference might be the bargaining power that net lenders enjoy as liquidity suppliers. This is also supported by unequal distribution of net borrowers (that represent majority) and net lenders (that represent minority) in the sample. The extant literature shows that lenders, as oligopolistic liquidity sellers, may extract rent from borrowers (liquidity buyers) by negotiating convenient for themselves terms of loans (e.g. by setting higher interest rates) or even discriminating against illiquid borrowers by refusing in financing. On the other hand, the highly negative economically and statistically effect of interbank participation of the probability of insolvency of borrowers tells us that even in the presence of above discrimination, borrowers are not severely harmed, and interbank exposure was rather welfare improving for them than detrimental.

As before, we conduct several robustness checks. First, we employ the 2SLS estimation with the linear probability model in the second stage. Second, we restrict our sample only to medium and large banks by dropping banks with assets smaller than $200,000. Third, we cut our sample only to well-capitalized banks with paid in capital not less than 20%. Fourth, we re-define time mismatch as a natural logarithm.[40] Fifth, we exclude banks in the reserve city Boston. Sixth, we re-define gross lending as net lending measured as the ("Due from other banks and bankers" - "Due to other national banks" - "Due to State banks and bankers")/"Total assets". Similarly we-redefine gross borrowing as net borrowing which is just a negative value of net lending. Seventh, we re-define failure to include charter expirations and reorganizations. Panels A and B in Table 10 show that the above discovered

[40] In unreported regressions, we also tried to re-define gross lending as a natural logarithm of "Due from other banks and bankers", and gross borrowing as a natural logarithm of the sum of "Due to other national banks" and "Due to State banks and bankers". The results are robust to such specifications as well.

finding is robust to all alternative model specifications for net borrowers and net lenders, respectively.

Table 11 tests the robustness of our estimations to the alternate time horizons over which failure is measured. As before, we re-define failure as forced and voluntary liquidation not followed by reorganization (a) from 1884 till 1900 inclusive (over the full length of the sample period); (b) from 1893 till 1900 inclusive (from the start of the main course of the panic till the end of the third year succeeding the panic); and (c) from 1893 till 1897 inclusive (over the main course of the panic). Table 11 confirms that the results are robust to these specifications as well.

5.4 Non-Linearity

We now want to check how the effect of interbank exposure on the probability of insolvency varies with the exposure itself. Ideally, we would test it by assessing the effect for the most connected banks and then, moving to less connected banks, check for the non-linearity of the effect. In a perfect scenario, we would sort our data based on the interbank exposure, split our sample into quintiles (or any other percentile groups based on the probabilistic distribution of the exposure) and compare the probit coefficients between the quintiles. Nonetheless, our relatively small sample and highly positively skewed distribution of the exposure do not allow us creating such quintiles for a sensibly tractable test. As an alternative, we impose a number of right tail cut-off values on the probabilistic distribution of the exposure and see how the effect of the interbank exposure varies once we move from a larger to a smaller cut-off.

Table 12 presents the results of such a test. Panel A shows the coefficients at CON similar to the specification (7) in table 6, but with two differences. First, we use only connected banks (with non-zero exposure). Second, CON is truncated on the right. When we estimate the model with the right tail cut-off on CON at 40%, the coefficient at CON is estimated to be -17.7727. As we move the cut-off to the left, the absolute value of the coefficient monotonically increases and reaches its maximum when CON is truncated at 2.5%. This indicates that the negative effect of interbank exposure on the rate of insolvency is non-linear. It is the largest for the lowest levels of exposure but has diminishing marginal returns as we increase the exposure. Such finding is supported by other Panels, in which we use alternative measures of exposure (BOR and LEND) and alternative samples (net lenders and net borrowers).

These results indicate that banks benefit from interbank market participation the most at reasonably low levels of interbank exposure. At a sufficiently high level of exposure, increasing it might not be that beneficial, as counterparty risk will suppress any positive benefits of risk sharing. Unfortunately, we cannot test for a counterfactual what would happen once banks increase the exposure well beyond their optimum, since majority of banks in our sample seem to be complying with the rule of not overextending their interbank activity. This prudent strategy of signing bilateral lending contracts could also serve as a partial explanation why banks were able to withstand contagion.[41]

6. DISCUSSION AND CONCLUSION

In this paper we managed to establish a positive causal link between the banks' participation in the interbank lending market and their survival rates during the panic of 1893, the biggest financial crisis before the Great Depression. We turned to economic history to avoid potential sources of omitted variable bias present in modern settings, such as

[41] This might also explain why our findings diverge with the results obtained by Calomiris and Carlson (2015). The interbank exposure of reserve city banks in their sample significantly exceeds the exposure observed among country bank in our sample. As a matter of fact, those reserve city banks were more susceptible to contagion by over-relying on counterparties and therefore crossing the safe boundaries of risks.

anonymous liquidity provision by a central bank, undisclosed subsidizing of bigger banks ("too-big-to-fail"), undetectable derivative cross-holdings and existence of alternative safety nets (e.g. deposit insurance, off-balance sheet derivative hedging, etc.). Given the absence of such concerns during the National Banking Era (a central bank, derivatives and deposit insurance did not exist at the time), we managed to discover that interbank market played a role of a safety net for national banks in New England during the panic. We improved identification of prior studies by adopting a quasi-experimental design that incorporated an exogenous shock triggered by the time standardization among all railroad stations in 1883. Given the importance of railroad connections for the 19th century communications, such shock artificially and unintentionally redistributed interbank assets by introducing search frictions and transactions costs within the interbank network, albeit having no direct effect on the bank failures.

Through a structural model, in which we explicitly modelled endogeneity of interbank exposure (frequently and detrimentally overlooked in similar studies), we arrived at a number of highly relevant policy implications for the resilience of interbank lending market. In particular, we found that in the presence of systemic risk interbank market benefitted banks with the contrasting liquidity needs: lenders profited from the investment opportunity for their liquidity surplus and borrowers financed their liquidity deficiency. Such results emphasize on the ability of interbank lending market to self-regulate in the competitive banking with minimal regulation by fulfilling its designated function of liquidity reallocation and therefore mutual co-insurance in the presence of systemic risk. Nevertheless, we find that increasing interbank exposure had diminishing marginal returns, and therefore it was the most beneficial at the lowest levels of exposure.

Our research leaves some avenues for further research. First, the detected positive effect of exposure can be partially explained by the absence of banks in the sample that kept unreasonably high exposure. Consequently, we cannot test for the counterfactual: what would happen to banks, provided that they recklessly integrated into financial network and kept interbank assets well beyond their optima.

Second, the results of the paper cast doubts on the interbank contagion as a primary cause of bank failures during the financial crisis. Other potential reasons of bank avalanches (simultaneous failures) during the crisis are mentioned to be the absence of deposit insurance (see Demirguc-Kunt and Detragiache 2002), the presence of the informational contagion (see Chen 1999) or even "joint failure risk arising from the correlation of returns on the asset side of bank balance sheets" (Acharya 2009, p.225). Answering this question is well beyond the scope of our analysis, but can be examined, given the efforts of future studies.

Finally, given the frequently highlighted importance of network topology for the resilience of interbank systems, future research may find it useful studying the effects of directional lending (which we omit lacking the data on bilateral interbank connections). In particular, future researchers could be interested in studying whether lending to and borrowing from banks with particular individual and network characteristics had any effect on the network stability during the panic of 1893 (see Calomiris and Carlson 2015 for their pioneering efforts).

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Table 1. Summary statistics, 1884

Panel A: Summary statistics

	N	Mean	St. Dev.	Min	Max	Skewness	Kurtosis
Total assets ($)	568	948,987.1	1,196,506	68,363.01	12,600,000	3.933	25.973
Capitalization	568	0.34	0.085	0.064	0.658	0.273	3.708
Deposit growth	559	-0.008	0.047	-0.268	0.18	-0.336	5.94
Liquidity (specie)	568	0.015	0.013	0	0.112	2.161	11.302
Liquidity (all)	568	0.042	0.025	0.001	0.175	1.354	5.961
Market power (county)	568	0.114	0.168	0	1	3.326	16.127
Market power (state)	568	0.011	0.014	0	0.117	3.018	15.494
Time mismatch (min)	568	13.518	4.266	5.5	28.3	0.461	3.728
Distance to Boston (km)	568	115.294	87.543	0	491.2	0.707	3.213
Distance to a state capital (km)	568	51.11	44.29	0	252.8	1.098	4.454
Number of banks (city)	568	9.82	17.57	1	59	2.253	6.463
Number of banks (county)	568	21.735	18.42	1	61	0.897	2.608
Population (units)	568	144,061.4	119,973	3,727	387,927	0.803	2.391
Farming land (acres)	568	298,382.1	190,476.7	4,327	732,807	0.473	2.842
Manufacturing capital (000$)	567	25,306.43	20,840.9	20.25	61,299.6	0.285	1.527
Connectedness (CON)	568	0.045	0.073	0	0.676	3.874	24.794
Gross borrowing (BOR)	568	0.029	0.059	0	0.617	4.835	36.323
Gross lending (LEND)	568	0.015	0.026	0	0.264	3.41	21.884

Panel B: Difference in means between net borrowers and net lenders

	Net lenders			Net borrowers			t-statistic
	N	Mean	St. Dev.	N	Mean	St. Dev.	
Total assets ($)	163	752,331	722,289.1	302	1,247,860	1,472,979	4.04
Capitalization	163	0.353	0.085	302	0.327	0.086	3.132
Deposit growth	160	0	0.053	301	-0.014	0.041	3.16
Liquidity (specie)	163	0.016	0.013	302	0.017	0.014	0.745
Liquidity (all)	163	0.043	0.002	302	0.044	0.001	0.676
Market power (county)	163	0.144	0.207	302	0.0923	0.126	3.346
Market power (state)	163	0.012	0.016	302	0.011	0.015	0.53
Time mismatch (min)	163	13.581	4.507	302	13.229	4.3	0.827
Distance to Boston (km)	163	128.79	93.861	302	109.05	83.239	2.332
Distance to a state capital (km)	163	52.036	47.398	302	50.779	45.98	0.278
Number of banks (city)	163	10.018	17.639	302	12.488	19.546	1.345
Number of banks (county)	163	19.529	18.943	302	24.904	18.946	2.972
Population (units)	163	127,237.7	119,670.2	302	160,849.7	120,955.2	2.87
Farming land (acres)	163	285,789.5	185,874.1	302	287,536.5	193,480	0.094
Manufacturing capital (000$)	162	23,162.27	21,631.6	301	28,294.9	19,861.57	2.571
Connectedness (CON)	163	0.035	0.044	302	0.065	0.089	4.12
Gross borrowing (BOR)	163	0.007	0.015	302	0.051	0.073	7.583
Gross lending (LEND)	163	0.027	0.034	302	0.014	0.022	5.132

Definition of variables is provided in Table A6 of the Appendix A. Difference in a number of observations between manufacturing capital and other county variables is due to its data unavailability for Nantucket county, MA in the U.S. Census of 1880. Difference in a number of observations between deposit growth and other bank specific variables is due to the fact that some banks did not exist in 1883.

Table 2. Correlation Matrix

	FAIL	CON	BOR	LEND	Time mismatch	Num. of banks	Deposit growth	Size	Capital	Market power	Liquidity	Distance to Boston	Distance to capital	POP	LAND	MANCAP
FAIL	1	-0.015	-0.074	-0.001	-0.016	-0.089	-0.0371	-0.171	0.123	-0.0982	-0.018	0.0238	-0.0282	-0.0388	0.0544	-0.0195
CON	-0.041	1	0.857	0.807	-0.223	0.472	-0.1402	0.449	-0.197	-0.0923	0.314	-0.0355	-0.2004	0.2189	-0.2232	0.2421
BOR	-0.058	0.956	1	0.487	-0.214	0.462	-0.1983	0.483	-0.228	-0.0748	0.258	-0.0403	-0.1523	0.2485	-0.1539	0.2624
LEND	0.017	0.679	0.434	1	-0.203	0.402	-0.0308	0.37	-0.105	-0.0916	0.273	-0.0118	-0.1738	0.1654	-0.2306	0.1899
Time mismatch	0.008	-0.106	-0.069	-0.154	1	0.158	0.1071	-0.004	-0.074	-0.0528	0.156	-0.3309	-0.2919	0.1853	-0.3505	0.0724
Num. of banks	-0.069	0.526	0.486	0.4	0.152	1	0.0251	0.727	-0.238	-0.1626	0.302	-0.3835	-0.4298	0.5018	-0.3870	0.4841
Deposit growth	-0.075	-0.135	-0.136	-0.074	0.13	0.047	1	-0.032	0.025	0.0688	-0.033	-0.0657	-0.0719	0.0036	-0.0203	0.0094
Size	-0.175	0.51	0.492	0.336	-0.046	0.664	-0.0098	1	-0.316	-0.0052	0.255	-0.3865	-0.3150	0.5459	-0.3218	0.5159
Capital	0.13	-0.289	-0.298	-0.144	-0.093	-0.161	-0.0291	-0.321	1	-0.2044	-0.338	0.1368	0.0071	-0.2530	-0.0061	-0.1424
Market power	-0.065	-0.116	-0.115	-0.069	0.108	-0.221	0.1468	-0.122	-0.066	1	0.007	0.5366	0.3592	-0.6318	0.2681	-0.6354
Liquidity	0.003	0.388	0.347	0.324	0.173	0.504	0.0178	0.343	-0.27	-0.0376	1	-0.1875	-0.2011	0.2648	-0.1439	0.1280
Distance to Boston	0.064	-0.383	-0.364	-0.265	-0.213	-0.844	-0.0732	-0.551	0.211	0.3151	-0.46	1	0.5460	-0.7552	0.4793	-0.7377
Distance to capital	0.004	-0.406	-0.377	-0.303	-0.176	-0.772	-0.0634	-0.537	0.06	0.2359	-0.339	0.6918	1	-0.4498	0.4645	-0.4770
POP	-0.032	0.282	0.28	0.166	0.074	0.552	0.0066	0.557	-0.235	-0.5032	0.293	-0.6922	-0.4979	1	-0.2309	0.9068
LAND	0.075	-0.462	-0.409	-0.396	-0.216	-0.878	-0.0419	-0.523	0.118	0.1865	-0.449	0.8341	0.6567	-0.3709	1	-0.2436
MANCAP	-0.02	0.245	0.241	0.152	-0.08	0.41	-0.0228	0.506	-0.137	-0.5689	0.164	-0.5512	-0.4183	0.9121	-0.2455	1

Pearson's correlations appear below the diagonal and Spearman's rank correlations appear above the diagonal. Definition of variables is provided in Table A6 of the Appendix A.

Table 3. The effect of time difference on total exposure to interbank market, 1884

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time mismatch	-0.0031***	-0.0027***	-0.0023***	-0.0024***	-0.0027***	-0.003***	-0.0036***
	(0.0007)	(0.0007)	(0.0008)	(0.0007)	(0.0008)	(0.0008)	(0.0009)
Num. of banks	0.0025***	0.0024***	0.0019***	0.0019***	0.0017***	0.0016***	0.001**
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0005)	(0.0004)
Deposit growth	-	-0.1832***	-0.1824***	-0.1919***	-0.1934***	-0.196***	-0.1839**
		(0.0665)	(0.06041)	(0.0588)	(0.0622)	(0.0638)	(0.0618)
Size	-	-	0.01971*	0.0129	0.0132	0.0142*	0.0154
			(0.0112)	(0.0091)	(0.0089)	(0.0096)	(0.0107)
Capital	-	-	-	-0.1771***	-0.1577**	-0.1547**	-0.1642***
				(0.0651)	(0.0673)	(0.0655)	(0.0668)
Market power (state)	-	-	-	-	0.01956	0.0221	-0.0024
					(0.0287)	(0.0286)	(0.0449)
Liquidity (specie)	-	-	-	-	0.7257***	0.7121***	0.6921***
					(0.1806)	(0.1632)	(0.1501)
Distance to Boston	-	-	-	-	-	-0.0035	0.0002
						(0.0053)	(0.0054)
Distance to a state capital	-	-	-	-	-	0.0014	-0.0004
						(0.003)	(0.0025)
POP	-	-	-	-	-	-	-0.0037
							(0.0087)
LAND	-	-	-	-	-	-	-0.0098**
							(0.0048)
MANCAP	-	-	-	-	-	-	0.0031
							(0.0055)
State effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.3585	0.3908	0.4186	0.4541	0.4667	0.4673	0.4765
N	568	558	558	558	558	558	557
F-statistic on the excluded instrument	17.0172	14.44	10.09379	10.7584	12.2499	12.3461	14.8035

The table presents OLS estimates. The dependent variable is the total exposure to interbank market in 1884. Heteroscedasticity robust standard errors clustered by county are provided in brackets. All continuous variables are winsorized at 1%. Constant is included into regressions. Stars denote significance: ***<1%, **<5%, *<10%.

Table 4. Placebo test (the effect of time difference on total exposure to interbank market, 1883)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Time mismatch	-0.0009*	-0.0009*	-0.0006	-0.0004	-0.0007	-0.0011*	-0.0013*
	(0.0005)	(0.0005)	(0.0006)	(0.0007)	(0.0007)	(0.0006)	(0.0007)
Num. of banks	0.0022***	0.0022***	0.0016***	0.0017***	0.0015***	0.0012***	0.001**
	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0003)	(0.0004)	(0.0004)
Deposit growth	-	-0.0263	-0.01***	-0.0728**	-0.0142**	-0.0138**	-0.0129**
		(0.019)	(0.0033)	(0.0278)	(0.0063)	(0.0063)	(0.0057)
Size	-	-	0.0192	0.0121	0.0136	0.0151	0.0172
			(0.0116)	(0.0093)	(0.0101)	(0.0106)	(0.0121)
Capital	-	-	-	-0.2111**	-0.1795**	-0.1744**	-0.1832**
				(0.0846)	(0.0722)	(0.0708)	(0.0738)
Market power (state)	-	-	-	-	0.0092	0.0136	-0.016
					(0.0321)	(0.033)	(0.0586)
Liquidity (specie)	-	-	-	-	0.665**	0.6653**	0.6525
					(0.279)	(0.2713)	(0.2492)
Distance to Boston	-	-	-	-	-	-0.0055	-0.0045
						(0.0043)	(0.0054)
Distance to a state capital	-	-	-	-	-	0.0014	0.0002
						(0.0027)	(0.0023)
POP	-	-	-	-	-	-	-0.0083
							(0.0075)
LAND	-	-	-	-	-	-	-0.0051
							(0.0037)
MANCAP	-	-	-	-	-	-	0.0015
							(0.0044)
State effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.3422	0.3596	0.3719	0.4232	0.4314	0.4333	0.4424
N	565	555	555	555	555	555	554
F-statistic on the excluded instrument	3.95369	3.7249	0.764368	0.5184	1.10195	3.37163	3.5549

The table presents OLS estimates. The dependent variable is the total exposure to interbank market in 1883. Heteroscedasticity robust standard errors clustered by county are provided in brackets. All continuous variables are winsorized at 1%. Constant is included into regressions. Stars denote significance: ***<1%, **<5%, *<10%.

Table 5. Reduced form probit estimation (the effect of total interbank market exposure on probability of failure, 1884)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total exposure (CON)	-3.1619	-4.1293	-1.8287	-1.2759	-1.6273	-1.9547	-1.4507
	(3.6686)	(3.8847)	(3.5743)	(3.502)	(3.5774)	(3.7968)	(3.5766)
Num. of banks	-0.013	-0.0116	0.014	0.0121	0.0053	-0.0047	0.0072
	(0.0084)	(0.0084)	(0.0119)	(0.0115)	(0.0121)	(0.012)	(0.0136)
Deposit growth	-	-3.4268	-3.2176	-3.0079	-2.8967	-2.8902	-3.0804
		(2.549)	(2.3376)	(2.3856)	(2.3809)	(2.5242)	(2.5505)
Size	-	-	-0.8124***	-0.7487***	-0.6982***	-0.9391***	-0.9468***
			(0.1619)	(0.1564)	(0.1527)	(0.1558)	(0.1569)
Capital	-	-	-	1.2145	1.2881	0.739	0.7377
				(1.2903)	(1.2647)	(1.2705)	(1.3336)
Market power (state)	-	-	-	-	-2.0456	-1.5902	-1.3866
					(1.932)	(1.9501)	(2.304)
Liquidity (specie)	-	-	-	-	13.3409	14.7983	14.408
					(9.0702)	(10.0775)	(9.8641)
Distance to Boston	-	-	-	-	-	0.1545	0.032
						(0.1554)	(0.2047)
Distance to a state capital	-	-	-	-	-	-0.3112***	-0.2796***
						(0.0771)	(0.073)
POP	-	-	-	-	-	-	-0.1229
							(0.3134)
LAND	-	-	-	-	-	-	0.2483
							(0.1635)
MANCAP	-	-	-	-	-	-	0.0176
							(0.1937)
State effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	-100.26513	-95.52031	-86.094815	-85.685592	-84.33157	-80.841489	-80.221077
N	568	558	558	558	558	558	557

The table presents probit estimates. The dependent variable is the probability of failure (voluntary or forced liquidation not followed by reorganization). Standard errors clustered by county are provided in brackets. Constant is included into regressions. All continuous variables are winsorized at 1%. Stars denote significance: ***<1%, **<5%, *<10%.

Table 6. Structural probit estimation (the effect of total interbank market exposure on probability of failure, 1884)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total exposure (CON)	-12.9074***	-14.9598***	-14.7217***	-14.9063***	-14.7446***	-15.281***	-15.3442***
	(4.7826)	(3.0056)	(4.3925)	(4.2989)	(4.103)	(4.1362)	(3.3925)
Num. of banks	0.0158	0.0215	0.0338**	0.0348**	0.0263**	0.0206	0.0232**
	(0.015)	(0.0141)	(0.0138)	(0.0137)	(0.0131)	(0.0139)	(0.0116)
Deposit growth	-	-4.7102***	-4.611***	-4.6715***	-4.5803**	-4.5857**	-4.5494**
		(0.9133)	(1.6973)	(1.7253)	(1.8411)	(1.8874)	(1.8187)
Size	-	-	-0.254	-0.2851	-0.2735	-0.4089	-0.3553
			(0.3848)	(0.3268)	(0.3159)	(0.3457)	(0.3288)
Capital	-	-	-	-1.704	-1.3131	-1.7656	-2.01*
				(1.4141)	(1.4265)	(1.2041)	(1.1889)
Market power (state)	-	-	-	-	-1.3043	-0.9949	-1.1773
					(1.2233)	(1.1292)	(1.3348)
Liquidity (specie)	-	-	-	-	17.9363***	18.8163***	17.8456***
					(5.5655)	(6.0928)	(5.8626)
Distance to Boston	-	-	-	-	-	0.0934	0.0541
						(0.1298)	(0.1604)
Distance to a state capital	-	-	-	-	-	-0.1822**	-0.1732***
						(0.0921)	(0.0741)
POP	-	-	-	-	-	-	-0.1437
							(0.2125)
LAND	-	-	-	-	-	-	0.0556
							(0.1153)
MANCAP	-	-	-	-	-	-	0.0471
							(0.1483)
State effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	703.70771	717.76599	740.17467	758.25957	766.08472	769.86195	774.00721
N	568	558	558	558	558	558	557
ρ	0.6426	0.7069	0.7623	0.7719	0.7476	0.7622	0.7921
H0: $\rho = 0$	2.54	5.1	3.13	3.56	3.39	3.81	5.75

The table presents results of conditional maximum likelihood estimation of structural probit. The dependent variable is probability of failure (voluntary or forced liquidation not followed by reorganization). Mismatch between bank city local time and standard time is used as an instrument. Standard errors clustered by county are provided in brackets. All continuous variables are winsorized at 1%. Constant is included into regressions. ρ is the correlation between error terms from structural and reduced form probit estimations. Stars denote significance: ***<1%, **<5%, *<10%.

Table 7. Robustness check: interbank market and bank failure (based on a model with a full set of controls)

Panel A: Connectedness and time difference

	2SLS	Assets >200K	Capital >20%	Log(Time mismatch)	Boston excluded	Only connected	All exits	Bills and reserves
Time mismatch	-0.0036***	-0.0037***	-0.0035***	-0.0472***	-0.0029***	-0.0039***	-0.0036***	-0.0031***
	(0.0009)	(0.0009)	(0.0008)	(0.0101)	(0.0007)	(0.001)	(0.0009)	(0.0007)
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.4765	0.4812	0.4977	0.4781	0.4441	0.4488	0.4765	0.4719
N	557	517	528	557	499	459	557	557

Panel B: Structural probit

	2SLS	Assets >200K	Capital >20%	Log(Time mismatch)	Boston excluded	Only connected	All exits	Bills and reserves
CON	-26.846**	-16.06***	-18.306***	-15.587***	-16.054**	-15.162***	-14.276***	-14.658***
	(12.961)	(3.344)	(4.052)	(3.13)	(7.077)	(3.51)	(3.435)	(1.869)
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-Likelihood	-79.256	647.443	874.953	775.104	858.794	602.538	752.745	666.588
N	557	517	528	557	499	459	557	557
ρ	N/A	0.8516	0.7134	0.8142	0.5757	0.783	0.71	0.9181
H0: $\rho = 0$	N/A	7.3	6.98	6.19	2.79	5.64	3.9	14.98

The table presents the robustness check for alternative model specifications: (a) two stage least squares; (b) sample with banks having more than \$200,000 in total assets; (c) sample with banks having more than 20% in capital to total assets ratio; (d) time mismatch is measured as a natural logarithm; (e) banks in the reserve city Boston are excluded; (f) sample with only connected banks; (g) definition of bank liquidation also includes charter expirations and reorganizations; and (h) a model when the definition of CON also includes "bills of other banks", "due from approved reserve agents", "national bank notes outstanding" and "state bank notes outstanding". Panel A presents OLS estimates where the dependent variable is the total exposure to interbank market (CON). Panel B presents conditional maximum likelihood estimates of structural probit where the dependent variable is the probability of failure (voluntary or forced liquidation not followed by reorganization, except the last column which also includes charter expirations and reorganizations). Mismatch between bank city local time and standard time is used as an instrument in Panel B. Standard errors clustered by county are provided in brackets. All continuous variables are winsorized at 1%. Constant is included into regressions. ρ is the correlation between error terms from structural and reduced form probit estimations. Stars denote significance: ***<1%, **<5%, *<10%.

Table 8. Robustness check: alternative time horizons used to measure bank failures

	1893-1897	1884-1900	1893-1900
CON	-17.726***	-14.892***	-17.19***
	(1.694)	(2.838)	(1.73)
Bank controls	Yes	Yes	Yes
City controls	Yes	Yes	Yes
County controls	Yes	Yes	Yes
State Effects	Yes	Yes	Yes
Log-Likelihood	670.219	695.524	588.315
N	537	557	537
ρ	0.922	0.794	0.9161
H0: $\rho = 0$	65.95	7.8	7.56

The table presents the results of structural probit estimation when alternative time horizons are used to compute bank failure. The definition of bank failure incorporates forced and voluntary liquidations not followed by reorganizations. Mismatch between bank city local time and standard time is used as an instrument. Standard errors clustered by county are provided in brackets. All continuous variables are winsorized at 1%. Constant is included into regressions. ρ is the correlation between error terms from structural and reduced form probit estimations. Stars denote significance: ***<1%, **<5%, *<10%.

Table 9. Gross borrowing (gross lending) and probability of failure of net borrowers (net lenders), 1884

Panel A: Net borrowers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gross borrowing (BOR)	-17.3345***	-17.1424***	-15.4682***	-15.5298***	-15.6029***	-17.4061***	-18.5056***
	(5.177)	(5.0441)	(4.4859)	(5.125)	(4.5815)	(4.6138)	(4.7102)
Controls	Num. of banks	Num. of banks and deposit growth	Num. of banks, size and deposit growth	Num. of banks, size, deposit growth and equity	Num. of banks and all bank controls	Num. of banks and all bank controls	Num. of banks and all bank controls
Distance controls	No	No	No	No	No	Yes	Yes
County Controls	No	No	No	No	No	No	Yes
State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	397.4577	398.21466	410.01585	426.15006	429.5343	432.89629	436.17095
N	302	300	300	300	300	300	300
ρ	0.8295	0.8563	0.8728	0.8168	0.8381	0.9094	0.9307
H0: $\rho = 0$	4.14	3.88	3.62	3.11	4.65	6.73	4.92

Panel B: Net lenders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gross lending (LEND)	-30.1403***	-37.3091***	-36.9885***	-37.8496	-27.4271	-29.3724**	-32.3553***
	(5.1046)	(5.7344)	(5.3158)	(41.5909)	(18.7596)	(13.899)	(7.3096)
Controls	Num. of banks	Num. of banks and deposit growth	Num. of banks, size and deposit growth	Num. of banks, size, deposit growth and equity	Num. of banks and all bank controls	Num. of banks and all bank controls	Num. of banks and all bank controls
Distance controls	No	No	No	No	No	Yes	Yes
County Controls	No	No	No	No	No	No	Yes
State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	261.41711	290.46942	295.27363	297.18274	302.7758	303.084	311.00724
N	163	160	160	160	160	160	159
ρ	0.9999	0.9984	0.9869	0.9999	0.7584	0.7968	0.8959
H0: $\rho = 0$	6.47	0.18	0.41	0.00	1.1	1.84	9.17

The table presents results of conditional maximum likelihood estimation of structural probit. The dependent variable is a probability of failure (voluntary or forced liquidation not followed by reorganization). Panel A has interbank gross borrowing as an endogenous variable and net borrowers as a subgroup. Panel B has interbank gross lending as an endogenous variable and net lenders as a subgroup. Mismatch between bank city local time and standard time is used as an instrument. All continuous variables are winsorized at 1%. Constant is included into regressions. Standard errors clustered by county are provided in round brackets in Panels A and B. ρ is the correlation between error terms from structural and reduced form probit estimations. Stars denote significance: ***<1%, **<5%, *<10%.

Table 10. Robustness check: lenders vs. borrowers (based on a model with a full set of controls)

Panel A: Net borrowers

	2SLS	Assets >200K	Capital >20%	Log(Time mismatch)	Boston excluded	Net borrowing	All exits
Gross borrowing (BOR)	-50.722	-18.667***	-27.076***	-18.638***	-20.937*	-19.988***	-19.326***
	(38.639)	(4.905)	(4.733)	(4.778)	(12.626)	(5.58)	(4.938)
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	-25.488	412.413	520.667	437.094	521.079	460.583	434.019
N	300	284	279	300	260	300	300
ρ	N/A	0.9453	0.8862	0.9386	0.6034	0.99	0.9443
H0: $\rho = 0$	N/A	4.47	4.58	8.56	0.44	7.75	7.75

Panel B: Net lenders

	2SLS	Assets >200K	Capital >20%	Log(Time mismatch)	Boston excluded	Net lending	All exits
Gross lending (LEND)	-60.985**	-38.23***	-31.911**	-35.193***	-35.791***	-39.696***	-28.796*
	(30.104)	(4.986)	(13.045)	(7.548)	(8.941)	(6.679)	(15.534)
Bank controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	-26.486	242.193	303.657	310.96	283.178	318.806	305.114
N	159	129	156	159	140	159	159
ρ	N/A	0.996	0.8904	0.9405	0.9061	0.9839	0.7412
H0: $\rho = 0$	N/A	1.88	8.73	9.94	4.81	5.41	1.74

The table presents the robustness check for alternative model specifications: (a) two stage least squares; (b) sample with banks having more than $200,000 in total assets; (c) sample with banks having more than 20% in capitalization; (d) time mismatch is measured as a natural logarithm; (e) banks in Boston are excluded; (f) when endogenous variable is net borrowing (for net borrowers) or net lending (for net lenders); and (g) the definition of bank liquidation also includes charter expirations and reorganizations. Panel A (panel B) has interbank gross borrowing (gross lending) as an endogenous variable (except for the specification with net borrowing) and net borrowers (net lenders) as a subgroup. All continuous variables are winsorized at 1%. Constant is included into regressions. Standard errors clustered by county are provided in round brackets in Panels A and B. ρ is the correlation between error terms from structural and reduced form probit estimations. Stars denote significance: ***<1%, **<5%, *<10%.

Table 11. Robustness check: alternative time horizons used to measure bank failures

Panel A: Net borrowers

	1893-1897	1884-1900	1893-1900
Gross borrowing (BOR)	-20.4085***	-17.766***	-15.277***
	(3.238)	(4.145)	(4.25)
Bank controls	Yes	Yes	Yes
City controls	Yes	Yes	Yes
County controls	Yes	Yes	Yes
State Effects	Yes	Yes	Yes
Log-Likelihood	463.259	390.621	324.985
N	294	300	294
ρ	0.9516	0.9262	0.7885
H0: $\rho = 0$	13.79	5.12	5.81

Panel B: Net lenders

	1893-1897	1884-1900	1893-1900
Gross lending (LEND)	-37.619***	-33.102***	-37.775***
	(4.98)	(6.099)	(4.546)
Bank controls	Yes	Yes	Yes
City controls	Yes	Yes	Yes
County controls	Yes	Yes	Yes
State Effects	Yes	Yes	Yes
Log-Likelihood	274.573	288.764	248.748
N	153	159	153
ρ	0.9997	0.9257	0.9919
H0: $\rho = 0$	3.85	13.19	5.27

The table presents the results of structural probit estimation when alternative time horizons are used to compute bank failure. The definition of bank failure incorporates forced and voluntary liquidations not followed by reorganizations. Panel A (panel B) has interbank gross borrowing (gross lending) as an endogenous variable and net borrowers (net lenders) as a subgroup. All continuous variables are winsorized at 1%. Constant is included into regressions. Standard errors clustered by county are provided in round brackets in Panels A and B. ρ is the correlation between error terms from structural and reduced form probit estimations. Stars denote significance: ***<1%, **<5%, *<10%.

Table 12. The test for non-linearity of the effect of interbank exposure on the probability of failure

Panel A: Total connectedness (CON) for all banks with non-zero exposure

Cut-off on CON	< 2.5%	< 5%	< 10%	< 15%	< 20%	< 25%	< 30%	< 35%	< 40%
Connectedness (CON)	-106.225	-61.801	-25.899	-25.019	-21.12	-19.986	-19.297	-18.102	-17.773
	(41.94)	(13.388)	(9.877)	(8.834)	(6.069)	(4.479)	(4.275)	(3.391)	(3.275)

Panel B: Gross borrowing (BOR) for all banks with non-zero exposure

Cut-off on BOR	< 2.5%	< 5%	< 10%	< 15%	< 20%	< 25%	< 30%	< 35%	-
Gross borrowing (BOR)	-152.812	-84.063	-42.305	-38.433	-32.79	-28.857	-28.253	-26.879	-
	(7.614)	(2.544)	(3.186)	(2.264)	(1.57)	(1.395)	(1.458)	(1.718)	-

Panel C: Gross lending (LEND) for all banks with non-zero exposure

Cut-off on LEND	< 2.5%	< 5%	< 10%	< 15%	-	-	-	-	-
Gross lending (LEND)	-145.968	-78.023	-45.195	-37.224	-	-	-	-	-
	(7.996)	(13.107)	(9.748)	(6.369)	-	-	-	-	-

Panel D: Gross borrowing (BOR) for net borrowers

Cut-off on BOR	< 2.5%	< 5%	< 10%	< 15%	< 20%	< 25%	< 30%	< 35%	-
Gross borrowing (BOR)	-116.104	-96.956	-35.634	-36.55	-30.986	-27.798	-27.187	-26.009	-
	(62.564)	(4.233)	(10.138)	(6.524)	(4.02)	(2.589)	(2.652)	(2.568)	-

Panel E: Gross lending (LEND) for net lenders

Cut-off on LEND	< 2.5%	< 5%	< 10%	< 15%	-	-	-	-	-
Gross lending (LEND)	-166.374	-73.892	-36.613	-28.968	-	-	-	-	-
	(9.503)	(21.424)	(11.59)	(15.314)	-	-	-	-	-

This table presents the coefficients of conditional maximum likelihood estimation of structural probit. The dependent variable is a probability of failure (voluntary or forced liquidation not followed by reorganization). Mismatch between bank city local time and standard time is used as an instrument. The appropriate right tail cut-offs are applied to the distributions of BOR, CON and LEND, as indicated in the first row of each Panel. Panels A, B and C use all banks with non-zero exposure as a sample. Panels D and E use net borrowers and net lenders as a sample, respectively. All models use a full set of controls and state effects. The coefficients of controls and constants are excluded to save space. Standard errors clustered by county are provided in brackets.

APPENDIX A

Figure A1. New England counties by a number of national banks, 1884

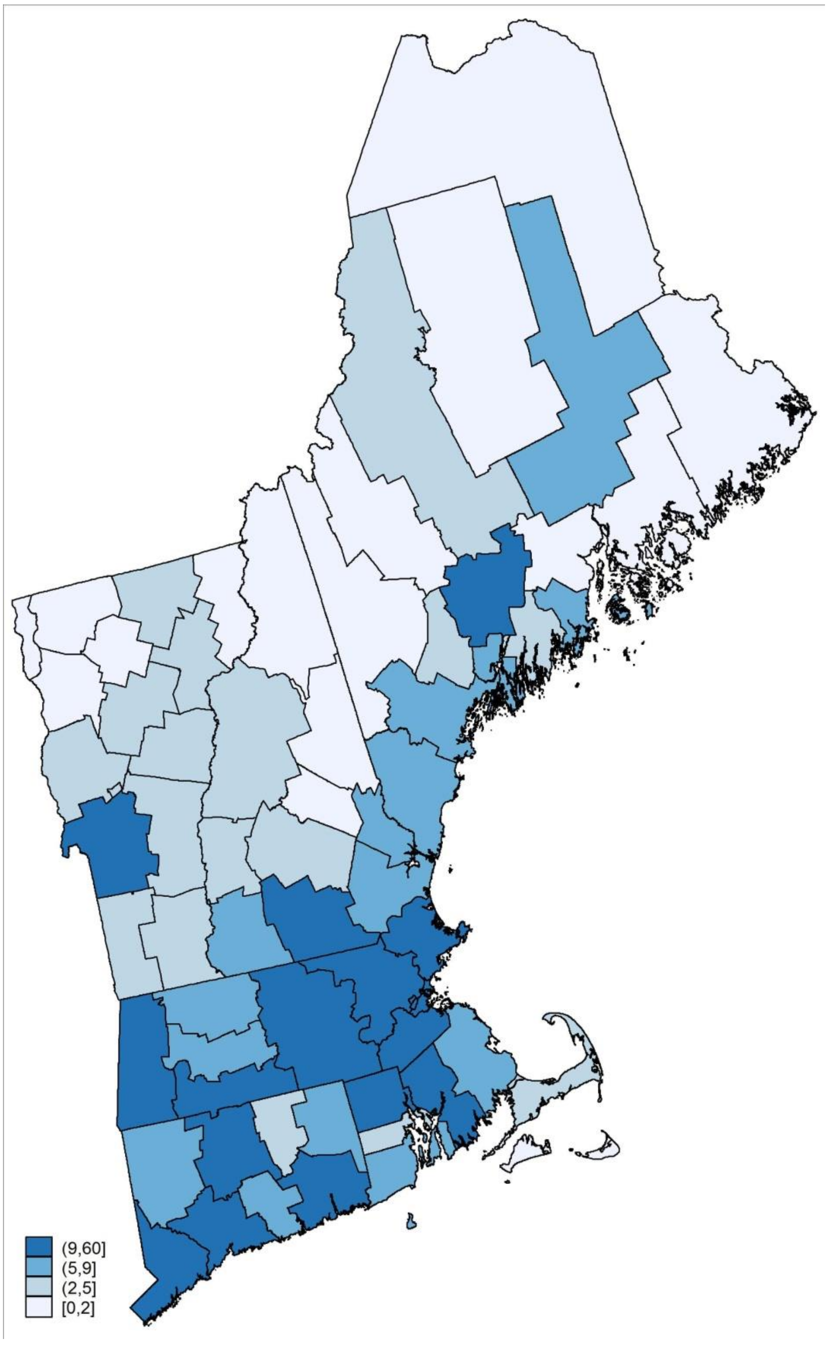


Figure A2. New England counties by average interbank exposure (CON), 1884

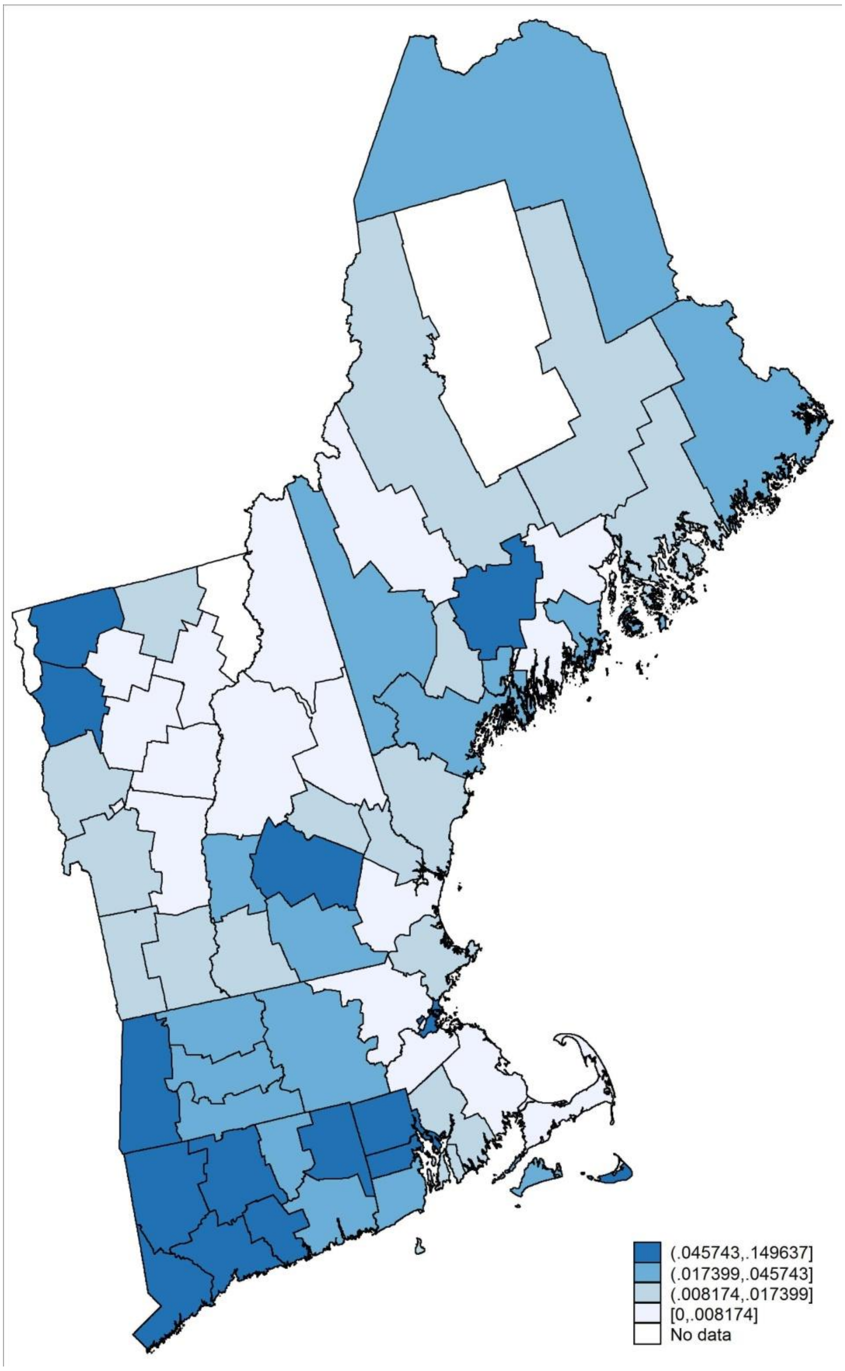


Figure A3. New England counties by average net lending (LEND minus BOR), 1884

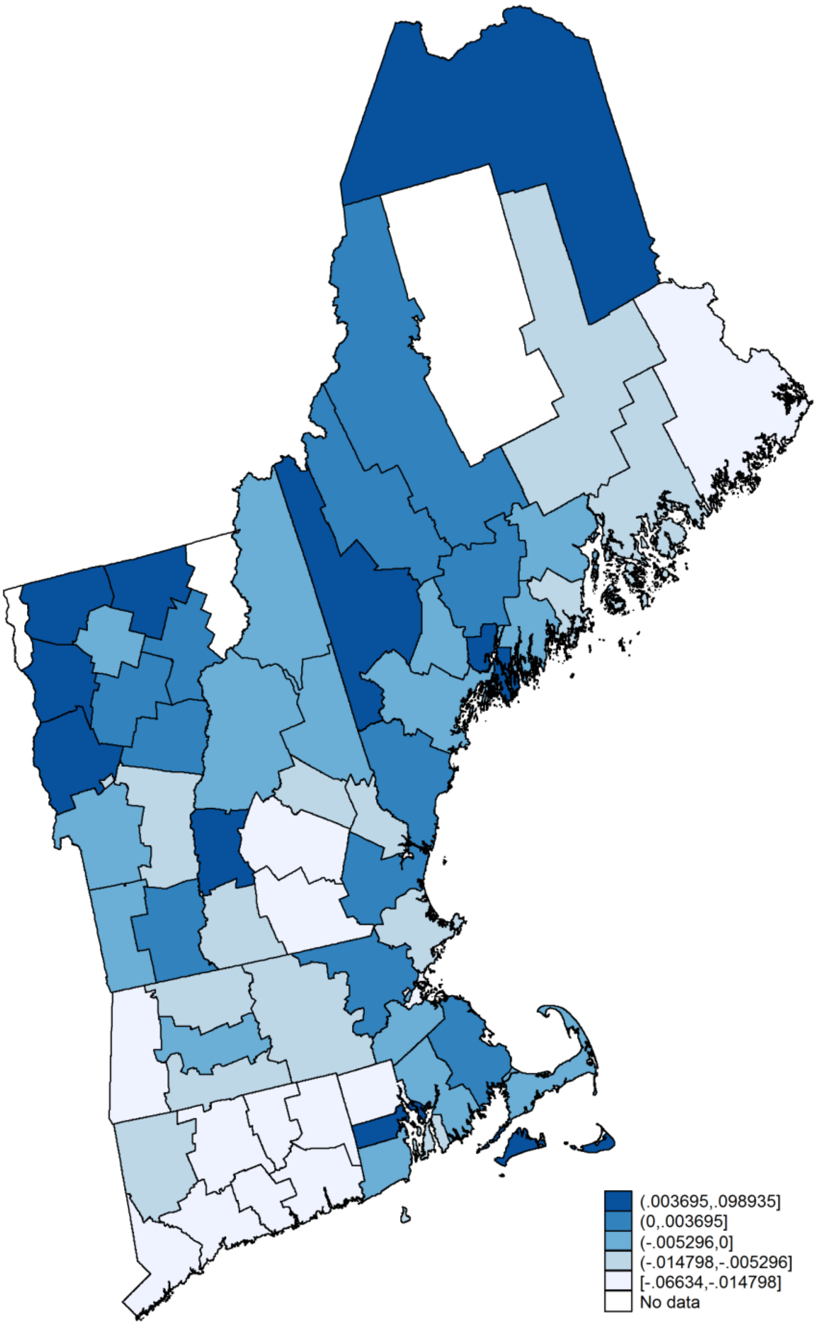
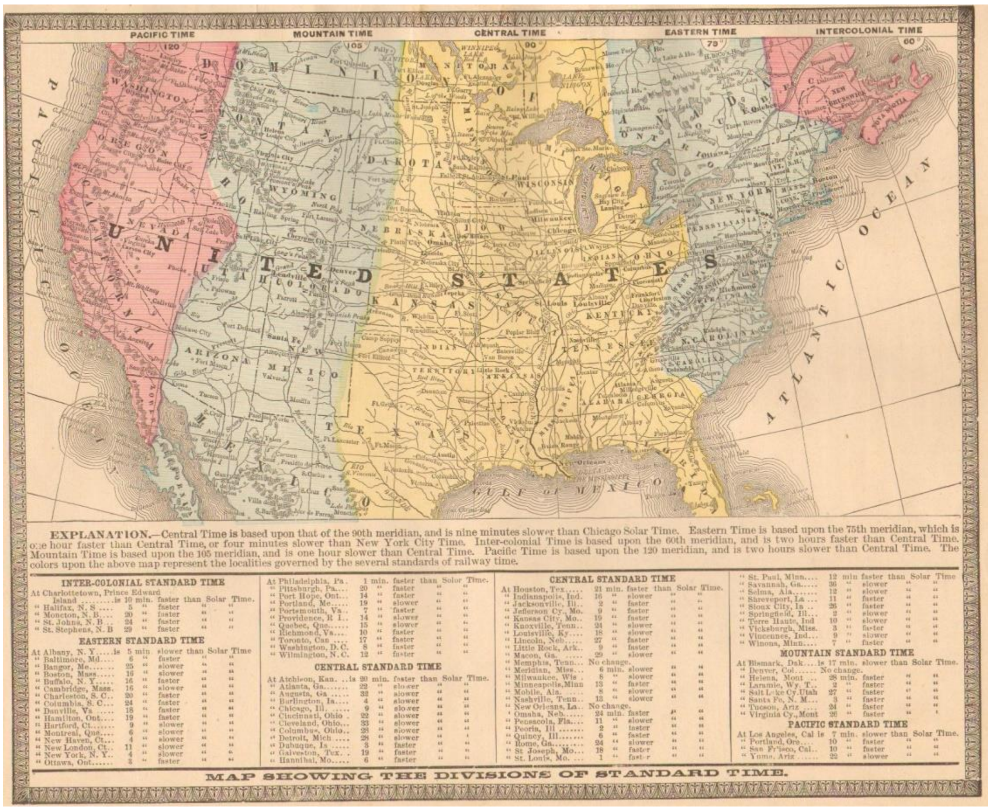


Figure A4. Examples of maps used to define time zones

Panel A. Cram, F. Geo. 1886. Cram's Unrivaled Family Atlas of the World. Henry S. Stebbins (Chicago), the revised edition of 1883.



Panel B. Corliss, Carlton Jonathan. 1956. The Day of Two Noons. Association of American Railroads

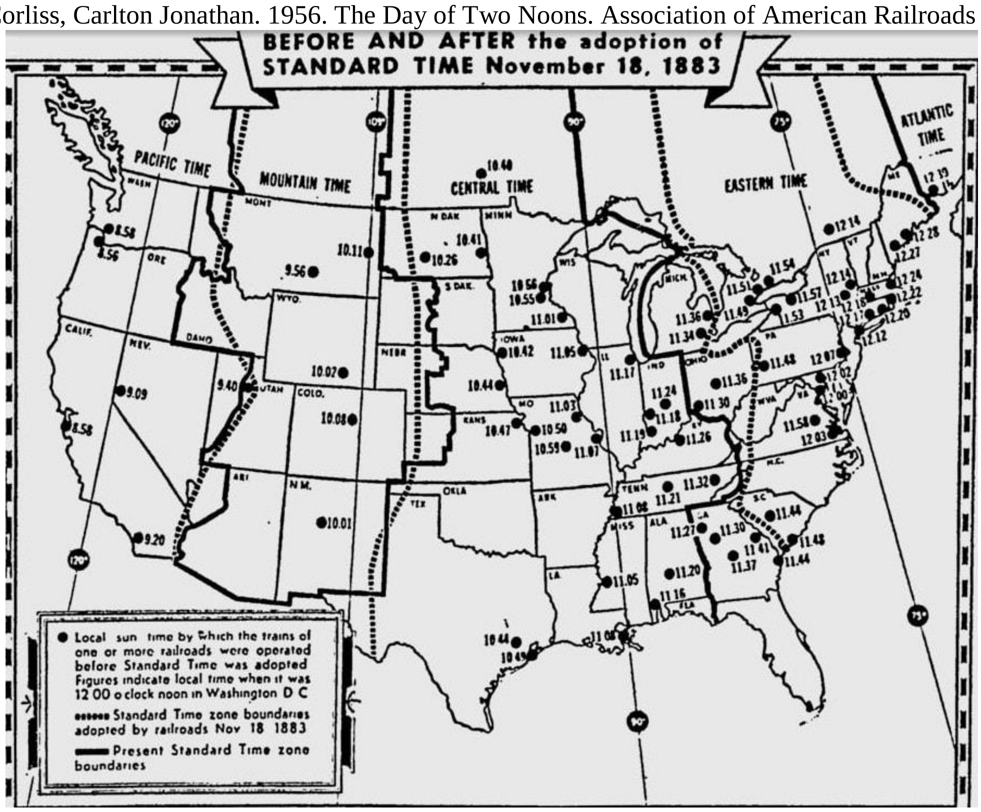


Table A1. Summary statistics when Boston is excluded, 1884

Panel A: Summary statistics

	N	Mean	St. Dev.	Min	Max	Skewness	Kurtosis
Total assets ($)	509	679,341.7	575,050.8	68,363.01	3,978,297	2.109	8.55
Capitalization	509	0.345	0.083	0.133	0.658	0.434	3.697
Deposit growth	500	-0.008	0.047	-0.268	0.18	-0.344	6.05
Liquidity (specie)	509	0.013	0.01	0	0.066	1.237	5.566
Liquidity (all)	509	0.04	0.023	0.001	0.175	1.474	6.665
Market power (county)	509	0.126	0.173	0	1	3.172	14.811
Market power (state)	509	0.011	0.015	0	0.117	2.944	14.643
Time mismatch (min)	509	13.297	4.455	5.5	28.3	0.592	3.598
Distance to Boston (km)	509	128.685	82.638	1.9	491.2	0.764	3.423
Distance to a state capital (km)	509	57.046	43.019	0	252.8	1.117	4.623
Number of banks (city)	509	4.12	5.577	1	26	3.065	12.237
Number of banks (county)	509	17.178	13.366	1	61	0.734	2.114
Population (units)	509	115,738.5	91,346.11	3,727	387,927	0.775	2.398
Farming land (acres)	509	332,534.1	171,091.8	4,327	732,807	0.713	3.046
Manufacturing capital (000$)	508	22,516.88	20,253.14	20.25	61,299.6	0.57	1.883
Connectedness (CON)	509	0.032	0.048	0	0.388	3.123	16.763
Gross borrowing (BOR)	509	0.02	0.033	0	0.228	2.997	14.829
Gross lending (LEND)	509	0.012	0.024	0	0.264	4.462	34.194

Panel B: Difference in means between net borrowers and net lenders

	Net lenders			Net borrowers			t-statistic
	N	Mean	St. Dev.	N	Mean	St. Dev.	
Total assets ($)	146	610,950.9	517,790.3	261	836,371.8	643,066.7	3.628
Capitalization	146	0.359	0.084	261	0.333	0.082	3.023
Deposit growth	143	-0.002	0.052	259	-0.015	0.042	2.76
Liquidity (specie)	146	0.013	0.011	261	0.014	0.01	0.167
Liquidity (all)	146	0.04	0.002	261	0.04	0.001	0.252
Market power (county)	146	0.159	0.017	261	0.105	0.008	3.22
Market power (state)	146	0.013	0.017	261	0.011	0.015	0.815
Time mismatch (min)	146	13.367	4.717	261	12.876	4.538	1.032
Distance to Boston (km)	146	143.786	87.588	261	126.666	76.24	2.057
Distance to a state capital (km)	146	58.095	46.428	261	58.982	44.4	0.19
Number of banks (city)	146	4.315	5.794	261	5.004	6.169	1.104
Number of banks (county)	146	14.682	13.232	261	19.096	13.139	3.2
Population (units)	146	96,883.42	84,289.02	261	124,168	85,382.27	3.104
Farming land (acres)	146	318,562.5	168,018.8	261	333,285.7	168,514.9	0.846
Manufacturing capital (000$)	145	20,100.47	20,813.76	260	24,905.38	19,378.41	2.329
Connectedness (CON)	146	0.032	0.044	261	0.045	0.053	2.458
Gross borrowing (BOR)	146	0.007	0.015	261	0.035	0.039	8.263
Gross lending (LEND)	146	0.025	0.033	261	0.01	0.018	5.954

Definition of variables is provided in Table A6 of the Appendix A. Difference in a number of observations between manufacturing capital and other county variables is due to its data unavailability for Nantucket county, MA in the U.S. Census of 1880. Difference in a number of observations between deposit growth and other bank specific variables is due to the fact that some banks did not exist in 1883.

Table A2. Balance sheet of a typical bank in 1884 (based on mean item values)

Assets			Liabilities		
Item	$	%	Item	$	%
Loans and discounts	534,303.2	56.3	Capital stock paid in	295,053.47	31.09
Overdrafts	841.61	0.09	Surplus fund	72,616.1	7.66
U. S. bonds to secure circulation	215,623.2	22.72	Other undivided profits	23,283.5	2.45
U. S. bonds to secure deposits	3,216.55	0.34	National bank notes outstanding	191,620.5	20.19
U. S. bonds on hand	1,372.98	0.14	State bank notes outstanding	103.04	0.01
Other stocks, bonds, and mortgages	22,119.51	2.33	Dividends unpaid	4,587.35	0.48
Due from approved reserve agents	52,302.38	5.51	Individual deposits	286,297.26	30.16
Due from other banks and bankers	24,737	2.61	United States deposits	1,751.91	0.18
Real estate, furniture, and fixtures	14,563.85	1.53	Deposits of U. S. disbursing officers	455.38	0.05
Current expenses and taxes paid	1,518.93	0.16	Due to other national banks	54,524.56	5.74
Premiums paid	5,741.89	0.61	Due to State banks and bankers	16,158.26	1.7
Checks and other cash items	4,598.58	0.48	Notes and bills re-discounted	1,872.52	0.2
Exchanges for clearing-house	13,142.71	1.38	Bills payable	663.41	0.07
Bills of other banks	8,900.94	0.938			
Fractional currency	248.08	0.03			
Specie	21,435.87	2.26			
Legal-tender notes	11,774.99	1.24			
U. S. certificates of deposit	2,737.68	0.29			
Due from U. S. Treasurer	9,807.17	1.03			
Total Assets	948,987.09	100	Total Liabilities	948,987.09	100

Table A3. Number of bank failures by year and type of exit

Year	Total bank exits	Forced liquidation	Voluntary liquidation		Expiration of charter	
			liquidated	reorganized	liquidated	reorganized
1884	1	0	1	0	0	0
1885	12	0	3	1	7	1
1886	0	0	0	0	0	0
1887	3	1	2	0	0	0
1888	3	1	2	0	0	0
1889	1	0	1	0	0	0
1890	4	0	3	1	0	0
1891	3	1	2	0	0	0
1892	2	0	2	0	0	0
1893	6	0	5	0	0	1
1894	5	1	3	0	0	1
1895	0	0	0	0	0	0
1896	1	0	1	0	0	0
1897	3	0	3	0	0	0
subtotal	*44*	*4*	*28*	*2*	*7*	*3*
1897	1	0	1	0	0	0
1898	16	0	15	1	0	0
1899	7	0	7	0	0	0
1900	13	1	10	2	0	0
subtotal	*37*	*1*	*33*	*3*	*0*	*0*
TOTAL	*81*	*5*	*61*	*5*	*7*	*3*

Table presents the distribution of bank exits by year and type of exit between December 1, 1884 and December 6, 1897, and between December 6, 1897 and December 3, 1900.

Table A4. All forced and voluntary liquidations not followed by reorganization between December 1, 1884 and December 6, 1897

Name	*City*	*State*	*Date of liquidation*	*Type of liquidation*
Freeman's National Bank	Augusta	Maine	Dec. 26, 1884	voluntary
National Union Bank	Swanton	Vermont	Apr. 28, 1885	voluntary
Shetucket National Bank	Norwich	Connecticut	May 18, 1885	voluntary
Cumberland National Bank	Cumberland	Rhode Island	June 5, 1885	voluntary
Abington National Bank	Abington	Massachusetts	Feb. 17, 1887	forced
Winsted National Bank	Winsted	Connecticut	Apr. 12, 1887	voluntary
Mystic National Bank	Mystic	Connecticut	July 7, 1887	voluntary
Scituate National Bank	Scituate	Rhode Island	Jan. 11, 1888	voluntary
South Framingham National Bank	South Framingham	Massachusetts	Sept. 8, 1888	voluntary
Stafford National Bank	Stafford Springs	Connecticut	Oct. 20, 1888	forced
Norwich National Bank	Norwich	Connecticut	Mar. 15, 1889	voluntary
Ferris National Bank	Swanton	Vermont	Apr. 18, 1890	voluntary
Wakefield National Bank	Wakefield	Rhode Island	July 1, 1890	voluntary
National Village Bank	Bowdoinham	Maine	Aug. 28, 1890	voluntary
Windsor National Bank	Windsor	Vermont	Feb. 24, 1891	voluntary
Lancaster National Bank	Clinton	Massachusetts	Sept. 14, 1891	forced
First National Bank	Francestown	New Hampshire	Oct. 10, 1891	voluntary
Castleton National Bank	Castleton	Vermont	Jan. 22, 1892	voluntary
First National Bank	Grafton	Massachusetts	June 21, 1892	voluntary
National Pemberton Bank	Lawrence	Massachusetts	Jan. 10, 1893	voluntary
Lake National Bank	Wolfboro	New Hampshire	June 29, 1893	voluntary
Orono National Bank	Orono	Maine	July 29, 1893	voluntary
Gray National Bank	Middletown Springs	Vermont	Sept. 20, 1893	voluntary
Randolph National Bank	Randolph	Massachusetts	Nov. 27, 1893	voluntary
Sagadahock National Bank	Bath	Maine	Apr. 11, 1894	voluntary
First National Bank	Mystic Bridge	Connecticut	May 21, 1894	voluntary
First National Bank	St. Albans	Vermont	May 25, 1894	forced
Lime Rock National Bank	Providence	Rhode Island	Nov. 27, 1894	voluntary
Traders' National Bank	Providence	Rhode Island	July 1, 1896	voluntary
Holliston National Bank	Holliston	Massachusetts	Jan. 1, 1897	voluntary
Hancock National Bank	Boston	Massachusetts	May 20, 1897	voluntary
Mercantile National Bank	Hartford	Connecticut	July 20, 1897	voluntary

Table A5. All forced and voluntary liquidations not followed by reorganization between December 6, 1897 and December 3, 1900

Name	*City*	*State*	*Date of liquidation*	*Type of liquidation*
National Bank	Winthrop	Maine	Dec. 31, 1897	voluntary
National City Bank	Boston	Massachusetts	Feb. 15, 1898	voluntary
National Bank of Commerce	New Bedford	Massachusetts	Apr. 1, 1898	voluntary
First National Bank of Killingly	Danielsonville	Connecticut	Apr. 11, 1898	voluntary
Everett National Bank	Boston	Massachusetts	May 19, 1898	voluntary
First National Bank	Ashburnham	Massachusetts	Oct. 4, 1898	voluntary
Boston National Bank	Boston	Massachusetts	Dec. 8, 1898	voluntary
Columbian National Bank	Boston	Massachusetts	Dec. 9, 1898	voluntary
Lincoln National Bank	Boston	Massachusetts	Dec. 12, 1898	voluntary
National Eagle Bank	Boston	Massachusetts	Dec. 13, 1898	voluntary
Market National Bank	Boston	Massachusetts	Dec. 17, 1898	voluntary
Howard National Bank	Boston	Massachusetts	Dec. 17, 1898	voluntary
North National Bank	Boston	Massachusetts	Dec. 17, 1898	voluntary
National Revere Bank	Boston	Massachusetts	Dec. 19, 1898	voluntary
Tremont National Bank	Boston	Massachusetts	Dec. 20, 1898	voluntary
National Bank of North America	Boston	Massachusetts	Dec. 22, 1898	voluntary
Continental National Bank	Boston	Massachusetts	Jan. 9, 1899	voluntary
Manufacturers' National Bank	Boston	Massachusetts	Jan. 9, 1899	voluntary
Hamilton National Bank	Boston	Massachusetts	Jan. 10, 1899	voluntary
Citizens' National Bank	New Bedford	Massachusetts	Feb. 21, 1899	voluntary
National Exchange Bank	Salem	Massachusetts	June 1, 1899	voluntary
Globe National Bank	Providence	Rhode Island	July 12, 1899	voluntary
Manufacturers' National Bank	Providence	Rhode Island	Dec. 30, 1899	voluntary
City National Bank	Providence	Rhode Island	Jan. 17, 1900	voluntary
Third National Bank	Providence	Rhode Island	Jan. 25, 1900	voluntary
Roger Williams National Bank	Providence	Rhode Island	Jan. 30, 1900	voluntary
Broadway National Bank	Boston	Massachusetts	Feb. 15, 1900	forced
Pacific National Bank	Pawtucket	Rhode Island	Mar. 8, 1900	voluntary
First National Bank	Pawtucket	Rhode Island	Mar. 8, 1900	voluntary
Slater National Bank	Pawtucket	Rhode Island	Mar. 31, 1900	voluntary
Greenwich National Bank	East Greenwich	Rhode Island	Apr. 30, 1900	voluntary
National Bank of Rhode Island	Newport	Rhode Island	May 3, 1900	voluntary
Woonsocket National Bank	Woonsocket	Rhode Island	July 19, 1900	voluntary
Phenix National Bank	Phenix	Rhode Island	Aug. 30, 1900	voluntary

Table A6. Definition of variables

Variable	*Definition*
FAIL	1 if bank is liquidated (forcedly or voluntarily, without being reorganized) and 0 otherwise
Total exposure (CON)	(“Due from other banks and bankers” + “Due to other national banks” + “Due to State banks and bankers”) / “Total assets”
Gross borrowing (BOR)	(“Due to other national banks” + “Due to State banks and bankers”) / “Total assets”
Gross lending (LEND)	“Due from other banks and bankers” / “Total assets”
Size	log(“Total assets”)
Deposit growth	(“Individual deposits” in 1884 / “Total assets” in 1884) - (“Individual deposits” in 1883 / “Total assets” in 1883)
Capital	“Capital paid in” / “Total assets”
Liquidity (specie)	“Specie” / “Total assets”
Liquidity (all)	(“Specie” + “Legal tender notes” + “Bills of other banks” + “Fractional currency” + “Checks and other cash items) / “Total assets”
Market power (county)	“Individual deposits” / sum of “Individual deposits” across banks in the county
Market power (state)	“Individual deposits” / sum of “Individual deposits” across banks in the state
POP	log(“Population in the county, units”)
LAND	log(“Farming land in the county, acres”)
MANCAP	log(“Manufacturing capital in the county, 000$“)
Net borrowing	(“Due to other national banks” + “Due to State banks and bankers” - “Due from other banks and bankers”) / “Total assets”
Net lending	(“Due from other banks and bankers” - “Due to other national banks” - “Due to State banks and bankers”) / “Total assets”

Table A7. The list of locations that were renamed

Old city, as in the OCC reports	*Modern city (or location)*
East Jaffrey, NH	Jaffrey, NH
Great Falls, NH	Somersworth, NH
West Randolph, VT	Randolph, VT
Marlboro', MA	Marlborough, MA
South Framingham, MA	Framingham, MA
Westboro', MA	Westborough, MA
Anthony, RI	Area west of West Warwick, RI
Phenix, RI	Area north of West Warwick, RI
Wickford, RI	North Kingston, RI
Danielsonville, CT	Danielson, CT
Mystic Bridge, CT	Mystic Bridge Historic District, south of Mystic, CT
Mystic River, CT	Mystic River Historical Society, west of Mystic, CT
South Norwalk, CT	Area south of Norwalk, CT
West Winsted, CT	Area west of Winsted, CT
Factory Point, CT	Manchester, CT

Table A8. Distribution of national bank assets across the U.S. regions, 1884 (OCC 1884)

Region	*Number of national banks in operation*	*Total area (in sq. miles)*	*Number of banks per sq. mile (multiplied by 1,000)*	*Capital paid in (in USD)*	*Capital per bank (in USD)*	*U.S. bonds on deposit (in USD)*	*U.S. bonds on deposit per bank (in USD)*
New England	**568**	**71,987.95**	**7.89**	**168,921,670**	**297,397.31**	**122,784,850**	**216,170.51**
Mid-Atlantic	739	124,294.90	5.95	178,264,595	241,224.08	109,640,700	148,363.6
Southern	282	835,584.51	0.34	42,871,200	152,025.53	26,815,950	95,092.02
Western	949	662,463.14	1.43	129,026,700	135,960.7	60,313,250	63,554.53
Pacific	133	1,344,749.87	0.1	13,470,000	101,278.2	5,661,550	42,568.05
TOTAL	2,671	3,039,080.37	-	363,632,495	-	325,216,300	-

New England States: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.
Mid-Atlantic States: New York, New Jersey, Pennsylvania, Delaware, Maryland, Dist. Columbia.
Southern States: Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Arkansas, Kentucky, Tennessee.
Western States: Missouri, Ohio, Indiana, Illinois, Michigan, Wisconsin, Iowa, Minnesota, Kansas, Nebraska.
Pacific States and Territories: Nevada, Oregon, Colorado, Utah, Idaho, Montana, Wyoming, New Mexico, Dakota, Washington, Arizona, California.

APPENDIX B

Note that if y_2 was exogenous, there would be no need to include equation (3) into the model and the coefficient of interest β_2 could be estimated by maximizing the usual likelihood function for the reduced form probit, as described by the equations (1) and (2).[42] On the other hand, the likelihood function for a bank in the structural model can be written as:

$$L = f(y_1 = 1, y_2)^{y_1} f(y_1 = 0, y_2)^{1-y_1} \qquad \text{(B1)}$$

To obtain parametric representation of (B1), we need to derive the above densities $f(.)$. To simplify procedure, we will use properties of joint probability density functions for continuous variables. We will represent joint density of y_1 and y_2 as a product of conditional density of y_1 on y_2 and unconditional density of y_2, i.e. $f(y_1, y_2) = f(y_1|y_2)f(y_2)$. Now we only need to calculate $f(y_1|y_2)$.

Before we proceed, by means of properties of bivariate normal distributions, it is convenient to write $E(\epsilon_1|\epsilon_2) = (\rho/\sigma_2)\epsilon_2$ and $Var(\epsilon_1|\epsilon_2) = 1 - \rho^2$. Given ϵ_2, we can define the conditional probabilities of a bank failure and survival respectively:

$$f(y_1 = 1|y_2) = \Phi(\omega) = \Phi\left(\frac{x_1\beta_1 + y_2\beta_2 + (y_2 - x_1\theta_1 - x_2\theta_2)\rho/\sigma_2}{(1-\rho^2)^{0.5}}\right) \qquad \text{(B2)}$$

$$f(y_1 = 0|y_2) = 1 - \Phi(\omega) \qquad \text{(B3)}$$

where $\Phi(.)$ is the cumulative distribution function of the standard normal distribution and $\epsilon_2 = y_2 - x_1\theta_1 - x_2\theta_2$.

[42] Assuming that ϵ_1 is normally distributed with mean 0 and variance 1, we can derive a maximum likelihood estimator for the reduced form probit as follows. In the reduced form model, the probability of bank failure is given by:

$$P(y_1 = 1) = P(\epsilon_1 \geq -x_1\beta_1 - y_2\beta_2) = 1 - \Phi(-x_1\beta_1 - y_2\beta_2) = \Phi(x_1\beta_1$$

$$P(y_1 = 0) = 1 - \Phi(x_1\beta_1 + y_2\beta_2)$$

where $\Phi(.)$ is the cumulative distribution function of the standard normal distribution.
The density of y_1 (a likelihood function) becomes:

$$f(y_1) = \Phi(x_1\beta_1 + y_2\beta_2)^{y_1}(1 - \Phi(x_1\beta_1 + y_2\beta_2))^{1-y_1}$$

Then parameters can be estimated by maximizing the log-likelihood function for an individual bank:

$$l = y_1 ln\Phi(x_1\beta_1 + y_2\beta_2) + (1 - y_1)ln(1 - \Phi(x_1\beta_1 + y_2\beta_2))$$

Substituting equations (B2) and (B3) into equation (B1), we obtain our likelihood function:

$$f(y_1, y_2) = \Phi(\omega)^{y_1}(1 - \Phi(\omega))^{1-y_1}(2\pi\sigma_2^2)^{-0.5}\exp(-0.5\,\frac{(y_2 - x_1\theta_1 + x_2\theta_2)^2}{\sigma_2^2})$$

(B4)

Implied Maturity Mismatches and Investor Disagreement

with

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Abstract

Maturity mismatches (MMs) expose banks to interest rate risk and thus add to the uncertainty and ambiguity of the bank's performance. Given the significance of interest rate risk for banking operations, we study the relationship between MMs and investor disagreement, as proxied by trading volume in the banks' equity. We overcome infrequency and opacity of accounting disclosures, which interfere with direct measurements of MMs, by resorting to implied MMs, computed as stock return sensitivity to interest rate changes. We find that implied MMs are positively associated with trading volume, and that the role of returns in this relationship is minimal or null.

JEL Classification: G12, G14, G21

Keywords: Asset-liability mismatch, maturity mismatch, trading volume, investors disagreement

1. INTRODUCTION

In this paper we explore the extent to which changes in bank exposure to interest risk, impacted by implied maturity mismatches (MMs), affect trading volumes, which indicate the dispersion of investors' beliefs.[43] MMs are of interest since they are a crucial factor in determining the vulnerability of banks' profits to interest rate changes, and since banks are central to the economy. Ideally, MMs could be measured directly from the banks' financial disclosures. But financial reports are subject to managerial discretion, e.g., managers are reluctant to disclose the detailed maturity of the assets and liabilities in their portfolio, which are necessary for the explicit computation of their interest risks (Morgan 2002, Flannery et al. 2004 and Flannery et al. 2013). Even if MMs are disclosed, the reported maturities are often different from the actual ones due to aggregation of reported items, prepayment and extension risks and the existence of items with ambiguous maturities such as saving and demand deposits. This makes maturity evaluation even more challenging (we expand on this issue in the next section). In view of the opaqueness of accounting data and the low frequency of their release, it becomes evident that the estimation of MMs based on financial reports cannot be precise.

Such flaws in measuring MMs from accounting data led us to infer MMs from the observed bank return sensitivities to interest rate changes. Based on such estimates, we extend the literature by exploring the effects of banks' (implied) MMs on the volume of trading. We find that monthly changes in MMs are positively correlated with increased trading, which, consistent with the extant literature, can serve as proxies to investors' disagreement about

[43] *The relationship between risk, prices and trading volume is important, because return reflects changes in the expectations of the market as a whole, and is not necessarily associated with trading, while trading reflects changes in the expectations of individual investors, and is not necessarily associated with price changes (Beaver 1968). The relations between individuals' expectations and those of the market may shed light on how the former are integrated into the latter. Following the Beaver's (1968) seminal article, trading volume has been explored from the point of view of investor disagreement (see also Harris and Raviv 1993, Gervais and Odean 2001, Huberman and Regev 2001, DellaVigna and Pollet 2009).*

stock prices.[44] We document a positive relationship between implied MMs and stock trading volume on a sample of AMEX, NYSE and NASDAQ listed financial institutions in the post-decimalization era, spanning from January, 2000 to December 2012.[45] Our results appear robust to the several classes of interest rates and to alternative measures of disagreement. We further show that MMs influence volume beyond their indirect effects on trading, through their possible effects (if such effects are present) on prices.

Our findings shed light on the functioning of capital markets, and may be useful to investors, analysts and regulators. If MMs cause investor disagreement and therefore induce costly trading, then the provision of additional information on MMs is beneficial and actions encouraging the dissemination of pertinent information about MMs that would reduce disagreement should be applauded.

The rest of the paper is organized as follows. In Section 2 we review the literature. Section 3 describes the data. In Section 4 the testable predictions are constructed, and the methodology and estimation procedures are explained. In Section 5 the results are presented and discussed, and Section 6 provides a number of conclusions.

2. MOTIVATION AND RELATED LITERATURE

We review the extant literature that directly relates to the issues of investor disagreement stemming from MMs, in three stages: Subsection 2.1 reviews related literature on MMs. In Subsection 2.2 we discuss the issues of the banks' opacity obscuring MM measurements, as well as stress the advantages of using interest rate sensitivities as implied

[44] *See, e.g., Karpoff 1987, Harris and Raviv 1993, Blume et al.1994, and Kim and Verrecchia 1994.*
[45] *Among other studies of the effects of several other types of information on disagreement we can find: Kandel and Pearson 1995 (earning announcements), Lo and Wang 2000 (market beta), Dzielinski and Hasseltoft 2014 (news flows) and Ferson and Lin 2014, (Jensen's alpha).*

MMs. Subsection 2.3 covers the relevant literature related to disagreement among investors and its correlation with trading volume.

2.1 MMs and interest rate risk

The extent of the literature on banks MMs does not match the importance of this topic. Past research investigating MMs mostly concentrates on risk management techniques in response to interest rate risk exposure. Purnanandam (2007) finds that U.S. banks intensify hedging of on-balance sheet exposure with interest rate derivative contracts once their probability of default increases. Ruprecht et al. (2013) model the simultaneous choice of an on-balance duration gap and off-balance interest rate swap use of German banks. They find that higher bankruptcy risk induces banks to reduce MM and increase the propensity to hedge this gap with interest rate swaps. Landier et al. (2013) study income gaps (the difference between interest rate sensitive loans and deposits). They report that, on average, banks tend to hold positive gaps, and the larger the gaps the more sensitive banks are to interest rate changes, despite the use of derivatives to hedge these risks. Similar conclusions were also reached by English et al. (2012).

2.2. Deficiencies of estimating MMs from financial reports and the advantages of implied MMs

The above studies on MMs and risk suffer from very serious shortcomings, since they measure MMs based on balance sheet information. First, the maturities of many banks' assets and liabilities, such as cash holdings, saving accounts and demand deposits, are ill-defined and researchers do not fully agree on whether to classify these as long-term or short-term items.

Second, there is a considerable distinction between actual and stated maturity of items on the balance sheet. Data on the actual maturities of items are rarely available to bank outsiders due to non-mandatory disclosure of such information, but banks do take the data into account while building risk hedging strategies. In financial literature, this dissimilarity between actual and stated maturities is known as prepayment or extension risk. As an example of prepayment risk, consider the case where the rate payable on a floating rate loan is expected to increase but the borrower may choose to prepay the entire loan earlier than expected. When such a situation arises, the bank will experience a reduction in interest income. The opposite scenario is known as the extension risk.

Third, instruments with the same repricing dates may respond differently to changes in different interest rates (known as a basis risk). When an asset and a liability otherwise having the same repricing date are tied to different rates (say, Treasury bill and LIBOR), the fluctuation in underlying rates will create exposure of the bank to the spread between the rates. The stated maturities would ignore this nuance and give a researcher misleading information about the quality of balance sheet items.

Fourth, there is a problem of over-aggregation coupled with managerial reporting discretions that is allowed by regulators, such as the Generally Accepted Accounting Principles (GAAP) and bank-specific regulations, together with managerial opportunism. These issues are nicely summarised by Saunders and Cornett (2008, p.203): "defining buckets over a range of maturities ignores information regarding the distribution of assets and liabilities within those buckets... On average, liabilities may be repriced toward the end of the bucket's range, while assets may be repriced toward the beginning, in which case a change in interest rates will have an effect on asset and liability cash flows that will not be accurately measured".

There are further interest rate risks that are not divulged in the banks reports, such as the risk of exposure stemming from extensive usage of complex derivatives (e.g., cross-currency swaps) and off-balance sheet items that are intangible contract obligations.

In light of the inadequacies of accounting data for measuring MMs, we suggest using implied MMs measured as return sensitivities to interest rate changes. We base this choice on the pioneering findings of Flannery and James (1984), who documented a strong link between traditionally measured and implied MMs in the cross-section of U.S. traded banks. Extensive research has confirmed the conclusions of Flannery and James (1984) by expanding them to account for several types of interest rates, different time frames and different methodologies (see, e.g., Choi et al. 1992, Song 1994, Chamberlain et al. 1997, and Schrand 1997).

2.3. Investor disagreement and trading volume

Beaver's (1968) seminal article paved the way for studying the issue of dispersion in beliefs among shareholders and volume by documenting unusually high trading volume around earning announcement dates. The robustness of Beaver's (1968) finding was further established by a series of studies (e.g., Bamber 1987, Bamber and Cheon 1995, Garfinkel and Sokobin 2006, Garfinkel 2009, D'Agusta et. al. 2015). Kandel and Pearson (1995) documented a significant increase in trading activity around earning announcements even when event returns were close to zero, thus showing that it is disagreement rather than returns that affects the volume. Chae (2005) interpreted the observed patterns in trading before scheduled and unscheduled events from the perspective of strategic planning of informed and uninformed traders who act to minimize adverse selection costs. Carlin et al. (2014) pointed out that disagreement produces risk premium by increasing expected return, but periods of high disagreement are followed by periods of lower trading once investors learn from the observed patterns.

A large body of theoretical work builds upon the divergence of opinions among equity-holders and provides diverse motives for investor disagreement.[46] Harrison and Kreps (1978) suggest a model of speculative trading by heterogeneous investors anticipating time-varying information flow. The importance of noise traders was first established in the seminal paper of Milgrom and Stokey (1982), who showed that no trading will occur in an environment with identical investors in the absence of noise traders. Kyle (1985) posits that information asymmetry increases trading because informed investors attempt to exploit their private information. Foster and Viswanathan (1996) build a model in which differentially informed traders attempt to predict the behaviour of each other, and where trading outcome is determined by the correlation structure of subjective signals.

Some of the literature studies the mechanisms of investor disagreement occurrence. According to the gradual information flow hypothesis, at any one time period traders share different information sets on bank risks, and therefore trading occurs as an outcome of continuous information disclosure to each group of traders (Huberman and Regev 2001). Limited attention theory posits that traders might have equal access to information and share similar heuristics, and yet trade differently because of information overload and cognitive distractions (DellaVigna and Pollet 2009). Heterogeneous (prior) beliefs may cause disagreement about the significance of events (news), since by Bayes Rule they induce heterogeneous posterior beliefs (Harris and Raviv 1993). If investors are overconfident (but not all at the same level) then they will differ in their assessment of the accuracy of their prior

[46] *Another strand of literature studies the disagreement between other two groups of stakeholders: investors and managers (see Dittmar and Thakor 2007, Huang and Thakor 2013). Nonetheless, in this paper we choose to concentrate on the more canonical version of disagreement among investors themselves because of its established effect on trading leaving the other type of disagreement for further research.*

information, and hence, as in the Heterogeneous Beliefs theory, they will differ in their posterior beliefs (Gervais and Odean 2001).

Given heterogeneity of investors in their beliefs, preferences and endowments, they are different in marginal propensities to trade at different risk levels. Credit risk, as an amalgam of a number of risks, is difficult to measure, and so for exhibition purposes we will concentrate on interest rate risk (i.e. MMs), which is easier to compute but, nonetheless, is a vital source of risk for banking operations. We hypothesise that implied MMs, as surrogates for bank interest rate risks, are positively associated with trading volume, and that the role of realized returns in this relationship is minimal or non-existent.

3. DATA

For banks' stock market data we use the Center for Research in Security Prices (CRSP)/COMPUSTAT merged database accessible through Wharton Research Data Service (WRDS). We broadly define banks as firms having 60 (depository institutions) or 67 (holding companies and other investment offices) as the first two digits in the Standard Industrial Classification (SIC). This choice expands our dataset beyond commercial banks to also cover, for example, mutual funds and trusts. Since interest rate sensitivity due to MMs is pertinent for these institutions as well as for banks, we opted to include them in the sample.[47] Accordingly, our data set includes 270,981 bank-month observations.

Risk factors are obtained from several sources. From CRSP we retrieve returns on value-weighted S&P 500 index and on risk free indices constructed from Treasury bond rates with maturities of 1 and 7 years. From the Federal Reserve Board we obtain 3 month LIBOR, 1 year LIBOR and 7 year swap rates. Our data on LIBOR, interest rate indices, and S&P 500

[47] *The beginning of our sample, circa 1999, coincides with the Gramm-Leach-Bliley Act, also known as Financial Services Modernization Act of 1999, which repealed the Glass-Stegall Act, thus allowing financial institutions to engage in banking activities.*

Index span the period from January 1999 to December 2013 and on swap rates from August 2000 to December 2013. All interest and market returns are computed as the monthly changes in the corresponding rates.

We retain in the sample only actively traded stock, while excluding stocks whose trading is classified as ‘halted’ or ‘suspended’. We include common shares, certificates, American Depository Receipts (ADRs) and shares of beneficiary interest (SBIs), but excluded shares classified as units because of their limited liquidity and since they may possess option-like characteristics which make their trade different from other securities in the sample. Lastly, in view of the differences between firms listed on global and on regional stock exchanges, we include cross-listed shares but retain only stock whose primary listing is in one of the major stock exchanges (NYSE, AMEX or NASDAQ).[48] The end sample contains 45,471 bank-quarter observations.

For robustness tests we also used dispersion of analysts' forecasts retrieved from I/B/E/S, as an alternative measure of investor disagreement. We collected our data from the section classified as “Banks” in I/B/E/S and for the time period of January, 2000 to December, 2012. The items collected were standard deviation of 12-month forward earnings per share (EPS) forecasts, their means and the number of analysts who made these forecasts. Within the above-mentioned sample we kept only U.S. incorporated and AMEX, NYSE and NASDAQ listed banks.

[48] *Stocks which are not listed on global stock exchanges usually do not comply with their listing requirements and, being listed regionally, are smaller and less liquid. Additionally, dissimilarities in trading psychology and information flows may significantly bias estimates in the second stage. This last exclusion of regionally listed firms, however, is not very restrictive, because once all data clearing is executed only a small portion of stock is primarily listed outside of the major three.*

4. METHODOLOGY

Our hypotheses are that bank'-implied MMs affect trading volume, and that the role of realized returns in explaining this effect is minimal or even non-existent. In such a way, the banks' implied MMs induce investor disagreement. To test our hypotheses we first calculate the sensitivity of returns to interest rates in order to construct our implied MMs, and then run regressions to test the extent to which these MMs are correlated with volume.

4.1. Estimating the implied MMs

To compute the implied MMs, we use the Fama-French 3 factor model and add to it a sensitivity to interest rate factor, R_t^I. We thus run regressions of the following form for each bank (dropping the bank's subscript i from the equation to reduce clutter):

$$R_t = \alpha_t + \beta_t^{CAPM}\left(R_t^M - R_t^f\right) + \beta_t^I R_t^I + \beta_t^{HML} HML_t + \beta_t^{SMB} SMB_t + \epsilon_t \qquad (1)$$

where R_t is a total monthly holding period return (capital gain plus dividend yield) on a bank's stock for period t, $\left(R_t^M - R_t^f\right)$ is a market risk premium factor, R_t^I is a monthly change in a given interest rate (we used the following alternative measures of interest rate: Treasury 1 year, Treasury 7 years, LIBOR 3 months, LIBOR 1 year or swap rate 7 years), and SMB and HML are the standard Small-Minus-Big and High-Minus-Low Fama French factors.[49] The

[49] *Risk factors could be cross-correlated, but we choose to deal with the potential correlation in the second stage exclusively by controlling for possible sources of covariation. We do not orthogonalize risk factors because this can bias the coefficients (Giliberto 1985). Another alternative to orthogonalization would be to compute principal components of market, interest returns and plug them into equation (1) as a risk factor. We did execute principal component analysis for the returns but, because of evenly high correlations between some components and some returns, we couldn't find a "good" match between the former and the latter. In the presence of such ambiguous correlations, the interpretation of beta coefficients at principal components would be too perplexing. So, while principal components may successfully resolve multicollinearity, they would introduce another, much more corrupting issue – incomprehensibility of beta estimates.*

estimates of the $\beta_t^{I\prime}s$ – the bank's sensitivities to interest rate returns – serve as our estimates of the implied MMs.

We use rolling windows of 48 months each to compute the sensitivities according to a 'symmetric' algorithm, i.e., for each period (month) we estimate the above three-factor model using observations over 24 months before it and 24 months after it. We use this method to allow for the possibility that the β_t^I's change over time. Accordingly, for any period t, starting the month t = 25 we estimate the β_t^I using information from both past observations during periods (t-1) to (t-24) and from future observations (t+1) to (t+24), and proceed this way up to the latest sample period.[50]

Our choice of monthly frequency reflects a balance between the pros and cons of this frequency compared to its alternatives. As opposed to more informative weekly and daily data, monthly data are less noisy and contain more economically relevant information. As opposed to quarterly data, monthly data ensure the sufficient number of observations needed to implement a moving beta procedure, even though they do not fit the quarterly accounting reporting frequency.[51]

[50] *Eliminating current period t's observations from the estimates may help avoid reverse causality in the next stage. Exclusion of the current return from estimating sensitivities may be a sufficient condition for exogeneity of the effective MMs only if there is strong autocorrelation in returns. In our sample, the average first order autocorrelation of returns across panels is already close to 0%, with higher order correlations gradually decreasing. The benefit of this method over using a 'lead' approach implemented on purely historic data is twofold. First, it allows us to eliminate bank-month observations on young banks (first 12 months after IPO or first date when data for a bank are available) that did not have time to form mature portfolios and gain sufficient visibility among investors. Their presence would introduce downward bias in trading volume in the next stage. Second, it allows us to exclude bank-month observations on banks close to their liquidation date (last 12 months before running bankrupt or being acquired), which may be characterized by abnormal trading due to distress (e.g., coming from extensive fire sales as a result of liquidity issues). Their presence would introduce upward bias in trading volume in the next stage.*

[51] *By using monthly date we lose comparisons with quarterly reports, but gain more information on time periods not included in these reports.*

4.2. The correlation between implied MMs and volume

While there is no perfect or unique measure of trading activity, turnover has several benefits over the alternatives (see Lo and Wang 2000 for a detailed discussion). Hence, we use the following metric. For each pair of month and bank we compute the monthly turnover as the sum of its daily turnovers (as in equation 1, we drop the bank subscript):[52]

$$V = \sum_s V_s = \sum_s \frac{volume_s}{shares_s} \qquad (2)$$

where V stands for monthly turnover, V_s stands for total turnover on a particular day s, $volume_s$ is the total number of the bank's stocks traded on all stock exchanges on day s and $shares_s$ is the total amount of common shares outstanding on day s. Our measure of common shares outstanding is adjusted for ADR conversion ratio for foreign incorporated banks. To deal with positive skewness in turnover, we calculate its natural logarithm. Our primary measure of investor disagreement is thus the industry-adjusted turnover, G, defined by:

$$G = \log(V) - \log(V^M) \qquad (3)$$

where V^M is a monthly turnover in the banking industry obtained by summing up the daily turnovers of all the banks in our sample in a given month and $\log(.)$ denotes natural logarithm. Throughout the paper we use log-log as our main specification, except for when we note otherwise. This specification is advantageous as it transforms and approximates even

[52] *The primary advantage of using turnover is that it allows capturing the change in trading volume due to changes in the number of shares outstanding, such as stock splits, share repurchases and seasoned equity offerings.*

highly skewed variables to normal.[53] In the robustness check, we examine some of the implications of this formulation.

We run generalized least squares (GLS) regressions of the following form to estimate the relationship between our measures of industry-adjusted volume and the implied MMs[54]:

$$\log(V_{it}) - \log(V_{Mt}) = \gamma_0 + \gamma_1 \log\left|\beta_{it}^{I}\right| + \tau' X + \pi_i + u_{it} \qquad (4)$$

The π_i are bank fixed effects, the $\left|\beta_{it}^{I}\right|$'s are the absolute values of interest rate risk and X denotes a vector of the following covariates:

- $|\alpha_{it}|$ is an absolute value of the intercept estimated from Equation (1);
- $|\epsilon_{it}|$ is an absolute value of an error term from Equation (1);
- $\log(p_{it})$ is a logarithm of the opening monthly price;
- $\log(c_{it})$ is a logarithm of capitalization computed by multiplying its opening price with the number of total shares outstanding on the first day of the month;
- $\log(d_{it})$ is a dividend-to-price ratio;
- σ_{it} is standard deviation of daily returns;
- $\chi_{it}(1)$ is first order auto-covariance of daily returns;
- $\left|\beta_{it}^{CAPM}\right|$ is an absolute value of CAPM beta from Equation (1);
- $\left|\beta_{it}^{SMB}\right|$ is an absolute value of SMB beta from Equation (1);
- $\left|\beta_{it}^{HML}\right|$ is an absolute value of HML beta from Equation (1);

[53] *We also calculate (not tabulated) the vector inflation factors (VIF) for the MMs in the next step. The VIF values range from 2.5 to 3.5, sufficiently low to avoid the critical values recommended by the rule of thumb of '10 or higher' for defining multicollinearity. We achieve an increased precision of the coefficients' estimates by using a large sample, which by the central limit theorem drives the variables close to normal.*

[54] *We use GLS to correct for the autocorrelation resulting from using overlapping data. For a robustness check, we also repeated all our tests using Newey-West estimation using lag length 3, 6, 12 and 24. The results (unreported) obtained under this procedure are qualitatively similar to the ones obtained under the GLS procedure. The results can be obtained from the authors upon request.*

- $YEAR$ is a vector of year dummies;
- $MONTH$ is a vector of month dummies.[55]

In line with our hypothesis, γ_1, the effect of interest rate sensitivity on volume is expected to have a positive sign.[56]

We use bank capitalization as a proxy for visibility (Merton 1987, Dahlquist and Robertsson 2001, Chordia et al. 2007). Larger firms have a more diverse ownership, which leads to more active trading (Merton 1987). Additionally, institutional investors follow the Prudent Man Rule by investing more in larger capitalization firms (Badrinath et al.1989, Del Guercio 1996). Size is also positively correlated with a number of analysts following a bank (Chordia et al. 2007), which stands for the larger mass of informed agents (Brennan and Subrahmanyam 1995). Price levels are also related to stock visibility. They are inversely related to brokerage commissions, and so brokers tend to advertise low-priced stock more actively in an attempt to increase brokerage revenues (Brennan and Hughes 1991, Angel 1997, Schultz 2000).

The inclusion of alpha in our model is motivated by its link to the expected return from CAPM and APT models. It may also contain a liquidity premium as documented by a number of previous studies (see Amihud and Mendelson 1986a, 1986b; Hu 1997). It also captures the extent of heterogeneous information about the stock (Wang 1994, He and Wang 1995, Ferson and Lin 2014). Similarly, absolute values of errors are included in the equation to control for the possibility that unobservable effects (for example losses from liquidity

[55] *Equation (4) represents a 'full' model. To preclude the possibility of simultaneity and reverse causality in the presence of some of the above listed controls, we also try a 'restricted' model which excludes some potentially endogenous controls (alpha, errors, volatility and autocovariance) from Equation (4). The results of such an examination will be highlighted later on.*

[56] *In this paper, we focus on the interest rate risk as a source of investor disagreement but we will also discuss the effects of other sources of risk in the model, namely CAPM, HML and SMB betas, on the investors' divergence of opinions*

drains or fluctuation in other market risks such as oil prices) might have consequences for trading.

We include market beta in the controls of Equation (4) since in addition to measuring systematic risk it also proxies estimation uncertainty about fundamental value of a stock, thus potentially affecting trading volume (Coles and Loewenstein 1988, Coles et al. 1995). Absolute values of HML and SMB betas are included as controls since they may reflect a particular composition of the bank's balance sheets and risk structures. Dividend yield is positively related to abnormal returns in the extant empirical literature. For example, according to the so-called dividend-capture trades, investors acquire stock just before the ex-dividend date and then sell it shortly after the date.[57]

Standard deviation of daily returns is used as a proxy for uncertainty about fundamental values (Karpoff 1987, Gallant et al. 1992, Zhao and Wang 2003, Yin 2010). In particular, in periods of high uncertainty stock could be more frequently traded because of upward and downward trajectory reversals in the price movements (Karpoff 1987). High volatility may also lead to higher rebalancing needs, and thus to higher turnover (Lo and Wang 2000). On the other hand, high and negative daily stock return autocovariance is synonymous to larger effective bid-ask spread (Roll 1984).[58] Consequently, we expect it to have a positive effect on turnover. We control for possible seasonality in turnover by using month and year dummy variables. Finally, bank effects are used to capture the 'normal' level of trading in the bank's stock.

[57] *See Lakonishok and Smidt (1986), Lakonishok and Vermaelen (1986), Karpoff and Walkling (1988, 1990), Michaely (1991), Stickel (1991), Michaely and Murgia (1995), Michaely and Vila (1995, 1996), and Lynch-Koski (1996).*

[58] *The positive values of autocovariance are associated with negative effective bid-ask spread. Instead of setting positive values to zero or even dropping them, as some authors do in an attempt to derive Roll measure, we follow Lo and Wang (2000) and keep its actual values in all our regressions.*

5. RESULTS AND DISCUSSION

5.1 Descriptive statistics

Panel A of Table 1 presents the descriptive statistics of all returns used to estimate the coefficients of Equation (1). Note that, among all non-equity returns, 1-year Treasury bond return has the lowest volatility, and 3-month LIBOR return exhibits the highest volatility. Accordingly, 3-month LIBOR produced the largest (47.14%) and the smallest returns (-43.85%) in the sample. Also note that all returns are clustered around zero, indicating that investments in financial instruments, despite having different levels of riskiness, did not produce risk premiums over the sample horizon.

Panel B of Table 1 presents the correlation matrix of the return variables on the RHS of Equation (1). One may note that for both the Spearman and the Pearson correlations of market returns are highly negatively correlated with Treasuries returns. This result is not surprising, given that increases in risk free federal fund rates are commonly associated with worsened economic conditions. Another interesting correlation is between LIBORs and swap rates. The co-movement of those time-series is clear if we think of the long-term swap rate as an expected future cash flow from the investment under the floating short-term LIBORs.

Table 2 presents summary statistics of all the non-return variables on the RHS of Equation (1). Given that the sample consists of banks listed on global stock exchanges, their average market value is quite high and constitutes $1.88 billion, with standard deviation of $10.4 billion. The average number of shares outstanding is 82.33 million, whereas the mean turnover is 0.06, which is very similar to those reported in prior studies.[59] Additionally, note that the prices’ and dividends’ distributions are highly positively skewed (5.95 and 2.52, respectively). Our sample is comprised of securities with share prices ranging from as low as

[59] *This number of mean turnover is similar to the one found in prior studies. In particular, turnover was found to be 0.054 in a sample of the largest NYSE/AMEX listed firms in Tkac (1999), 0.045 in all AMEX/NYSE listed and 0.084 in all NASDAQ listed companies in Chordia et al. (2007).*

\$0.1 to \$504.7, with a mean of \$17.1. The total annual cash dividend paid varies from \$0 to \$10 per share, with a mean of \$0.8. As a matter of fact, similar to turnover, the natural logarithm transformation of those variables will be used to approximate their distributions close to normal.

5.1. First stage estimation: estimating implied MMs

Before we can assess the effect of MMs on investor disagreement, we estimate implied MMs with rolling window procedure, as described by Equation (1). Table 3 presents the coefficients of interest as well as auxiliary parameters recovered from such estimation. Note that the distributions' means of the interest rate betas are clustered around zero with approximately symmetric tails, implying that on average banks in the sample did not play the role of maturity transformers (e.g., issuers of long-term loans and holders of short-term deposits). The table also indicates that, while interest rates represent no price factors, CAPM beta, HML beta and SMB beta are all highly positive, indicating that bank portfolios tend to co-move with the market, value and small-cap stocks. The co-movement of banking sector with small-cap stock returns is not surprising, given the reliance of small firms on bank financing (as opposed to large firms with more diversified sources of funding). The correlation of this sector with value stocks can be explained by banks' conservativeness.

One may also observe that the average of the interest beta estimates of the 1-year Treasury rate (1.993) is larger than that of the 7-year rate (0.193), as well as more dispersed. This feature is consistent with previous studies showing that shorter maturity Treasury rates have a higher absolute value effect on stock returns and embody larger variation (e.g., Flannery and James 1984, Choi et al. 1992, Song 1994).[60] This is in line with the financial

[60] *Beta estimates are not directly comparable, that is, in principle the coefficient for a 7-year Treasury rate risk and that of a 7-year swap rate could signal the equivalent 7-year maturity mismatches in a dollar amount. So,*

instruments of shorter maturities being more frequently repriced, and therefore posing a source of short-term shocks to the banks' returns.[61]

5.2 Second stage estimation: the effects of MMs on volume

Based on the time-series of implied MMs for each bank in the sample, obtained in stage 1, we next test our hypothesis that increases in implied MMs increase investor disagreement. Table 5 presents the results of GLS estimation of the relationship between our measures of industry-adjusted volume and the implied MMs as presented in Equation (4). These estimates are made for the five alternative interest returns: 3-month LIBOR, 1-year LIBOR, 1-year Treasury, 7-year Treasury and 7-year swap rate. We use two models, labelled (a) and (b), for each class of interest rates. In both models the dependent variable is the logarithm of the bank's industry-adjusted turnover.[62]

Model (a) is our base model, which controls for the following variables: absolute value of interest beta, absolute value of CAPM beta, absolute value of market-to-book beta

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while the signs of the imputed betas should coincide with the signs of the actual exposures, the sizes (absolute values) of betas can tell us little about the sizes (absolute values) of actual mismatches in the cross-section. In other words, beta estimates of the different rates, but of the same maturity, may signify the same size of the actual mismatch; the ratio at which each beta could be precisely converted into the actual mismatch of the corresponding maturity is, however, unknown and might be time dependent. Still, information contained in absolute values of interest rate betas is fairly useful for comparisons of changes in actual exposure over time for separate banks.

[61] *Table 4 presents a correlation matrix of the actual beta estimates from Equation (1). The lower triangle exhibits Pearson correlations and the upper triangle exhibits Spearman rank correlations. Note that the interest betas estimated on treasuries with maturities of 1 year and 7 years have the highest correlations in the sample (with 73.0% and 60.7% for Spearman and Pearson correlations, respectively), stressing on the co-movement of the banks' exposure to the risk-free bonds of different maturities. Similarly, interest betas for LIBOR rates are highly positively correlated with each other, possibly indicating that if a bank is active in the LIBOR market than it is simultaneously exposed to a movement in a number of LIBOR maturities. Correlations among other interest betas are lower and sometimes even negative. For example, the interest beta from the swap rates is highly negatively correlated with both interest betas estimated on the treasuries. Their Spearman correlations are -46.08% for 1-year treasuries and -67.15% for 7-year treasuries. This may be explained by the swap positions of the banks, e.g. banks that take a fixed side of the swap rate payers become counterparties to the floating treasuries-rate payers. Such a correlation matrix of implied MMs will let us comparing if there are potentially different responses of investors to different types of exposures*

[62] *Petersen (2009) argues that clustering by bank and using time effects is optimal for having unbiased standard errors in wide panels characterized by a large number of banks and a small number of time points. White's (1980) heteroscedasticity robust standard errors clustered by bank are reported in brackets and all data are winsorized at 0.5%.For the sake of simplicity, the tables do not report the regressions' intercepts.*

(SMB), absolute value of size beta (HML), opening stock price, dividend yield, bank size (market capitalization), and firm and time fixed effects. To reduce the chance of bias due to omitted variables model (b) adds the following controls: return volatility, daily returns' auto-covariance (a proxy for effective bid-ask spread suggested by Roll 1984), absolute value of Jensen's alpha (as a proxy for abnormal returns), and the absolute value of the disturbance terms (ε_{it}) from Equation (1) which stand for unexpected returns.

First note that in Table 5 all the estimates of the coefficients of the interest rate betas, i.e., the implied MMs, are significantly positive indicating that larger implied MMs induce higher turnover. The implied MM range from 0.0116 to 0.0369, implying that a 1% change in stock return sensitivity to interest returns entails an increase of 0.012% to 0.037% in turnover. We note that the introduction of more variables lowers the estimated coefficients at implied MMs (as we move from a model (a) to (b)), but they remain significant and roughly of the same magnitude. The R^2's of all the models are around 80%, indicating a very good fit.

Interestingly, as the coefficients values indicate, the magnitude of the effect of market beta on turnover is either insignificantly different from zero (as in specifications with swap and Treasury returns) or significant and negative (as in specifications with LIBOR returns), thus strongly refuting the argument in favour of the two-fund separation theorem (see Lo and Wang 2000).[63]At the same time the betas of the market-to-book (HML) and size (SMB) factors are generally significant and positive in all models, with the coefficients at HML beta being generally higher than the corresponding coefficients at the interest beta. The positive effect of SMB betas can be partially explained by the higher disagreement on the chances of

[63] *In alternative specifications (market model and CAPM) we confirm the finding of Lo and Wang (2000) that market beta (and CAPM beta) is positively related to turnover. But adding HML and SMB factors to the model suppresses its positive effect on turnover.*

small firms to not repay their loans. The positive effect of HML may stem from higher disagreement on the merits of value stocks relative to growth stocks.

Table 5 reveals that for both models (a) and (b) price, capitalization and dividend yield are highly significant (at 1% level or lower) and have the expected effects on turnover, thus explicitly describing the liquidity characteristics of equity. Additionally, the idiosyncratic risk and the absolute values of the alphas are significantly positively related to turnover, stressing that both expected and unexpected components of returns are incorporated into equity trading. Finally, as expected, return volatility and auto-covariance are found to be increasing with turnover, but their corresponding coefficients are statistically insignificant.

5.3 MMs and returns

In this part of the paper we examine whether the detected positive relationship between turnover and the implied MMs can be attributed to the effect of MMs on contemporaneous absolute values of returns, which in turn affect trading volume. For that purpose, we add the variables absolute 'marginal interest returns' (a product of interest rate beta and change in interest rate) as controls to all the specifications of Table 5. We hypothesize that, after controlling for marginal returns, the coefficients γ_1 remain significantly positive, thus indicating that the expected price effects of interest risk subsume little or naught from the effects of MMs on volume.

The results of models (a) and (b), which include the marginal returns, are presented in Table 6. One observes that in all the models the coefficients of the MMs are positive and highly significant, while the coefficients of the marginal returns are not; in various specifications they are not significantly different from zero, in others they are sometimes negative and sometimes positive. That is, the results reported above confirm our hypothesis that the MMs affect turnover beyond their expected effect on returns, and consequently we infer that they affect disagreement among investors. Investors, cautious about MMs in banks incorporate interest risks in their investments decisions. The information that different investors possess (as it is possibly extracted through different channels) is apparently heterogeneous and hence induces disagreement, but this heterogeneity does not affect prices.

5.4 Implied MMs and investor disagreement: robustness tests

We next present further tests to rule out the possibility that the effect of MMs on trading stems from their effects on returns. We employ Kandel and Pearson's (1995) methodology of testing for turnover differences between non-event (smallest or no MMs) and event samples (largest MM). Thus, we classify the sample into deciles according to actual returns and absolute MMs. Within each return decile, we test for the difference in mean turnover between the smallest and the largest MM deciles (applying t-tests). In line with our expectation that MMs increase investor disagreement, we anticipate mean turnover to be consistently higher for larger MMs across all return deciles and in particular in the decile with zero return.

Table 7 presents the results of some of these tests. In Panel A we present the full statistics for one class of MMs, the 1-year Treasury interest rates. One may observe that within each return decile, the largest MMs sample yields consistently higher mean turnover, and the difference in mean turnover between the largest MMs and the smallest or no MMs is highly statistically significant ($p < 0.0001$). This result implies that even when there is no (or negligible) change in price, the mean turnover in the largest MMs sample is significantly higher than in the smallest or no MMs. This reinforces our claim that investor disagreement rather than returns is a key explanation for the observed patterns in the data. The same conclusions are gleaned from Panel B of Table 7 which repeats the above analysis for the other four classes of interest rates.[64]

Robustness tests were also conducted by running regressions (employing GLS procedure) of alternative specifications of Equation (4), alternative betas estimation procedures and alternative definitions of investor disagreement based on the dispersion of analyst forecasts.[65] The results are presented in the six panels of Table 8 (for brevity we present only the most salient statistics). Panel A presents results when the CAPM model is used to compute the betas. Panel B presents results when the market model is used to compute betas. Panel C shows the alternative estimates of beta, i.e., log-linear specification of the model where, for ease of comparison of the coefficients, all betas are normalized by their corresponding standard errors. Panel D shows the outcome of log-log specification where estimation is conducted only on 48 months rolling windows each. Panel E presents the output of the model in which log of standard deviation of analyst EPS forecasts normalized by opening price is used as a dependent variable. Panel F presents the output of the model in which log of standard deviation of analyst EPS forecasts normalized by absolute value of mean EPS forecast is used as a dependent variable. The various panels differ also in the controls used. Panel A uses CAPM beta, dividend yield, capitalization and price as controls. Panel B uses market beta, dividend yield, capitalization and price as controls. Panels C and D use CAPM beta, HML beta, SMB beta, dividend yield, capitalization and price as controls. Panels E and F use CAPM beta, HML beta, SMB beta and a number of analyst forecasts as controls. White's (1980) heteroscedasticity robust t-statistics clustered by bank are reported in brackets. One may observe that under different specifications, betas estimation procedures and definitions of investor disagreement, the estimated interest rate betas are still significantly

[64] *In order to conserve space not all the statistics shown in in Panel A are also presented in Panel B.*
[65] *All models use time and fixed effects. Time effects are month and year dummies. All the data are winsorized at 0.5%.*

positive, thus confirming our hypothesis that the implied MMs increase investor disagreement.

6. CONCLUSION

In classical financial theory the exposure of a firm's return to interest rate risk is constant, and therefore it does not affect pricing. This, however, is not the case for financial institutions whose day-to-day decision making implies time varying shifts in the composition of interest rate risks, which reveal themselves through the existent maturity mismatches (MMs). In this paper we argue that, being positively correlated with opacity and complexity of portfolio compositions of the banks, MMs exacerbate uncertainty and ambiguity about the banks' performance and, as a result, provide more grounds for investor disagreement. On the other hand, evaluation of MMs based on financial reports entails serious deficiencies, since such reports do not contain adequate information for flawless computation of MMs (think extensive off-balance sheet positions, basis risk, prepayment of loans, etc.). To circumvent this problem, we use implied MMs measured as stock return sensitivities to changes in interest rates. By means of regression analysis, we found a significant positive relationship between the implied MMs and their stock turnover, even in the absence of price changes. This effect is preserved in a number of specifications, after controlling for contemporaneous returns and standard determinants of trading volume.

Our paper still leaves some avenues for future research. First, even though we have shown that investor disagreement increases with implied MMs, it has not been shown how this phenomenon occurs. An increase in trading can be attributed to one or more theories of investor disagreement (e.g., gradual information flow, limited attention, overconfidence and heterogeneous priors); identifying the precise channels of the effect requires gathering data on individual investors and their trading patterns. Second, one may wonder whether the *inter-group* disagreement between investors and managers also affects volume, and to what extent (if any) it interferes with the *intra-group* disagreement among investors themselves. These interesting questions however are a task beyond the space of this paper and are left for future research.

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Table 1. Descriptive statistics and correlations of returns

Panel A: Summary statistics

Return	N	Mean (%)	Std. Dev.	Min	Max	Skewness	Kurtosis
bank return	270,981	0.81235	0.1417657	-0.93333	11	156.9086	52,878.58
S&P500 return	180	0.32793	0.0447173	-0.16942	0.107723	-0.54757	3.783146
treasury 1 year	180	0.23544	0.0028278	-0.00331	0.013061	1.028052	4.409037
treasury 7 year	180	0.47705	0.0176322	-0.04695	0.081895	0.1185403	4.602073
LIBOR 3 month	180	-1.14183	0.1013871	-0.43846	0.471423	-0.2193746	8.008165
LIBOR 1 year	180	-0.90169	0.0760415	-0.25497	0.252964	0.0425271	4.550293
swap 7 year	161	-0.40041	0.0776338	-0.30028	0.288591	0.4874431	5.72525

Panel B: Correlation matrix of returns

	market	1y Treasury	7y Treasury	3m LIBOR	1y LIBOR	7y swap
Market	1.000	-0.286	-0.361	-0.073	-0.001	0.215
1 year Treasury	-0.309	1.000	0.569	-0.127	-0.291	-0.290
7 year Treasury	-0.345	0.564	1.000	-0.070	-0.246	-0.584
3 month LIBOR	-0.119	-0.184	-0.075	1.000	0.834	0.192
1 year LIBOR	0.008	-0.415	-0.331	0.781	1.000	0.430
7 year swap	0.183	-0.315	-0.609	0.101	0.416	1.000

Panel A presents summary statistics of monthly returns. See the text for the definition of variables. Except for swap 7 year returns, all data are for the period from January 1999 to December 2013. For swaps, they are from September 2000 to December 2013. Panel B presents return correlations. Pearson's correlations appear below the diagonal and Spearman's rank correlations appear above the diagonal.

Table 2. Summary statistics of bank specific variables

Variable	N	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
total shares outstanding (000s)	45,471	82,329.58	522,023.9	450	1.78E+07	19.08	495.91
total trading volume (000s)	45,471	7,282.36	98,854.12	0.2	1.02E+07	55.51	4,156.58
monthly turnover	45,471	0.06	0.08	5.42E-05	2.344	6.49	81.59
capitalization ($000s)	45,471	1,879,590	1.04E+07	496.98	2.41E+08	11.19	159.67
price ($)	45,471	17.1	14.09	0.1	504.69	5.95	99.95
total dividend yield ($)	45,471	0.8	0.58	0	10	2.52	20.88
standard deviation	45,471	0.04	0.19	0	33.22	128.2	20,049.58
autocovariance	45,471	-0.01	0.87	-183.02	0.013	-207.5	43,749.21
dispersion of EPS forecasts	14,318	0.2162	1.1647	0.001	49.21	23.385	800.5691
mean EPS forecast	14,318	2.0326	5.7882	-174.7	56.43	-5.555	205.7528
number of analysts	14,318	7.9381	6.4321	2	37	1.4291	4.6117

The table describes summary statistics of variables other than those estimated by the equation (1) for the period from January 2000 to December 2012. Shares outstanding is the total shares outstanding as indicated on the balance sheet adjusted for stock splits and ADR conversion ratio in a given month. Trading volume is the sum of daily volume of a stock traded on all stock exchanges in a given month. Monthly turnover is the sum of daily turnover which is defined as the ratio of trading volume to shares outstanding on a given day. Capitalization is computed as a product of shares outstanding and opening price on the first day of a given month. Price is the opening monthly price in a given month. Dividend is a total per share dividend distribution over the last calendar year. Volatility is a standard deviation of a daily stock return in a given month. Autocovariance is first order autocovariance in daily returns in a given month. Dispersion of earnings per share (EPS) forecasts is standard deviation of analysts' long term (12 months ahead) EPS forecasts. Mean EPS forecast is a simple average of analysts' EPS forecasts. Number of analysts is the number of analysts based on whom the mean EPS forecast is computed. All the data are presented before winsorization.

Table 3. Summary statistics of coefficients estimated by moving windows procedure in equation (1)

$$R_t = \alpha_t + \beta_t^{CAPM}\left(R_t^M - R_t^f\right) + \beta_t^I R_t^I + \beta_t^{HML} HML_t + \beta_t^{SMB} SMB_t + \epsilon_t$$

Var.	Equation	N	Mean	Std. Dev.	Min	Max
interest beta	libor 3 month	45,471	-0.028699	0.2753671	-28.1357	2.93844
	libor 1 year	45,471	-0.066486	0.2113216	-3.51409	12.23115
	treasury 1 year	45,471	1.99365	11.10982	-399.859	1043.701
	treasury 7 year	45,471	0.1930636	1.134057	-42.7082	44.05197
	swap 7 year	33,523	-0.083321	0.7365496	-8.16373	78.24302
CAPM beta	libor 3 month	45,471	0.6487412	0.6497398	-13.148	16.2623
	libor 1 year	45,471	0.6636418	0.6546981	-6.53234	16.24798
	treasury 1 year	45,471	0.6862281	0.6633411	-8.01359	16.68794
	treasury 7 year	45,471	0.6881732	0.6583725	-5.47522	17.07118
	swap 7 year	33,523	0.6638898	0.6555041	-5.46204	16.72149
SMB beta	libor 3 month	45,471	0.3722266	1.087224	-93.6242	10.11503
	libor 1 year	45,471	0.376794	1.240512	-110.196	10.20944
	treasury 1 year	45,471	0.363119	1.177353	-107.971	10.18982
	treasury 7 year	45,471	0.3687886	1.212374	-106.896	10.62877
	swap 7 year	33,523	0.3293167	1.105185	-90.1402	10.44012
HML beta	libor 3 month	45,471	0.2916107	1.443909	-15.1877	166.0134
	libor 1 year	45,471	0.3047995	1.413549	-13.9012	154.2205
	treasury 1 year	45,471	0.3221886	1.384499	-13.4294	155.2885
	treasury 7 year	45,471	0.3026157	1.39251	-8.8904	152.3229
	swap 7 year	33,523	0.3258248	1.438025	-12.0325	149.6964
constant	libor 3 month	45,471	0.0041049	0.0182736	-0.11843	1.142008
	libor 1 year	45,471	0.0040072	0.025445	-0.11398	2.650547
	treasury 1 year	45,471	0.0004797	0.0333444	-0.22545	3.330951
	treasury 7 year	45,471	0.0035839	0.0255549	-0.1284	2.407672
	swap 7 year	33,523	0.0045496	0.0279515	-0.14944	2.815912

The table presents summary statistics of coefficients estimated by the rolling window procedure in the equation (1): interest betas, CAPM betas, SMB betas, HML betas and intercept terms. The column "equation" specifies interest rate used for estimation of the equation (1). All the data are presented before winsorization.

Table 4. Correlation matrix of interest betas and CAPM betas

		interest beta					CAPM beta				
		tr 1y	tr 7y	lib 3m	lib 1y	sw 7y	tr 1y	tr 7y	lib 3m	lib 1y	sw 7y
interest beta	treasury 1 year	1	0.7303	0.1529	-0.1248	-0.4608	0.0648	0.0896	-0.0883	-0.0707	-0.0284
	treasury 7 year	0.6067	1	0.1051	-0.2199	-0.6715	-0.1343	-0.0408	-0.2719	-0.2493	-0.2076
	LIBOR 3 month	0.1172	0.032	1	0.6678	0.0524	0.127	0.1333	0.0959	0.0821	0.116
	LIBOR 1 year	-0.0754	-0.2049	0.6776	1	0.5008	0.0986	0.0926	0.141	0.1109	0.1446
	swap 7 year	-0.3168	-0.6209	0.0644	0.4716	1	0.1454	0.0805	0.2514	0.2177	0.179
CAPM beta	treasury 1 year	0.193	-0.0243	0.1342	0.0654	0.0025	1	0.9791	0.9726	0.9793	0.9691
	treasury 7 year	0.1993	0.0541	0.1271	0.0745	-0.0315	0.9825	1	0.9568	0.9644	0.9698
	LIBOR 3 month	0.0662	-0.1602	0.1073	0.1127	0.1091	0.9749	0.9709	1	0.9967	0.9832
	LIBOR 1 year	0.0789	-0.1377	0.0912	0.0826	0.073	0.9808	0.9765	0.9972	1	0.9848
	swap 7 year	0.1126	-0.0932	0.1241	0.1048	0.0246	0.9745	0.9803	0.9861	0.9879	1

Pearson's correlations appear below the diagonal and Spearman's rank correlations appear above the diagonal.

Table 5. GLS estimation of industry adjusted turnover on interest rate risk (log-log)

	LIBOR 3 month		LIBOR 1 year		Treasury 1 year		Treasury 7 year		Swap 7 year	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
interest beta	0.0145***	0.0116***	0.0366***	0.0313***	0.0369***	0.0253***	0.0214***	0.0154***	0.0295***	0.0236***
	(0.0043)	(0.0042)	(0.005)	(0.0049)	(0.0042)	(0.0045)	(0.0051)	(0.005)	(0.0054)	(0.0052)
CAPM beta	-0.0122*	-0.0124**	-0.0167***	-0.0155**	0.0002	-0.0019	0.0095	0.0068	0.0042	0.0038
	(0.0062)	(0.0061)	(0.0063)	(0.0063)	(0.007)	(0.0068)	(0.0077)	(0.0075)	(0.0067)	(0.0066)
SMB beta	0.0149***	0.0133***	0.0192***	0.0177***	0.0251***	0.0221***	0.0265***	0.0248***	0.0205	0.019
	(0.0042)	(0.0041)	(0.0041)	(0.0041)	(0.0043)	(0.0042)	(0.004)	(0.0039)	(0.016)	(0.0158)
HML beta	0.0458***	0.0423***	0.0482***	0.044***	0.0377***	0.0331***	0.0434***	0.0401***	0.1486***	0.1375***
	(0.0051)	(0.005)	(0.0053)	(0.0051)	(0.0052)	(0.0052)	(0.0051)	(0.0051)	(0.0145)	(0.0144)
price	-0.1595***	-0.1404***	-0.1395***	-0.1154***	-0.1414***	-0.1269***	-0.1422***	-0.1266***	-0.0848**	-0.0605
	(0.0424)	(0.0421)	(0.042)	(0.0418)	(0.042)	(0.0414)	(0.0425)	(0.0422)	(0.0409)	(0.041)
Div yield	1.375***	1.2117***	1.3715***	1.1963***	1.4185***	1.2733***	1.4149***	1.2797***	1.3422***	1.1739***
	(0.204)	(0.2158)	(0.2038)	(0.2143)	(0.2066)	(0.2218)	(0.2046)	(0.216)	(0.1966)	(0.2071)
capitalization	0.139***	0.1633***	0.1291***	0.154***	0.1321***	0.1538***	0.131***	0.1516***	0.1007**	0.1289***
	(0.0429)	(0.0454)	(0.0422)	(0.0448)	(0.0425)	(0.045)	(0.0425)	(0.0455)	(0.0402)	(0.0438)
volatility	-	0.3959	-	0.3751	-	0.3943	-	0.3993	-	0.3579
		(0.2544)		(0.248)		(0.2511)		(0.2537)		(0.2393)
covariance	-	0.0769*	-	0.0733	-	0.0766*	-	0.0776*	-	0.0716
		(0.0465)		(0.0453)		(0.0459)		(0.0464)		(0.0437)
alpha	-	3.5468***	-	3.6879***	-	1.7978**	-	2.1772*	-	3.6957***
		(1.0972)		(1.0827)		(0.7119)		(1.1615)		(1.1106)
error	-	0.6246***	-	0.7254***	-	0.5738***	-	0.5877***	-	0.9349***
		(0.184)		(0.1824)		(0.1458)		(0.1747)		(0.1553)
time effects	yes	Yes	yes	yes	yes	yes	yes	yes	yes	yes
fixed effects	yes	Yes	yes	yes	yes	yes	yes	yes	yes	yes
N	45,471	45,471	45,471	45,471	45,471	45,471	45,471	45,471	33,523	33,523
R2	0.7997	0.8019	0.8009	0.8032	0.8007	0.8027	0.8002	0.802	0.8039	0.8062

The table presents results from generalized least squares (GLS) estimation of turnover on interest rate risk and controls. White's (1980) heteroscedasticity robust standard errors clustered by bank are in brackets. Time effects are month and year dummies. All the data are winsorized at 0.5%. Constant is included into regressions but excluded from the table for the sake of economy of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Table 6. Betas and marginal returns

	LIBOR 3 month		LIBOR 1 year		Treasury 1 year		Treasury 7 year		Swap 7 year	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
interest beta	0.016***	0.0149***	0.0366***	0.028***	0.0142***	0.0149***	0.0157***	0.0177***	0.0142***	0.014***
	(0.005)	(0.0051)	(0.0056)	(0.0056)	(0.0051)	(0.0053)	(0.0054)	(0.0054)	(0.005)	(0.005)
CAPM beta	0.0032	0.0079	-0.0069	0.0042	0.0126*	0.0177***	0.015**	0.0174**	0.0014	0.0097
	(0.0068)	(0.0069)	(0.0073)	(0.0068)	(0.0069)	(0.0068)	(0.0072)	(0.0073)	(0.0067)	(0.0065)
SMB beta	0.0031	-0.002	0.0085	0.0016	0.0078*	0.0027	0.009**	0.0014	0.008*	0.0041
	(0.0045)	(0.0044)	(0.0043)	(0.0043)	(0.0045)	(0.0044)	(0.0042)	(0.0042)	(0.0045)	(0.0045)
HML beta	0.017***	0.0162***	0.0206***	0.0151***	0.0205***	0.0201***	0.0181***	0.0135**	0.015***	0.011**
	(0.0057)	(0.0056)	(0.0056)	(0.0054)	(0.0058)	(0.0057)	(0.0056)	(0.0054)	(0.0055)	(0.0052)
interest marginal return	0.0626	0.0052	0.2183	0.5206	-0.0806	0. 003	0.1091**	0.0637	1.1171***	0.3447
	(0.0443)	(0.0569)	(0.3322)	(0.3293)	(0.0757)	(0.1295)	(0.0521)	(0.1206)	(0.3033)	(0.3066)
CAPM marginal return	-0.1674	-1.3253***	-0.0576	-1.4237***	-0.1114	-0.8544**	-0.1785	-0.8652***	-0.2661	-1.6846***
	(0.2284)	(0.2573)	(0.2374)	(0.2486)	(0.2073)	(0.3445)	(0.1931)	(0.2681)	(0.2484)	(0.258)
SMB marginal return	-0.2634	0.1455	-0.6288**	0.1025	-0.4838**	0.1096	-0.4924**	0.1877	-0.5051	-0.1197
	(0.1908)	(0.2016)	(0.2539)	(0.2961)	(0.2368)	(0.2796)	(0.206)	(0.2621)	(0.3199)	(0.3311)
HML marginal return	-0.0586	0.0275	-0.2729***	0.5915*	-0.0753	0.0013	-0.2148**	0.5994*	-0.0317	0.6019*
	(0.0718)	(0.1095)	(0.0988)	(0.3425)	(0.1066)	(0.1596)	(0.0977)	(0.3265)	(0.3074)	(0.3208)
time effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
N	45,471	45,471	45,471	45,471	45,471	45,471	45,471	45,471	33,523	33,523
R2	0.838	0.846	0.8391	0.8468	0.8383	0.8463	0.8383	0.846	0.8382	0.8465

The table presents results from generalized least squares (GLS) estimation of turnover on betas and controls. Marginal returns are absolute values of multiplication of betas and their corresponding risk factors, e.g. HML marginal return is absolute value of multiplication of HML beta and change in HML factor. Not displayed firm specific controls in basic model (a) are price, capitalization and dividend yield. Not displayed firm specific controls in the full model (b) are price, capitalization, dividend yield, volatility, autocovariance, alpha and residuals. White's (1980) heteroscedasticity robust standard errors clustered by bank are in brackets. Time effects are month and year dummies. All the data are winsorized at 0.5%. Constant is included into regressions but excluded from the table for the sake of economy of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Table 7. Mean turnover across MM and return deciles

Panel A: 1 year Treasury bond

Return decile	Return range	Smallest MM decile		Largest MM decile		P-value
		N	mean	N	mean	
1	R < -0.0769	495	0.0667	578	0.1655	<0.0001
2	-0.0769 < R < -0.0381	475	0.0459	469	0.1015	<0.0001
3	-0.0381 < R < -0.01723	489	0.0433	412	0.0867	<0.0001
4	-0.0172 < R < -0.0034	504	0.0437	374	0.0702	<0.0001
5	-0.0034 < R < 0.008	420	0.0418	354	0.0731	<0.0001
6	0.008 < R < 0.0193	419	0.0453	369	0.0686	<0.0001
7	0.0193 < R < 0.0323	390	0.0425	419	0.0757	<0.0001
8	0.0323 < R < 0.0508	402	0.0458	445	0.0702	<0.0001
9	0.0508 < R < 0.0874	474	0.0538	513	0.0938	<0.0001
10	0.0874 < R	479	0.0715	613	0.1602	<0.0001

Panel B: other MMs

Return decile	7 year Treasury		7 year swap		3 month LIBOR		1 year LIBOR	
	smallest	largest	smallest	largest	smallest	largest	smallest	largest
1	0.0860	0.1235	0.0836	0.1742	0.0764	0.1343	0.0857	0.1306
2	0.0596	0.0760	0.0639	0.0813	0.0623	0.0801	0.0578	0.0853
3	0.0508	0.0668	0.0536	0.0594	0.0455	0.0638	0.0507	0.0662
4	0.0472	0.0595	0.0565	0.0583	0.0418	0.0607	0.0468	0.0670
5	0.0446	0.0583	0.0481	0.0536	0.0349	0.0550	0.0436	0.0631
6	0.0523	0.0592	0.0500	0.0562	0.0392	0.0609	0.0501	0.0642
7	0.0537	0.0610	0.0579	0.0640	0.0417	0.0699	0.0508	0.0762
8	0.0530	0.0619	0.0575	0.0590	0.0468	0.0673	0.0521	0.0744
9	0.0661	0.0764	0.0676	0.0749	0.0622	0.0737	0.0692	0.0805
10	0.0898	0.1313	0.0919	0.1777	0.0893	0.1189	0.0829	0.1203

The table presents mean turnover across return and MM deciles. In panel A, interest betas used to form deciles are recovered from the specification with 1 year Treasury bond. P-values are reported from the two-tailed t-test applied to test the significance of difference in mean turnover between the smallest and the largest MM deciles within each return decile. In panel B, interest beta used to form deciles are recovered from all other specifications except for 1 year Treasury bond.

Table 8. Alternative specifications (robustness check)

	3 month LIBOR	1 year LIBOR	1 year Treasury	7 year Treasury	7 year swap
	Panel A: industry adjusted turnover (CAPM)				
interest beta	0.0161	0.038	0.0505	0.0268	0.0511
	(3.57)	(7.6)	(10.74)	(5.25)	(9.12)
R^2	0.7988	0.7993	0.8	0.7993	0.7997
N	45,471	45,471	45,471	45,471	33,523
	Panel B: industry adjusted turnover (market model)				
interest beta	0.0192	0.0236	0.0247	0.0103	0.0426
	(5.05)	(5.49)	(5.61)	(2.15)	(7.75)
R^2	0.7964	0.791	0.794	0.7981	0.7968
N	45,471	45,471	45,471	45,471	33,523
	Panel C: industry adjusted turnover (log-level)				
interest beta	25.7111	49.4555	13.4125	0.9228	1.241
	(4.15)	(4.49)	(4.78)	(2.65)	(7.74)
R^2	0.7996	0.8024	0.8129	0.8019	0.8091
N	45,471	45,471	45,471	45,471	33,523
	Panel D: industry adjusted turnover (only windows 48 months each)				
interest beta	0.0185	0.0274	0.0378	0.0151	0.051
	(4.15)	(5.36)	(7.98)	(2.8)	(8.39)
R^2	0.8683	0.8686	0.8734	0.8682	0.8667
N	34,012	34,012	34,012	34,012	26,927
	Panel E: dispersion of EPS forecasts normalized by opening price				
interest beta	0.0454	0.0468	0.0544	0.0361	0.0415
	(2.1)	(2.63)	(3.47)	(2.18)	(2.08)
R^2	0.5634	0.5636	0.5555	0.5527	0.6057
N	14,318	14,318	14,318	14,318	10,108
	Panel F: dispersion of EPS forecasts normalized by mean EPS forecast				
interest beta	0.0384	0.0371	0.0517	0.0502	0.0209
	(2.39)	(2.48)	(3.42)	(3.73)	(1.11)
R^2	0.4885	0.489	0.4843	0.4836	0.5253
N	14,318	14,318	14,318	14,318	10,108

The table presents alternative specifications for the relationship between the MMs and investor disagreement. Panel A presents results when the CAPM model is used to compute betas. Panel B presents results when the market model is used to compute betas. Panel C presents results of the log-linear specification where, for ease the sake of comparison of the coefficients, all betas are normalized by their corresponding standard errors. Panel D shows the output of log-log specification where estimation is conducted only on rolling windows having 48 months each. Panel E presents the output of the model in which the log of standard deviation of analyst EPS forecasts normalized by opening price is used as a dependent variable. Panel F presents the output of the model in which log of standard deviation of analyst EPS forecasts normalized by absolute value of mean EPS forecast is used as a dependent variable. Panel A uses CAPM beta, dividend yield, capitalization and price as controls. Panel B uses market beta, dividend yield, capitalization and price as controls. Panels C and D use CAPM beta, HML beta, SMB beta, dividend yield, capitalization and price as controls. Panels E and F use CAPM beta, HML beta, SMB beta and a number of analyst forecasts as controls. The estimation method used is generalized least squares (GLS). White’s (1980) heteroscedasticity robust t-statistics clustered by bank are reported in brackets. All models use time and fixed effects. Time effects are month and year dummies. All the data are winsorized at 0.5%.

Discount Windows, Equity Runs and Market Revelation

March 17, 2016

Abstract

The information on bank illiquidity (funding liquidity) has long been kept secret as a preventive measure against bank runs. In this paper, we argue that, despite its confidentiality, it is propagated to a stock market and therefore incorporated into equity trading by uninformed investors (market liquidity). Building on theories of asymmetric information and asset mispricing, we draw a channel through which outsiders are hit by privately known, but insider-mediated, bank-specific shocks to liquidity. On the example of discount window (DW) borrowing, we illustrate that information on bank illiquidity can be inferred from the insider initiated equity runs, i.e. (1) greater equity supply by a troubled bank but (2) lower net insider demand for it. While (1) is driven by both more intensive seasoned equity offering and less intensive repurchase plans, (2) is explained by insider unwillingness to buy but not by predisposition to sell the stock. We attribute the null result for selling to trading constraints imposed on insiders by regulation and banks themselves, as well as insiders' inclination to maintain original secrecy of the DW borrowing.

JEL Classification: G02, G21, G30

Keywords: discount window, liquidity need, adverse selection cost, insider trading, seasoned equity offering, capital structure

1. INTRODUCTION

Interconnectedness of markets plays a vital role for the healthiness of a financial system. Consequently, the analysis and timely identification of connections may play a prophylactic role in preventing the crisis. In literature, the triad of linkages among a real sector, a financial market and financial institutions are often studied as potential channels of shock dissemination over the entire financial system (Pritsker 1999). Complementing the existent literature, we illustrate the potential reaction of an equity market to an exogenously generated shock in a banking sector. More specifically, we draw a channel through which a negative shock to funding liquidity of a bank (i.e. capability of a bank to finance itself) is transformed into a shock to market liquidity (i.e. the easiness with which its stock is traded).

The information on bank illiquidity has long been kept secret as a preventive measure against bank runs. Given the secrecy of information about the bank’s financial well-being (especially at times when it deteriorates), we overcome this obstacle by considering informed agents as potential mediators in the shock propagation process. We study open market operations undertaken by insiders (officers, directors and beneficial owners of more than 10% of the bank’s equity) and their banks that transmit the shock to a general market and thus reveal poor financial performance. More importantly, we detect palpable symptoms that such shock transmission affects outsiders, uninformed about the bank’s financial hardship, which gives us a reason to assume that the insider activity itself serves as a market revelation mechanism addressed at the disclosure of bank’s illiquidity. To some extent, this finding also serves as a token of the strong market efficiency hypothesis, according to which private information about the bank is incorporated into equity trading and therefore a stock price.

On the example of discount window (DW) borrowing, we claim that the incidences of bank illiquidity can be learnt by the general mass of uninformed investors (outsiders), since market based corrective actions can reveal the banks' financial state. We argue that, despite the confidentiality of DW usage, the signs of poor financial standing of the banks-borrowers can be chased through the publicly observable open market operations undertaken by the informed parties. The first such activity is seasoned equity offering undertaken by the troubled bank, and the second is stock trading commenced by the bank's insiders (officers, directors and beneficial owners of more than 10% of the bank's equity). Building on theories of asymmetric information and asset mispricing, we hypothesize that at times of DW borrowing, 1) insider demand for their own equity drops, 2) the troubled bank is more likely to increase the supply of ownership rights, and 3) the two phenomena are proportional to each other therefore being an indicator of the insider initiated equity run. The above premises allow us deriving a notion of the "unwanted stock", the type of a stock which is oversupplied to the market and which insiders are unwilling to purchase.

To test our hypotheses, we collect previously unexplored data available through the FED on all large and listed banks which borrowed funds through the DW facilities. The public disclosure of these data became accessible as an outcome of the lawsuit filed by Bloomberg LP and News Corp.'s Fox News Network, as a response to the FED's opacity in its provision of individual bank bailouts. The mandatory disclosure of the identities of DW borrowers, the amounts borrowed and other related items was legally consolidated by The Dodd–Frank Wall Street Reform and Consumer Protection Act of 2010. Using this unique source, we managed to collect information on all DW loans classified as primary credit over the period from Q3 2010 (the first quarter when the data are available) to Q4 2012 (the last available quarter at the time of the study). We supplement these data with sources of insider trading (insidertrading.org which contains extracts from the SEC form 4 filings), stock price information (CRSP) and bank related fundamentals (Compustat).

We begin by studying the effect of the bank's illiquidity on the insiders' demand for their own bank's equity. We ground our argumentation on the fact that the incidence of the DW borrowing raises the asymmetric information between insiders and outsiders. Insiders are well acknowledged about the bank's poor financial standing as well as about its quality of an overpriced asset relatively to the bank's contemporaneous market price. We predict that the overvaluation of the bank's equity impels insiders to lessen their buying behaviour and potentially increase their propensity to sell. On the other hand, such rise in the adverse selection costs caused by informational assymetry increases chances of loss avoidance (in case of reduced buying) and profitable trades (in case of increased selling) by the insiders.

We carry on the analysis by constructing the unique measure of the bank's liquidity need. Given the availability of the DW borrowing data, our measure is directly based on the historic amounts of borrowing from the FED (i.e. borrowing of last resort) and so is an excellent proxy for the bank's shortage of disposable assets. On each day we generate a ratio of the total amount of funds borrowed through DW to the bank's market capitalization on that day, and then we sum these daily ratios within a quarter. We supplement this metrics with two other proxies of bank illiquidity: (a) an indicator variable taking value 1 if the bank borrowed funds through DW in the quarter and 0 otherwise, and (b) the frequency of DW borrowings within the quarter.

To proxy for the insiders' predisposition to acquire their own stock, we build four metrics: *net insider demand* (NID), as the quarterly difference between total volume of equity purchased and sold normalized by total shares outstanding; *order based net insider demand* (ONID), as the quarterly difference between total number of insider purchase and sale orders normalized by the total number of insider orders; *purchase ratio* (PR), as the quarterly ratio of total volume of shares bought by the insiders to the total volume of shares traded by the insiders; and *sell ratio* (SR), as the quarterly ratio of total volume of shares sold by the insiders to the total volume of shares traded by the insiders.

To examine the effect of DW borrowing on the insider demand we employ the fixed effect generalized least square (GLS) estimation. With and without controls, we find a significant negative correlation between DW borrowing and the three metrics of insider demand: NID, ONID and PR. Unsurprisingly, the coefficient at SR is found to be positive but statistically insignificant. Consistent with the large prior research on legal prohibition of insider trading, we attribute such finding to trading constraints levied upon insiders by both legislation and banks themselves, as well as the insiders' ambition to maintain the original secrecy of the DW borrowing by keeping low profile on a sale side.

Borrowing through the DW facility effectively means that the bank was unable to attract debt through other sources. Impossibility of entrance to credit markets, coupled with the bank's urgency to finance maturing obligations, reduces the insiders' resistance to resort to informationally sensitive means of financing, i.e. seasoned equity offering (Myers and Majluf 1984). The higher probability of stock issuance around the events of DW borrowing is further reinforced by a number of theories. In particular, market timing hypothesis of capital structure claims that it is less costly to offer the overvalued stock to the market (Baker and Wurgler 2002). Consistent with the trade-off theory, a risk of a death spiral financing and debt overhang may force banks to give priority to placing secondary offering instead of attracting even more liabilities (Kraus and Litzenberger 1973). This later argument may also induce banks to issue equity in order to meet its binding capital requirements in presence of the overleverage.

In light of the above theories, we anticipate banks in the sample to issue equity in quarters when they borrow from the FED. To prove or disprove it, we investigate the effect of the bank's financial need (as measured by the amount of DW borrowing) on the quarterly changes in a number of shares outstanding (CS). The adopted fixed effect GLS produces a significant positive effect of a liquidity need on CS. We further attempt to explain the effect by breaking it onto the effects DW borrowing might have separately on seasoned equity offerings (SEO), when CS is positive, and repurchase activities (REP), when CS is negative. Our results indicate that the increased equity supply during the DW borrowing quarters is driven by both more intensive secondary share placement (SEO) and less intensive buy back plans (REP). Interestingly, we discover that when banks resort to DW borrowing to cover their liquidity gap, net insider demand and stock issuance activity are inversely correlated which each other. This gives us a reason to introduce the label of "unwanted stock", e.g. the kind of equity oversupplied to the market which insiders abstain from acquiring.

Inspired by the vast empirical research examining a market reaction around the corporate events, we finish by positing that the DW borrowing by banks is taken into consideration by the uninformed investors. Even though they do not directly observe the events of DW borrowing, they do react to it indirectly by observing the rise in the "unwanted stock". To check our hypothesis, we first build the quarterly measure of uninformed trading and call it outsider turnover (OT). To construct it, on each day we subtract the total volume of insider trading (net of private transactions) of the stock from its total trading volume and normalize the residual by the number of shares outstanding on that day. OT is obtained by summing these daily measures of uninformed trading within the quarter. OT is not a perfect measure of outsider trading for it can be contaminated by the presence of investors sharing informational sets with insiders, for example insiders' family members, friends or relatives. But the proportion of such investors is expected to be very small for large listed banks with highly diversified shareholder base. On the other hand, OT can be biased if it includes the trades which insiders do not report on the SEC forms 4. Given the evidence from prior literature, we reasonably assume that the current legislation is sufficient to preclude misappropriate trading.

To test for outsider reaction at times of "equity runs", we proceed by employing the fixed effect GLS estimation where OT is a dependent variable and independent variables include CS, insider demand (NID, ONID, PR) and their interactions with DW. Both with and without controls, this procedure yields the significant evidence that the general mass of uninformed shareholders (outsiders) amplify trading activity at times of DW borrowing. Even though causality is hard to state, this increased outsider trading might be viewed as response to the insider initiated "equity runs", e.g. lower net insider demand for their own stock and larger equity supply by the banks' themselves. Curiously, even after controlling for the channels identified in the paper (equity runs), DW borrowing is still strongly positively correlated with OT. In light of possible explanations brought up by practitioners, the existence of other learning channels may exist and their identification is a matter of further research.

The contribution of this paper is threefold. Firstly, it highlights a novel contagious link between a banking sector and an equity market through the existent relationship between funding liquidity and market liquidity. Secondly, the paper provides the evidence of market efficiency hypothesis in which, acting as an inefficiency correcting mechanism, insider actions lead to a better price discovery. Finally, we show that by affecting market liquidity insiders transmit negative shock to funding liquidity to outsiders and probably inform them about their bank's privately known financial hardship.

The rest of the paper is organized as follows. Section 2 builds hypotheses drawing from the related literature. Section 3 describes the variables constructed to test the hypotheses.

Section 4 describes the data. Section 5 discusses the empirical results, and Section 6 summarizes the results of the study.

2. LITERATURE REVIEW AND HYPOTHESES

Before we go into detail, let us have a closer look at risk management provisions by bank holding companies (BHCs). One of the core functions carried out by BHCs is maturity transformation, i.e. borrowing money through short term deposits and lending them in a form of long term loans (Paligorova and Santos 2014). The negative liquidity mismatch arising this way exposes banks to a liquidity risk, a positive probability that the bank will have insufficient funds to meet its obligations (Diamond and Dybvig 1983, Brunnermeier et al. 2014, etc.). Given that such illiquidity increases the risk of insolvency and also makes it hard to obtain external financing, the bank may fall back on lending of last resort provided by the Federal Reserve (FED) and borrow funds through the discount window (DW) accessible to cover the shortage of liquidity.

Even though the illiquidity of assets is theoretically attested source of the insolvency on its own, a bank run frequently serves as another serious reason for a bank to default. The adverse information about the bank's prospects may give rise to a massive withdrawal of deposits by panicking customers, in which case even an otherwise solvent bank may fall victim of a self-fulfilling prophecy cutting maturity of liabilities at the increasing pace (Diamond and Dybvig 1983, He and Manela 2015, etc.). For this reason the identity of DW borrowers has long been kept secret as a precautionary mechanism against bank runs.

Whether banking industry should turn transparent has recently become a matter of the hot debate among economists. Dang et al. (2014) proclaim that the trade in information insensitive assets is a necessary prerequisite for BHCs to exist, and so bank opacity arises as an equilibrium attribute. Goldstein and Leitner (2015) state that a regulator should not disclose too much information about the interconnected BHCs (e.g. the results of on-site conducted stress tests) in order not to demolish risk-sharing opportunities among BHCs within the interbank network.[66][67] On the other hand, proponents of transparency often link excessive opacity with weak financial conditions (Gunther and Moore 2003, Huizinga and Laeven 2009) or cite it as a frequent companion of the financial crisis (Park 1991, Flannery et al. 2010).

The urgency of the dispute peaked in November of 2008 when Bloomberg LP, a parent of Bloomberg News, and News Corp.'s Fox News Network initiated the lawsuit against the FED compelling to disclose identities of DW borrowers and the conditions of each bailout. Defending their inability to do so by labelling the data under question as "confidential commercial information" (disclosure of which may harm borrowing banks) the FED refused to satisfy the Bloomberg's inquiry at the first try. Upon the announcement of the court verdict the FED, who has kept this information undisclosed since 1914, was enforced to compromise. As a partial consequence of the trial, the Dodd–Frank Wall Street Reform and Consumer Protection Act signed on July 21, 2010 obligated the FED to collect and disclose information on each DW transaction on the premise of divulging it with the two year lag.

Bank state of solvency is best observed by the bank insiders who hold access to private information significant in assessing the bank's financial standing. Such information, undisclosed to the market, may be related to a number of private credit events which affect adverse selection costs of information based trading, e.g. change in the bank's CAMEL rating; the release of the results of the regulator initiated stress tests; confidential borrowing from the central bank and so forth. We study the trading patterns of insiders in their own

[66] This is also known as the Hirshleifer (1971) effect.
[67] Other papers stressing on the adverse consequences from the too much disclosure in one way or another include but are not limited to Lizzeri (1999), Morris and Shin (2002), Prescott (2008) and Leitner (2012).

stock who, as opposed to liquidity (uninformed) traders, are likely to be informed about the details of such private credit events. We hypothesize that periods of these privately observed credit events are characterized with the reduced demand for equity by rational risk averse insiders, e.g. the bank's officers, directors and beneficial owners of more than 10% stakes in the bank.

In this paper, we concentrate on probably the most frequent private credit event – discount window (DW) lending. The confidentiality of this event is insured to tackle the renowned DW stigma jeopardizing banks' incentives to resort to DW borrowing at difficult financial times (Bernanke 2008). The rich evidence of banks' reluctance to borrow from the FED was empirically noted by Friedman and Schwartz (1963), Peristiani (1998), Furfine (2001) and Gauthier et al. (2013). Recently, Armantier et al. (2015), studying the magnitude and economic costs of DW stigma, found empirically that banks choose to overpay up to 126 basis points on borrowed funds with the sole purpose to avoid borrowing through the DW. A theoretical foundation explaining the DW stigma is provided in particular by Ennis and Weinberg (2009) and Klee (2011).

In the realm of insider trading, prior research emphasizes that insiders correct market mispricing in their firm's stock by exploiting private information they possess (Rozeff and Zaman 1998, Ke et al 2003, Piotroski and Roulstone 2005, Sias and Whidbee 2010, Ali et al 2011). Cohen et al (2012) distinguish between "routine" and "opportunistic" insiders, and find that these are the trades by the latter which contain tangible information about the firm. DW borrowing by its nature is a strong signal of the bank's liquidity need and/or poor financial ,management. In addition, if the amount of DW borrowing is thought to be related to the amount of bank-specific opacity, then it might be also positively correlated with a crash risk

(Hutton et al. 2009). As a matter of fact, private information about the bank as of an overpriced asset induces insiders to trade in the direction to reduce its stock price.

Apart from being the source of the mispricing based trading, DW borrowing may serve the reason for the adverse selection costs of trading. The anonymous borrowing from the FED widens the asymmetry in information possessed by insiders and outsiders, thus increasing the odds of profitable trading by the insiders. The positive correlation between insider trading and the adverse selection component of the bid-ask spread was documented in a number of papers.

H1a: Insiders' demand for their own equity is lower in quarters of DW lending.

H1b: Insiders are less (more) likely to buy (sell) their own bank's stock in quarters of DW lending.

A number of models of capital structure in firm theory predict that banks, resorting to DW borrowing, will tend to increase the paid up capital. First, a pecking order theory popularized by Myers and Majluf (1984) predicts that banks will issue new equity only if other less information sensitive sources of financing, e.g. internal funds and debt, are completely depleted. This occurs exactly when the banks use lending of last resort, e.g. DW borrowing, as a mechanism of liquidity easing. Second, according to a trade-off theory (Kraus and Litzenberger 1973), diluting ownership to external shareholders may not be as harmful as being trapped in a debt spiral by issuing new liabilities above the already outstanding. In short, under lack of liquidity and presence of severe credit constraints, banks may choose to bring external ownership to repay obligations which are about to mature. Following the same line of reasoning, the distressed banks will be less likely to repurchase their own shares and even may be forced to cancel or postpone formerly planned repurchase programs. Third, market timing hypothesis proposed by Baker and Wurgler (2002) postulates that firms, similarly to insiders, arbitrage away the stock mispricing by issuing (repurchasing) equity in periods when they view it is overvalued (undervalued) by the market.

Contrary to non-financial firms, banks may have additional incentives to issue equity. When credit risk rises, buffer capital hold as insurance (e.g. reserves) dries out and banks can be forced to respond by placing secondary offering to meet minimal capital requirements. According to the first pillar of the notorious Basel Accords, banks are obliged to hold the risk predetermined levels of capital in their portfolios, namely Tier 1 and Tier 2 capital, computed as a prespecified percentage of their total risk weighted assets. Berger et al. (2008) write: "To meet the Basel I capital guidelines, U.S. BHCs must have Tier 1 capital of 4% of risk-weighted assets (RWA) and total regulatory capital (Tier 1 plus Tier 2) exceeding 8% of RWA. U.S. BHCs are also subject to a leverage requirement – most large BHCs must operate with Tier 1 capital equal to at least 3% or 4% of unweighted total assets (the "leverage ratio"), depending on the condition of the institution. It is widely believed that current supervisory procedures afford some discretionary benefits to institutions classified as "well capitalized" – those holding Tier 1 capital of at least 6% of RWA and total regulatory capital above 10% of RWA." In line with the above arguments, we expect banks to be more likely issuing additional stock at times of DW borrowing.

H2a: The supply in a banks' number of shares outstanding is increasing at times of DW borrowing.

H2b: Banks are more (less) likely to issue (repurchase) their own stock at times of DW borrowing.

A number of papers document the market inefficiency associated with stock returns subsequent to insider trades (Givoly and Palmon 1985, Seyhun 1986, Rozeff and Zaman 1988, Lakonishok and Lee 2001). Meulbroek (1992) finds that illegal insider trading produces 3% abnormal return before takeover announcements and that the transaction-specific information is successfully impounded into stock prices. Keown and Pinkerton (1981) detect that 40-50% of price gain by the target firm occurs before the takeover announcement. Ke et al. (2002) provide the evidence that insiders profit from trading on private information as long as 2 years before important accounting disclosure.

Brochet (2010) documents the increased informativeness of SEC form 4 filings after introduction of Sarbanes-Oxley Act of 2002 obliging insiders to file SEC form 4 within 2 days, as opposed to within 10 days after the month when the insider transaction took place. Fidrmuc et al. (2006) found two day positive (negative) abnormal return after the director's stock purchases (sales) on the sample of the UK firms. Related literature documents a significant negative return after SEO announcements (Asquith and Mullins 1986, Masulis and Korwar 1986) and poor stock performance in the long run, once SEO takes place (Loughran and Ritter 1995, Spiess and Affleck-Graves 1995, and Ahn and Shivdasani 1999).

Even though DW lending as such is unobserved by the banks' outsiders, hypotheses H1a trough H2b provide a channel through which the general mass of uninformed shareholders can learn about the bank's insolvency risk, e.g. DW borrowing. Given the negative content of information disclosed through the insiders' unwillingness to purchase their own stock and higher probability of the banks' SEOs, we test the conjecture that uninformed (liquidity) traders incorporate this information in their decision making.

H3: Lower net insider demand (H1a and H1b) and more intensive stock issuance activity (H2a and H2b) at times of DW borrowing increase trading volume in the bank's equity by the uninformed outsiders.

3. VARIABLE DEFINITIONS

3.1 Discount Window Borrowing

All throughout our study, we use the sum of daily amounts of loans attracted through DW normalized by the bank's market capitalization, as a proxy for the bank's activity on DW lending market in a given quarter:

$$DW_q = \sum_{i=1}^{T} \frac{Loan_i}{Capitalization_i}$$

where $Loan_i$ is a total borrowing through DW on a day i, $Capitalization_i$ is market capitalization on day i and T is a total number of days in a given quarter q. We define market capitalization in a classical way as the product of the bank's shares outstanding and their closing price on that day.

The above measure captures directly the magnitude of the liquidity need suffered by the bank. For a robustness check, we will also use alternative metrics such the number of times the bank borrowed through DW in a given quarter (NUM_q) and a dummy variable taking value 1 if the bank borrowed through DW in a given quarter and 0 otherwise (1_{DW}).

3.2 Insider Demand for Equity

To study the effect of DW borrowing on net insider demand for equity (H1a), we build several metrics. Following Sias and Whidbee (2010)[68], we build net insider demand as the difference between total volume of shares bought and sold by insiders in a given quarter, scaled by the number of shares outstanding:

[68] Cohen et al (2012) distinguish between "opportunistic" (informed) and "routine" (uninformed) insiders. The authors draw a line between the former and the latter by checking whether the insiders' trades earn monetary gains. In particular, they find that geographical location and trading frequency are factors determining the insiders' degree of information based trading (opportunism). Nonetheless, we believe that there is no reason to stick to such gain based classification as all insiders are knowledgeable about the banks' terms and conditions of DW borrowing. We follow the classical approach by treating all insiders as informed agents. As will be shown later, our results indeed hold even in presence of "routine" traders.

$$NID_q = \frac{Buy_q - Sell_q}{Shares_q} * 100$$

where Buy_q and $Sell_q$ are total volume of shares bought and sold by insiders respectively, and $Shares_q$ is the total amount of shares outstanding in a quarter q.

We complement the above measure, which is based on the share volumes traded by insiders, with the alternative proxy which is based on the number of transactions executed (times insiders filed SEC form 4). We call it order based net insider demand:

$$ONID_q = \frac{Number\ of\ BUY\ orders_q - Number\ of\ SELL\ orders_q}{Number\ of\ BUY\ orders_q + Number\ of\ SELL\ orders_q}$$

To study the drivers of the net insider demand measures (H1b), we turn our attention to measures which could explain the direction of insider trades. Following Piotroski and Roulstone (2004), we build a purchase (sell) ratio as the proportion of total volume of shares bought (sold) by insiders to the total insider trading in a given quarter:

$$PR_q = \frac{Buy_q}{Insider_q}$$

$$SR_q = \frac{Sell_q}{Insider_q}$$

where $Insider_q$ is the total insider trading volume in a quarter q.

3.3 Stock Issuance and Repurchase

To measure the changes in the stock supply (H2a), we follow Pontiff and Woodgate (2008) and use the actual quarterly change in natural logarithms of the total shares outstanding adjusted for neutral events such as stock dividends and stock splits:

$$CS_q = \ln(SharesAdjusted_q) - \ln(SharesAdjusted_{q-1})$$

Using the actual change in a number of shares outstanding has several advantages over other similar measures of banks' issuance (repurchasing) activities such SEO announcements.

The announcement of share issuance (repurchase) does not obligate a bank to actually issue (repurchase) its own shares. Some studies show that for various reasons (such as abrupt price changes) a significant portion of announcements are not followed by actual secondary offerings or buybacks. In a study by Kahle et al. (2001), the annual percentage of cancelled SEOs ranges from as low as 2.1% to as high as 12.8% and is year specific. Similarly, Stephens and Weisbach (1998) detect significant deviations in both the timing and the amounts of stock repurchase plans from the indicated in the buyback announcements. Given such discrepancy between "the word and the deed", we insist on the change in a number of shares outstanding as the most correct measure of the stock issue (repurchase).

To see directly whether the change in a number of shares outstanding is driven by share issuances or repurchases (H2b), we use the following two measures of the above activities, as suggested by Stephens and Weisbach (1998):

$$SEO_q = \begin{cases} CS_q \; if \; CS_q > 0 \\ 0 \; if \; CS_q < 0 \end{cases}$$

$$REP_q = \begin{cases} -CS_q \; if \; CS_q < 0 \\ 0 \; if \; CS_q > 0 \end{cases}$$

3.4 Outsider Learning

To assess whether the outsiders learn from the equity runs (e.g. low insider demand and higher stock issuance) during DW lending quarters (H3), we construct the measure of outsider activity based on subtracting the insider trading volume from the total bank's turnover on each trading day[69]:

$$OT_q = \sum_{i=1}^{T} \frac{Volume_i - Insider_i}{Shares_i}$$

where $Volume_i$ is the total trading volume on a day i.

[69] We filter our insider trading data by excluding private and miscoded transactions. See Jeng et al (2003) for a detailed algorithm.

This measure is not perfect for several reasons. First, it can be contaminated by inclusion of trading patterns of other informed parties, e.g. close relatives of insiders. Nonetheless, we find it reasonable to assume that the total proportion of informed parties beyond the insiders in SEC definition (e.g. officers, directors and beneficiary owners of more than 10% equity) is sufficiently small. This can be particularly true for large firms (such as listed US incorporated banks in our sample) whose ownership structure is highly diversified in presence of institutional holders and large mass of liquidity traders.

Second, bank insiders themselves may participate in fraudulent behaviour by trading equity without acknowledging publicity through filing SEC forms. The measure we construct assumes the absence of acts of misbehaviour which, though may seem strong at the first glance, can be justified by prior literature indicating that the insiders' deviation from truthful reporting is costly and so not practiced. For example, Garfinkel (1997) finds that the implementation of legislation banning insider trading in advance of the importance news disclosure significantly affected the timing of such trading postponing them from before to after earning announcements. Some studies concentrate on firm specific efforts to restrict insider trading. Beny and Anand (2011) study the determinants of voluntary adoption of private insider regulation policies beyond the ones imposed by the governmental regulation. Bettis et al (2000) find that over 92% of firms in the US voluntarily adopt procedures suppressing illegal insider trading in their own stock, and these private policies are more restrictive than federal regulation.[70]

[70] Striving for further precision of our measure of outsider trading, we survey all charges of illegal insider trading made public by SEC over the sample years, e.g. from 2010 till 2012. We looked for illegal trades either based on material information related to the banks in our sample or executed by the bank employees at the times of DW borrowing. We were not able to find any of such cases.

4. DATA

4.1 Discount Window

We use previously unexplored data on DW lending published quarterly by the FED starting Q3 2010 (the first date when the data are available) to Q4 2012 (the last available quarter at the time of the study). These data contain such information as the loan origination date, the loan maturity date, the repayment date[71], the name of the borrower, the borrower's location (city and state), the borrower's ABA routing number, the type of credit made (primary, secondary or seasonal), the interest rate payable, the total USD amount of the loan, the total USD amount of other outstanding loans as of the loan issuance date and the total USD amount of collateral pledged.[72]

Because of frequent repetitiveness of bank names, we use nine digit ABA routing transit numbers (ABA RTN) to identify banks and their holding companies. We drop banks which are not publicly traded (mostly private banks and credit unions) or had less than 1 billion USD in total assets on the date when it borrowed funds from the DW. If a bank is not listed but its holding company is listed, we keep it under the ticker symbol of its parent bank (holding company). Some banks were acquired, merged, delisted or closed since the time they used DW funds, so we look up in Google for information on each particular merger, acquisition, delisting or bankruptcy and keep the bank (or its holding company) under the ticker it had at the time it resorted to DW borrowing. Once we use tickers to merge banks with the stock data from CRSP, our sample goes down further because of exclusion of OTC traded or listed abroad banks absent in the CRSP database. We keep only banks whose stock

[71] Though the repayment date is not necessarily the loan maturity date, in our sample we are lucky to have both dates coinciding for all banks without exception.
[72] The total collateral category further provides USD amounts for such subcategories as commercial loans, residential mortgages, commercial real estate loans, consumer loans, U.S. Treasury agency securities, municipal securities, corporate market instruments, mortgage backed securities (MBS) and collateralized mortgage obligations (CMO), asset backed securities, international securities, Term Deposit Facility deposits, and other collateral.

market data is available in CRSP without disruptions over the period from Q3 2010 till Q4 2012 and thus exclude banks that fail or are delisted for various reasons over this period. Out of 7,934 bank-event observations we were able to identify 610 bank-event observations (with 155 unique banks according to the ticker symbol) which complied with the above size and listing requirements as well as CRSP data availability.

The Federal Reserve manages three types of credits to depository institutions: primary, secondary and seasonal. In our sample, we are fortunate to obtain a homogeneous group of illiquid but solvent banks which used primary credit facility, and so we do not have banks which borrowed funds through secondary (insolvent banks according to CAMEL ratings) and seasonal facilities (small financial institutions with recurrent financial needs). The interest rate payable on primary credit is constant all throughout bank-quarters and is equal to 0.75%. The credit itself is normally provided overnight with no restrictions on its use. Appendix A deliberates further on the differences between primary and secondary credit.

Panel A of table 1 presents summary statistics of individual loan transactions. It is seen that banks in our sample borrowed from as little as 1,000 USD to as much as 1.017 billion USD through a single transaction. On average, the amount of such lending accounted for 3% of the bank's market capitalization. Except few cases, the maturity of these loans constituted one day, and the average number of times the bank went to the FED for funds over the period from Q3 2010 to Q4 2012 was less than four with most banks using DW only once.

4.2 Insider Trading

We collect insider trading data available at the online source insidertrading.org which provides insider buying and selling volumes from SEC forms 4 for all AMEX, NYSE and NASDAQ listed firms being updated in real time. We concentrate on SEC form 4 as it is the record most frequently filed by insiders which directly tracks changes in the insiders' ownership rights.[73] Using SEC forms 4 has an additional advantage in that they also include transactions in options, warrants and convertible securities by corporate insiders and so conveniently generalize the results of our study. On the other hand, they may also include scheduled ahead automatic trades, executed by electronic platforms on behalf of insiders, which can be equally beneficial or detrimental for our analysis depending on the nature of such transactions.

Each entry of our data contains such information as issuer name, ticker issuer trading symbol, name of the insider, position occupied by the insider at the firm (director, officer, 10% beneficiary owner or other[74]), volume traded, direction of the trade (buy or sell), transaction price, total value of the transaction, transaction date, form filing date and shares owned following the transaction. As a matter of fact, we drop foreign incorporated banks whose insiders are exempt from filing SEC forms 3, 4 and 5 under the US legislation.[75] After April 10, 1991 insiders are not required to distinguish between open market and private transactions when reporting their sales and purchases, therefore our sample includes both types of trades coded as P (open market or private purchase) and S (open market or private sale). To correct for possible accounting miscodes, we drop duplicated transactions which appear similar along all lines. Panel B of table 1 presents summary statistics by individual transactions.

[73] Form 3 includes the information on initial ownership of the firm's equity by an individual once he occupies the insider position. Form 5 is the annual snapshot of ownership rights which may also contain transactions subject to the reporting delay and/or transactions which are exempt from reporting requirements on forms 4 (for instance, share gifts).

[74] Some studies drop owners of more than 10% stake from their analysis and pin down their definition of insiders to officers and directors. As seen in the Appendix B, the total share of trades executed by the former constitutes less than 2% of the total insider trades and so the results obtained in the study are not sensitive to their exclusion.

[75] On the SEC web-site it is stated: "Insiders of foreign private issuers are exempt from filing beneficial ownership reports required by Section 16(a) of the Exchange Act and are not subject to the short-swing trading rules under Section 16(b) of the Exchange Act." In A Compliance Manual for Non-US Companies (2014) by NADAQ a foreign private issuer is classified as "any non-government foreign issuer, except issuers meeting the following conditions: (i) more than 50% of the voting securities of the issuer are directly or indirectly held of record by United States residents; and (ii) any of the following: (a) more than 50% of the assets of the issuer are located in the United States; (b) the business of the issuer is administered principally in the United States; or (c) the majority of the executive officers or directors are United States citizens or residents."

Table 2 presents the summary statistics of the constructed variables and the controls used in the regression analysis. Panel A of table 2 depicts the descriptive statics of the full sample, and panel B shows only the bank-quarters when the funds were borrowed through DWs. It is immediate to observe that the means of both net insider demand metrics, NID and ONID, are lower in quarters of DW borrowing.

Table 3 presents the matrix of Pearson and Spearman's rank correlations among the variables of interest. As expected, all measures of insider demand including PR are negatively correlated and CS and SEO are positively correlated with the proxies for DW borrowing.

5. RESULTS

5.1 Insider Trading and DW Borrowing

To test whether DW borrowing has any effect on net insiders' demand for their own equity (H1a), we start by applying fixed effect generalized least squares (GLS) estimation.[76] Table 4 delivers the output of such estimation where dependent variables are net insider demand (NID) and order based net insider demand (ONID) in Panels A and B respectively. We use book-to-market ratio, book leverage, market capitalization, return on assets and a per share dividend as control variables because they were found to be significant determinants of insider trading in prior studies. To avoid simultaneity, we use the first lag of all controls except a per share dividend in all specifications whenever controls are included. To preclude outliers from driving our results, we winsorize all continuous variables at 0.5%. Standard errors are heteroscedasticity robust and clustered by bank all throughout the estimations. Time

[76] The usage of the fixed effect model is largely motivated by presence of time-invariant characteristics of insiders shaping the scope and the scale of their trading patterns. Hillier et al (2015) emphasize the importance of the insiders' personal attributes in shaping the direction and volume of their trades. Other relevant papers stress on genetics (Barnea et al 2010, Cesarini et al 2010), gender (Bharath et al 2009, Gregory et al 2013), IQ (Grinblatt et al 2012), materialism (Davidson et al 2014) and masculinity (Jia et al 2014) as possible explanations for insider trading.

effects, e.g. quarter and year dummies, are included to eliminate the possible spurious impact stemming from the corresponding quarters and years. The intercept term is included into estimations but excluded from the table to save space.

Panel A of table 4 reveals that DW borrowing, independently of specification, has a strong negative effect on NID. Interestingly, DW produces the greater effect in absolute terms than NUM and 1_{DW} . This observation probably emphasizes that the extent of the banks' liquidity problem is a better determinant of the lower NID than the mere fact itself that the bank borrowed through DW. In other words, insiders are more reluctant to buy their own shares when the bank suffers a serious liquidity mismatch and so borrows a sufficiently large sum from the FED.

Panel B of table 4 repeats the procedure for order based net insider demand (ONID) as a dependent variable. As before, we observe a strong negative (positive) relationship between the measures of DW borrowing and net insiders' willingness to purchase (sell) stock.

One may spot that in both Panels A and B of table 4, specification (7) produces a curious result. Once we control for seasoned equity offering (SEO) and its interaction with DW, it is immediate to observe that the coefficient at the interaction is negative and significant. In other words, at quarters of DW borrowing, stock issuance activity is proportional to the insider initiated "equity runs", e.g. lower demand for equity.

Now we move on to decomposing the effect which DW borrowing has on net insider demand on the two effects, on buying and selling. Table 5 presents the results of testing H1b, which predicts that insiders are less (more) likely to buy (sell) in quarters of DW borrowing. Again, we control for lagged book-to-market ratio, book leverage, market capitalization, return on assets and contemporaneous per share dividend. All continuous variables are winsorized at 0.5%. Standard errors are heteroscedasticity robust and clustered by bank all throughout the estimations. Time effects are quarter and year dummies. The intercept term is included into estimations but excluded from the table to save space.

Panel A of table 5 shows the output of fixed effect GLS estimation of purchase ratio (PR) on different proxies of bank's illiquidity. One may see that in all specifications the effect of DW borrowing on insiders' willingness to purchase their own stock is strongly negative and mostly significant. Again, this result persists even after controlling for the change in a number of shares outstanding (CS) in specification (7).

Similarly, Panel B of table 5 presents the results of fixed effect GLS estimation of selling ratio (SR) on different proxies of DW borrowing. The coefficients have consistently positive signs but are statistically insignificant. This observation is consistent with many previous studies finding that insider sales contain no informational content (e.g. Jeng et al 2003). First, this can be explained by selling constraints (in particular, a short-swing profit rule[77] and a short selling ban imposed on insiders by Sections 16b and 16c of Securities Exchange Act of 1934 respectively), restrictions on equity conversion and put option exercises imposed by firms on its insiders. In other words, while insiders cannot be restricted in or penalized for passive behaviour (e.g. not buying stock), they can definitely be significantly constrained in active behaviour (e.g. selling stock).

Second, theoretical research points out that large sell orders may convey significant negative information to the market (Kyle 1985, Gloston and Milgrom 1985, etc.). Therefore the imprecision of the above coefficient can be explained by the insiders' attempt to hide conspicuously large sales by postponing or spreading them over time (Foster 2000). In short, by restraining from selling stock insiders do not disclose the liquidity issues of the bank for which performance they are personally responsible.

[77] According to this rule, any insider making profit from his trades is obliged to return the money gain back to its firm within a six month period.

5.2 Secondary Offering and DW borrowing

Table 6 presents the results of testing H2a, e.g. the change in a number of shares outstanding is more positive in quarters when banks borrow through DW. In picking controls, we follow Gropp and Heider (2010) and choose standard determinants of firms' capital structure which are found to be also highly relevant for financial firms. They are book-to-market ratio, market capitalization, return on assets and a per share dividend. We also add book leverage as a measure of banks' under/overcapitalization. To avoid simultaneity, we use the first lag of all controls except a per share dividend in all specifications whenever controls are included. All continuous variables are winsorized at 0.5%. Standard errors are heteroscedasticity robust and clustered by bank all throughout the estimations. Time effects are quarter and year dummies. The intercept term is included into estimations but excluded from the table to save space.

Panel A of table 6 uses DW as an explanatory variable standing for the extent of the bank's illiquidity. Regardless of the specification, it becomes clear that the amount of the funds borrowed through DW by the bank is strongly positively correlated with its stock issuance pursuit. While it is difficult to argue that it is DW borrowing itself which pushes banks to increase its share supply, the causality can be motivated if one thinks of DW borrowing as a proxy for a liquidity need.

Panel B of table 6 uses an indicator variable, 1_{DW}, and Panel C of table 6 uses the frequency of DW borrowing, NUM, as a proxy for banks' illiquidity. As seen, the coefficients at both proxies are still positive but are much smaller in absolute terms. This serves as the evidence that DW borrowing itself is positively related to oversupply of equity only when the substantial amount is borrowed, e.g. bank experiences severe liquidity problems. Otherwise, when small amount is borrowed, banks do not issue new equity (likewise, do not cut down repurchase programs) because they simply do not see a need to do so. This motivates us using DW as a chief metrics for DW borrowing in the next table.

In Table 7, we study explicitly how DW borrowing affects stock issuance and repurchase activity (H2b). Panel A of table 7 is identical to Panel A of table 6 which is done to ease visual comparison of coefficients. Panel B of table 7 uses SEO and Panel B of table 7 uses REP as a dependent variable, respectively. As before, we control for lagged book-to-market ratio, market capitalization, return on assets, book leverage and a current per share dividend. All continuous variables are winsorized at 0.5%. Standard errors are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. The intercept term is included into estimations but excluded from the table to save space.

Panel B of table 7 supports our prediction that stock issuance activity (SEO) is more intensive when DW borrowing is larger. In other words, negative liquidity mismatch forces banks to dilute ownership by issuing additional shares to obtain financing needed to meet maturing financial obligations. Furthermore, there is a negative correlation between lower net insider demand for equity and the total volume of secondary offering in quarters of DW borrowing. The interaction term is positive and highly significant in all specifications.

Similarly, Panel C of table 7 supports our prediction that the total number of shares bought back (REP) is decreasing with the amount of funds borrowed through DW. Additional support of our concept of insider initiated “equity runs” is provided by the interaction term. Once significant, it is positive meaning that in periods of DW borrowing the repurchasing activity is positively correlated with the insider demand for equity. The lower estimated precision of this coefficient can be explained by the lower frequency of net repurchases during DW quarters.

5.3 Equity Runs and Outsider Learning

The foremost impetus of the paper is to highlight a channel through which uninformed investors can learn from market signals communicating the banks' financial hardship. This channel is the publicly observable rise in the equity supply. This hypothesis is formulated by H3 and is explicitly tested in table 8. Panel A of table 8 shows the regression output of outsider trading, OT, on DW borrowing, and Panel B of table 8 shows the repeated estimation after controlling for stock issuance activity. As control variables, we use standard determinants of trading activity in market microstructure literature: previous quarter market capitalization, previous quarter closing price and a current per share dividend. All continuous variables are winsorized at 0.5%. Standard errors are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. The intercept term is included into estimations but excluded from the table to save space.

The sign and significance of coefficients at the interaction terms in both Panels A and B of table 8 confirm H3. We find the evidence that outsiders do accommodate "equity runs" in their trading behaviour, e.g. in quarters of DW borrowing both lower net insider demand and higher stock issuance activity are positively related to more intensive equity trading in the stock market.

We do not distinguish between outsider buying and selling habits, but under plausible assumption of investor rationality, the direction of outsider trades should coincide with that of insiders. As a matter of fact, this lower net demand from outsiders functions as the momentum for the "equity run" started by banks and their insiders. In other words, the marginal willingness of insiders to sell stock may give a substantial spur for outsiders to take up selling which would only lead to a larger "equity run".

One could notice that outsider turnover is strongly increasing in the amount of DW borrowing, even after controlling for the possible explanations of this outcome (net insider demand and secondary offering). This result unveils the possibility of existence of other informative ways through which the uninformed investors could impute about the banks' state of distress. One of the possible explanations goes as follows. In a fed fund market, banks with an excess surplus of reserves tend to become net lenders to banks with an excess liquidity deficiency. Haltom (2011) writes: "Banks have existing legal agreements in place, and simply call each other up when they want to trade funds. That's why it wouldn't be difficult for other financial institutions to identify discount window borrowing… If an institution suddenly disappears from the fed funds market, other banks might assume… that they went to the FED." Unrelated to the discussed "equity runs", we leave the validity of this and possibly other channels as a subject of further research.

6. CONCLUSION

In this paper, we have confirmed the supposition that DW borrowing, despite its confidentiality, might be incorporated into stock market trading by uninformed market participants. We draw the channel through which the knowledge about the illiquidity of bank assets is transmitted to the general market through the increased circulation of the "unwanted stock". This is evident in the insiders' lower demand for their own bank's equity and their bank's urgent need for financing. The lower demand is seen in the insiders' unwillingness to buy their own stock at the times of DW borrowing (as confirmed by net insider demand, net order based demand and purchase ratio). The need for financing is manifested in the additional supply of equity (i.e. higher seasoned equity offering and lower repurchasing). We label the observed phenomenon with the term "equity run" and find some evidence that the uninformed traders do react to it by rebalancing their portfolios.

Our study opens a spacious room for further research. First, the results of the paper indicate that the underlined learning channel (equity run) is not the only way to infer about the bank's DW borrowing. Identifying other mediums of information leakages might be valuable for policy makers, uninformed traders and bank depositors. Moreover, DW borrowing presents an excellent set up to study how insiders' personal attributes affect their trading patterns in presence of a liquidity risk.

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Table 1. Summary Statistics (by transaction)

Panel A: DW lending

Variable	Obs.	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
loan amount ($000s)	552	11,198.35	52,068.47	1	1,017,018	14.01665	253.896
loan amount to capitalization	552	0.03138	0.116659	1.21E-08	1.490453	8.459347	91.51751
maturity (days)	552	1.181488	0.599775	1	4	3.190666	11.90683
num. of transactions (per bank)	155	3.721854	6.228064	1	56	5.653796	41.99875

Panel B: insider trading

Variable	Obs.	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
transacting volume	17,909	8,599.547	69,005.82	1	4,844,560	36.52211	1,945.87
- selling	7,005	8,703.205	77,130.42	1	4,844,560	43.24904	2,423.409
- buying	10,904	8,532.965	63,242.72	1	3,283,100	27.5314	1,086.386
transacting price	17,909	79.60962	5,532.793	0.13	1028	11.41032	158.6338
- selling	7,005	37.45959	100.787	0.13	1000	11.17811	162.0155
- buying	10,904	106.6854	7,090.076	0.13	1028	11.6818	159.3102
share ownership (after trade)	17,909	173,230.2	1,305,563	0	54,800,000	25.85379	835.6817
- selling	7,005	131,183.9	473,224.3	0	13,100,000	9.753848	148.3471
- buying	10,904	200,241.8	1,629,074	1	54,800,000	21.65857	564.1198
num. of trades (per bank)	155	148.0083	187.6982	9	1,332	3.465959	18.14096
- selling	155	57.8843	127.9886	0	1,108	5.999261	44.86259
- buying	155	90.12397	115.8196	0	858	3.535388	19.85025

The table presents summary statistics of DW lending and insider trades transaction-wise. Panel A presents summary statistics of all primary credit borrowings undertaken by large US listed banks over the period from Q3 2010 to Q4 2012. Panel B presents the summary statistics of all insider transactions by these large US listed banks (DW borrowers) over the period from Q3 2010 to Q4 2014. All continuous variables are winsorized at 0.05%.

Table 2. Summary Statistics (quarterly)

Panel A: full sample

Variable	Obs.	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
NID	1,550	0.0515392	0.4025904	-0.781535	4.874483	9.382085	106.1772
ONID	1,550	0.200446	0.588149	-1	1	-0.18	2.441927
PR	1,550	0.383562	0.429818	0	1	0.469704	1.456275
SR	1,550	0.2200602	0.3462535	0	1	1.26045	3.033194
NUM	1,550	0.376928	0.997368	0	12	6.325848	56.08182
DW	1,550	0.011512	0.0982	0	2.35436	14.68572	277.4535
CS	1,550	0.0091544	0.1414112	-1.378525	0.8472822	-3.355679	62.81578
SEO	1,550	0.0179231	0.0879116	0	0.8472822	7.441565	63.29637
REP	1,550	0.0095747	0.1008457	0	1.378525	13.00273	173.2798
OT	1,550	0.2386594	0.2661344	0.0002419	2.700798	2.280163	11.41237
BM	1,550	1.302584	1.03404	0.2959584	16.54362	6.474258	72.48485
Price	1,550	17.17984	18.66502	0.28	200.58	4.898998	39.13219
Size ($000s)	1,550	5,420,956	1.53e+07	3,111.897	1.06e+08	3.614645	15.89586
Dividend	1,550	0.0936657	0.1410411	0	1.38	2.866629	15.72299
Leverage	1,550	0.8931906	0.0336727	0.7001681	0.9907648	-1.081497	6.366896
ROA	1,550	.0009292	.0046309	-0.0677048	0.0334273	-5.324355	56.81487

Panel B: only bank-quarters of DW borrowing

Variable	Obs.	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
NID	395	0.0102185	0.1440862	-0.781535	1.563582	4.006058	46.76572
ONID	395	0.172048	0.596485	-1	1	-0.183976	2.438574
PR	395	0.3715	0.417701	0	1	0.5180036	1.555599
SR	395	0.2538164	0.3609269	0	1	1.042276	2.51417
NUM	395	1.422785	1.506664	1	12	4.568679	24.9573
DW	395	0.043456	0.187287	0	2.35436	7.496453	74.15523
CS	395	0.0151154	0.1158584	-1.378525	0.8472822	-1.698951	77.60705
SEO	395	0.0188153	0.0853711	0	0.8472822	7.042143	59.20293
REP	395	0.0049628	0.0695771	0	1.378525	19.55631	386.4884
OT	395	0.2475308	0.2839913	0.0002419	2.700798	2.779198	17.53853
B-to-M	395	1.2741	1.101512	0.397766	14.77464	7.173797	75.85927
Price	395	16.69138	17.09746	0.28	187.22	5.223624	46.12213
Size ($000s)	395	5,301,355	1.61E+07	8225.28	8.65E+07	3.569624	14.61322
Dividend	395	0.099607	0.160345	0	1.38	3.592659	22.74452
Leverage	395	0.894724	0.033255	0.712549	0.990765	-0.828146	5.503867
ROA	395	.0013442	.0042932	-0.0272833	0.0334273	-0.530838	26.2722

The table presents summary statistics of variables constructed quarterly. B-to-M is a quarterly ratio of book equity to its market value as of the last trading day of the quarter. Price is a closing price on the last trading day of the quarter. Size is quarterly market capitalization constructed as a product of closing quarterly price and total shares outstanding on the last trading day of the quarter. Dividend is a total quarterly per share dividend. Leverage is a quarterly ratio of total liabilities to total assets. ROA stands for return on assets defined as a quarterly ratio of net income to total assets. For other variables see the text for their definitions.

Table 3. Correlation Matrix

	NID	ONID	PR	SR	DW	NUM	1_{DW}	CS	SEO	REP	OT
NID	1	0.7872	0.6881	-0.4284	-0.0457	-0.0624	-0.0592	0.0727	0.054	-0.0893	-0.0333
ONID	0.2312	1	0.7944	-0.457	-0.0278	-0.0378	-0.0378	-0.0233	-0.0478	-0.0637	0.0317
PR	0.2615	0.8055	1	-0.0196	-0.0097	-0.0177	-0.0182	0.0289	0.0166	-0.0672	0.1283
SR	-0.1795	-0.6056	-0.2364	1	0.0552	0.0645	0.0595	0.0514	0.0806	0.0353	0.118
DW	-0.0176	-0.0064	-0.0286	0.0023	1	0.9768	0.9755	0.0237	0.0227	-0.0154	0.0139
NUM	-0.057	-0.0287	-0.029	0.1092	0.4559	1	0.995	0.022	0.0223	-0.0107	0.0054
1_{DW}	-0.0704	-0.0378	-0.0314	0.0683	0.2002	0.6303	1	0.0192	0.0195	-0.0091	0.0029
CS	0.2518	0.0371	0.0101	-0.0308	0.0954	0.0259	0.0119	1	0.979	-0.7106	-0.0121
SEO	0.329	0.0403	0.0193	-0.0617	0.1191	0.0254	0.0097	0.7638	1	-0.5811	0.0197
REP	-0.0067	-0.0104	0.0068	-0.0242	-0.009	-0.0105	-0.0071	-0.6588	-0.0176	1	0.0787
OT	-0.0135	0.0424	0.1021	0.0599	0.1591	0.0529	0.0113	0.0472	0.131	0.0796	1

Pearson's correlations appear below the diagonal and Spearman's rank correlations appear above the diagonal.

Table 4. Insider Demand for Equity and Discount Window Lending (H1a)

Panel A: net insider demand (NID) is a dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DW_q	-0.2207***	-	-0.1914***	-	-	-0.2142***	-0.1567**
	(0.0866)	-	(0.0648)	-	-	(0.0865)	(0.0633)
DW_{q-1}	-	-0.2197**	-0.1885**	-	-	-	-
	-	(0.1133)	(0.0918)	-	-	-	-
NUM_q	-	-	-	-0.0122*	-	-	-
	-	-	-	(0.0065)	-	-	-
1_{DW}	-	-	-	-	-0.035**	-	-
	-	-	-	-	(0.0158)	-	-
CS_q	-	-	-	-	-	-	0.7633**
	-	-	-	-	-	-	(0.3623)
$DW_q * CS_q$	-	-	-	-	-	-	-0.7972***
	-	-	-	-	-	-	(0.2624)
Controls	No	No	No	No	No	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,550	1,395	1,395	1,550	1,550	1,550	1,550
R2	0.2605	0.2322	0.2328	0.2591	0.2597	0.2607	0.3111

Panel B: order based net insider demand (ONID) is a dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DW_q	-0.2566***	-	-0.2447***	-	-	-0.3082***	-0.2235**
	(0.0943)	-	(0.0954)	-	-	(0.1113)	(0.0972)
DW_{q-1}	-	-0.1182	-0.0784	-	-	-	-
	-	(0.1271)	(0.1007)	-	-	-	-
NUM_q	-	-	-	-0.0512**	-	-	-
	-	-	-	(0.0226)	-	-	-
1_{DW}	-	-	-	-	-0.0585*	-	-
	-	-	-	-	(0.0323)	-	-
CS_q	-	-	-	-	-	-	0.1311
	-	-	-	-	-	-	(0.1495)
$DW_q * CS_q$	-	-	-	-	-	-	-0.4274**
	-	-	-	-	-	-	(0.1651)
Controls	No	No	No	No	No	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,550	1,395	1,395	1,550	1,550	1,550	1,550
R2	0.4132	0.4233	0.4241	0.4162	0.4133	0.4188	0.4203

The table reports results of fixed effect GLS estimation of quarterly insider demand for equity on DW borrowing. Net insider demand (NID) and order based insider demand (ONID) are used as dependent variables in panels A and B, respectively. Controls used are lagged B-to-M, leverage, size, ROA and current quarter per share dividend. B-to-M, leverage and size are logged. Standard errors used are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. All continuous data are winsorized at 0.5%. Constant is included into regressions but excluded from the table in sake of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Table 5. Direction of Insiders' Trade and Discount Window Lending (H1b)

Panel A: purchasing ratio (PR) is a dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DW_q	-0.2471***	-	-0.2217***	-	-	-0.2695***	-0.2173***
	(0.0745)	-	(0.0677)	-	-	(0.0958)	(0.0746)
DW_{q-1}	-	-0.2012***	-0.1651***	-	-	-	-
	-	(0.0758)	(0.0638)	-	-	-	-
NUM_q	-	-	-	-0.0231**	-	-	-
	-	-	-	(0.0107)	-	-	-
1_{DW}	-	-	-	-	-0.015	-	-
	-	-	-	-	(0.0215)	-	-
CS_q	-	-	-	-	-	-	0.0819
	-	-	-	-	-	-	(0.121)
$DW_q * CS_q$	-	-	-	-	-	-	-0.4088***
	-	-	-	-	-	-	(0.1275)
Controls	No	No	No	No	No	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,550	1,395	1,395	1,550	1,550	1,550	1,550
R2	0.5146	0.5271	0.5281	0.5139	0.5124	0.5192	0.52

Panel B: selling ratio (SR) is a dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DW_q	0.0112	-	0.0085	-	-	0.02072	0.026
	(0.067)	-	(0.0962)	-	-	(0.0703)	(0.0864)
DW_{q-1}	-	0.0117	0.0138	-	-	-	-
	-	(0.0463)	(0.091)	-	-	-	-
NUM_q	-	-	-	0.0295***	-	-	-
	-	-	-	(0.01)	-	-	-
1_{DW}	-	-	-	-	0.0403**	-	-
	-	-	-	-	(0.0199)	-	-
CS_q	-	-	-	-	-	-	-0.0111
	-	-	-	-	-	-	(0.0425)
$DW_q * CS_q$	-	-	-	-	-	-	-0.1042
	-	-	-	-	-	-	(0.2018)
Controls	No	No	No	No	No	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,550	1,395	1,395	1,550	1,550	1,550	1,550
R2	0.4461	0.4575	0.4575	0.4503	0.4480	0.4505	0.4582

The table reports results of fixed effect GLS estimation of direction of insiders' trade on DW borrowing. Purchasing ratio (PR) and selling ratio (SR) are used as dependent variables in panels A and B, respectively. Controls used are lagged B-to-M, leverage, size, ROA and current quarter per share dividend. B-to-M, leverage and size are logged. Standard errors used are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. All continuous data are winsorized at 0.5%. Constant is included into regressions but excluded from the table in sake of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Table 6. Change in a Number of Shares Outstanding (CS) and Discount Window Lending (H2a)

Panel A: loan amount to capitalization (DW_q) is a proxy for DW borrowing

	-	NID	PR	ONID	-	NID	PR	ONID
DW_q	0.1017***	0.1186**	0.1367***	0.12***	0.1222**	0.1398**	0.1582***	0.141***
	(0.032)	(0.0515)	(0.0297)	(0.0354)	(0.057)	(0.0653)	(0.0457)	(0.0505)
Demand	-	0.0794***	0.0107	0.0079	-	0.0819***	0.0104	0.0084
	-	(0.022)	(0.0155)	(0.009)	-	(0.0214)	(0.0127)	(0.008)
DW_q*Demand	-	-0.1329***	-0.205***	-0.136***	-	-0.1062**	-0.2091**	-0.139**
	-	(0.0546)	(0.0624)	(0.0397)	-	(0.051)	(0.0931)	(0.0606)
Controls	no	no	no	no	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.08	0.1381	0.0835	0.0825	0.1101	0.1720	0.1137	0.1127

Panel B: indicator variable (1_q) is a proxy for DW borrowing

	-	NID	PR	ONID	-	NID	PR	ONID
1_q	0.0057	0.0101	0.0186*	0.0069	0.0042	0.0089	0.0201*	0.0053
	(0.0072)	(0.0076)	(0.0101)	(0.0077)	(0.0071)	(0.0079)	(0.011)	(0.008)
Demand	-	0.0809***	0.0143	0.007	-	0.0833***	0.0149	0.0069
	-	(0.0213)	(0.0167)	(0.008)	-	(0.0207)	(0.0136)	(0.0071)
1_q* Demand	-	-0.0924***	-0.035**	-0.004	-	-0.099***	-0.0409***	-0.0034
	-	(0.024)	(0.017)	(0.0129)	-	(0.0249)	(0.0156)	(0.0128)
Controls	no	no	no	no	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.0747	0.1339	0.0775	0.0753	0.1022	0.1651	0.1057	0.1028

Panel C: frequency (NUM_q) is a proxy for DW borrowing

	-	NID	PR	ONID	-	NID	PR	ONID
NUM_q	0.0026	0.0035	0.0076**	0.003	0.0018	0.0024	0.0081**	0.0022
	(0.0023)	(0.0028)	(0.0032)	(0.0021)	(0.0027)	(0.0032)	(0.0035)	(0.0025)
Demand	-	0.0786***	0.0118	0.007	-	0.081***	0.0122	0.0076
	-	(0.021)	(0.0153)	(0.0086)	-	(0.0203)	(0.0118)	(0.0074)
NUM_q* Demand	-	-0.0157	-0.0159**	-0.0022	-	-0.0211	-0.0203***	-0.0039
	-	(0.0214)	(0.0073)	(0.0028)	-	(0.0226)	(0.0064)	(0.0031)
Controls	no	no	no	no	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.0746	0.1312	0.0768	0.0753	0.1021	0.1622	0.1054	0.1030

The table reports results of fixed effect GLS estimation of changes in the quarterly amount of shares outstanding (CS) on insider demand (NID, PR or ONID), DW borrowing and their interaction term. Controls used are lagged B-to-M, leverage, size, ROA and current quarter per share dividend. B-to-M, leverage and size are logged. Standard errors used are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. All continuous data are winsorized at 0.5%. Constant is included into regressions but excluded from the table in sake of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Table 7. Alternative Measures of Issuance/Repurchase Activity and Discount Window Lending (H2b)

Panel A: net change in a number of shares outstanding (CS_q) is a dependent variable

	-	NID	PR	ONID	-	NID	PR	ONID
DW_q	0.1017***	0.1186**	0.1367***	0.12***	0.1222**	0.1398**	0.1582***	0.141***
	(0.032)	(0.0515)	(0.0297)	(0.0354)	(0.057)	(0.0653)	(0.0457)	(0.0505)
Demand	-	0.0794***	0.0107	0.0079	-	0.0819***	0.0104	0.0084
	-	(0.022)	(0.0155)	(0.009)	-	(0.0214)	(0.0127)	(0.008)
DW_q*Demand	-	-0.1329***	-0.2047***	-0.136***	-	-0.1062**	-0.2091**	-0.1385**
	-	(0.0546)	(0.0624)	(0.0397)	-	(0.051)	(0.0931)	(0.0606)
Controls	no	no	no	no	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.08	0.1381	0.0835	0.0825	0.1101	0.1720	0.1137	0.1127

Panel B: seasoned equity offering (SEO_q) is a dependent variable

	-	NID	PR	ONID	-	NID	PR	ONID
DW_q	0.0511***	0.066***	0.0773***	0.0631***	0.0579***	0.0734***	0.0839***	0.0698***
	(0.018)	(0.0245)	(0.0131)	(0.016)	(0.022)	(0.0281)	(0.0139)	(0.017)
Demand	-	0.0746***	0.0121	0.004	-	0.0751	0.0108	0.0034
	-	(0.0186)	(0.0078)	(0.004)	-	(0.0186)	(0.0077)	(0.0041)
DW_q*Demand	-	-0.0226***	-0.1467***	-0.093***	-	-0.017***	-0.146***	-0.093***
	-	(0.0086)	(0.0564)	(0.0311)	-	(0.0057)	(0.0549)	(0.031)
Controls	no	no	no	no	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.1276	0.2187	0.1318	0.1295	0.1348	0.2273	0.1385	0.1365

Panel C: repurchase (REP_q) is a dependent variable

	-	NID	PR	ONID	-	NID	PR	ONID
DW_q	-0.0507**	-0.052**	-0.0593***	-0.056***	-0.0644**	-0.0664**	-0.0743**	-0.0712**
	(0.0225)	(0.0237)	(0.0224)	(0.021)	(0.0326)	(0.0344)	(0.0359)	(0.035)
Demand	-	-0.0039	0.0015	-0.0034	-	-0.0067	0.0003	-0.0049
	-	(0.0052)	(0.001)	(0.0071)	-	(0.005)	(0.0087)	(0.0068)
DW_q*Demand	-	-0.0073	0.0574**	0.0385*	-	-0.007	0.0632	0.0455
	-	(0.0063)	(0.0268)	(0.0218)	-	(0.0114)	(0.0678)	(0.0475)
Controls	no	no	no	no	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.1021	0.1025	0.1027	0.1028	0.1585	0.1595	0.1592	0.1597

The table presents the robustness of results presented in the table 6 using alternative measures of stock issuance activity (CS, SEO and REP). Fixed effect GLS estimation is used. Controls used are lagged B-to-M, leverage, size, ROA and current quarter per share dividend. B-to-M, leverage and size are logged. Standard errors used are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. All continuous data are winsorized at 0.5%. Constant is included into regressions but excluded from the table in sake of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Table 8. Outsider Learning and Insider Demand for Equity at Times of Discount Window Lending (H3)

Panel A: w/o controlling for stock issuance/repurchase

	NID	PR	ONID	NID	PR	ONID
DW_q	0.4331***	0.5124***	0.4768***	0.403***	0.4758***	0.4441***
	(0.1634)	(0.1503)	(0.1533)	(0.1501)	(0.1325)	(0.1328)
Insider Demand	0.0132	0.0207	0.006	0.0103	0.0195	0.0059
	(0.0335)	(0.0157)	(0.008)	(0.0333)	(0.0162)	(0.0085)
DW_q*Insider Demand	-0.5054***	-0.4936***	-0.3892***	-0.5255***	-0.4496***	-0.3683***
	(0.1162)	(0.1564)	(0.114)	(0.1993)	(0.1356)	(0.1014)
Controls	no	no	no	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.8163	0.8195	0.8188	0.8176	0.8211	0.8207

Panel B: w/ controlling for stock issuance/repurchase

	NID	PR	ONID	NID	PR	ONID
DW_q	0.2206**	0.2683***	0.2568***	0.2251**	0.2779***	0.2691***
	(0.1075)	(0.105)	(0.0967)	(0.1044)	(0.0982)	(0.0884)
Insider Demand	0.0177	0.0278*	0.0123	0.0183	0.0261*	0.0115
	(0.0291)	(0.0145)	(0.0075)	(0.0292)	(0.0152)	(0.0078)
DW_q*Insider Demand	-0.0154	-0.2293**	-0.2428**	-0.0377	-0.2451**	-0.272**
	(0.0585)	(0.1086)	(0.1176)	(0.0671)	(0.1187)	(0.1131)
CS_q	0.0405	0.052	0.0527	0.0309	0.0442	0.0436
	(0.1042)	(0.1138)	(0.1135)	(0.105)	(0.115)	(0.1146)
DW_q*CS_q	1.4414***	1.3831***	1.3852***	1.4325***	1.3665***	1.3649***
	(0.2396)	(0.248)	(0.2587)	(0.2486)	(0.2626)	(0.2764)
Controls	no	no	no	yes	yes	yes
Time effects	yes	yes	yes	yes	yes	yes
Fixed effects	yes	yes	yes	yes	yes	yes
N	1,550	1,550	1,550	1,550	1,550	1,550
R2	0.8371	0.8379	0.8380	0.8376	0.8383	0.8384

Panel A presents the output of fixed effects GLS estimation of outsider turnover (OT) on insider demand (NID, PR or ONID), DW borrowing and their interaction term. Panel B presents similar results after controlling for change in shares outstanding (CS) and its interaction term with DW borrowing. Controls used are lagged price, size and current quarter per share dividend. Price and size are logged. Standard errors used are heteroscedasticity robust and clustered by bank. Time effects are quarter and year dummies. All continuous data are winsorized at 0.5%. Constant is included into regressions but excluded from the table in sake of space. Stars denote significance: *** <0.01 **<0.05 *<0.1

Appendix A. Difference between Primary and Secondary Credit

Feature	Primary Credit	Secondary Credit
Rate	Above the FOMC's target for the federal funds rate (except during a financial emergency, when the primary credit rate may be lowered to the FOMC's target for the federal funds rate).	Primary credit rate plus 50 basis points.
Term	Overnight	Short-term, usually overnight. Can be extended for a longer term if such credit would facilitate a timely return to reliance on market funding or an orderly resolution of a failing institution, subject to statutory requirements (FDICIA restrictions).
Eligibility	Depository institutions in generally sound financial condition; essentially the same as eligibility for daylight credit.	Depository institutions that do not qualify for primary credit.
Use	No restrictions. May be used to fund sales of federal funds.	As a backup source of funding on a very short-term basis, or to facilitate an orderly resolution of serious financial difficulties.
Administration	Ordinarily no questions asked.	Reserve Banks will collect information necessary to confirm that borrowing is consistent with the objectives of the program.

Source: https://www.frbdiscountwindow.org/Frequently_Asked_Questions.aspx

Appendix B. Insider Trades by the Insider Position Occupied

Insider Position	Freq.	Percent	Cum.
10% owner	224	1.25	1.25
director	7,334	40.95	42.2
director + 10% owner	91	0.51	42.71
director + 10% owner + other	1	0.01	42.72
director + officer	2,131	11.9	54.61
director + officer + 10% owner	299	1.67	56.28
director + other	116	0.65	56.93
officer	7,534	42.07	99
officer + other	56	0.31	99.31
other	123	0.69	100
Total	17,909	100	