Are risky banks rationed by corporate depositors?

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Abstract

We analyze auctions of unsecured money market deposits of firms to banks via a FinTech intermediary. In each auction, only the firm observes the banks and their interest rate bids and decides where to deposit its funds. We observe that deposit interest rate bids increase monotonically with banks' risk and that firms in general prefer higher deposit interest rates. However, our results show that firms' selection of banks in which to deposit is concave in the bid interest rate in line with the general notion of credit rationing as modeled in Stiglitz and Weiss (1981). We find this confirmed on the intensive as well as on the extensive margin. Risky banks eventually exit the market, and re-enter when their risk decreases again in the long term. Relatedly, we observe that risky banks exit when the interest rate they have to offer increases above the interest rate charged by the central bank. This has important implications for banks' access to unsecured corporate funding, central bank liquidity provision and the understanding of deposit markets as well as FinTech in general.

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1. Introduction

Stiglitz and Weiss (1981) suggests that lenders might ration borrowers and that rationing can occur in equilibrium even though borrowers offer to pay a higher interest rate. Interest rates serve as a screening device for lenders and a borrower who is willing to accept a higher rate signals potentially higher risk. If information is imperfect and costly, an optimal interest rate exists that maximizes a lender's expected return, and offers beyond this rate are rejected even though there is a higher demand for loans. Interestingly, despite the large and still growing theoretical literature on credit rationing, little empirical evidence exists linking a borrower's interest rate offers to a lender's decisions. An important reason might be data availability. Even if information on loan applications and rejections is available, residual imperfect information remains. Ideally, we would like to investigate loan applications where borrowers signal their risk via the interest rate they are willing to pay (conditional on their observable characteristics). In a competitive market, this interest rate might then allow lenders to screen borrowers, which in turn would allow researchers to test hypotheses related to credit rationing.

In this paper, we empirically investigate credit rationing as broadly modeled in Stiglitz and Weiss (1981) using unique data of a FinTech intermediary. However, and in contrast to their perspective that banks lend to firms, we investigate firms that are lending to banks in the corporate deposit market and examine whether risky banks are rationed by depositing firms. Specifically, we use data on auctions of deposits from a multi-dealer trading platform over the 2005 to 2015 period. On this platform, firms are able to offer funds at a maturity of their choice.[1] The usual offer period is 2 minutes for an overnight deposit. Firms' selection of banks follows a two-step process. In a first step, firms decide which banks to invite to an auction. These banks are then able to bid for the offered deposit amount during the offer period of usually 2 minutes

[1] We provide a detailed explanation of the auction format on the platform in the next section.

and, in a second step, the firm has the choice to select a bank bid or to select no bid at all. It might also select several banks and divide the offered amount according to its preferences. In all auctions, only the firm observes the bidding information during the auction, i.e. banks do not observe the other banks' bids. We observe all offers and the corresponding bids together with the outcome. We know the identities of banks and observe the timestamp and information of each of their bids. We also have a numerical identifier for each of the firms available and are thereby able to track these and their matching with banks over time.[2]

This market is important for both firms and banks. Recent research on liquidity management suggests that many firms invest their short-term funds to earn higher returns (Duchin et al., 2017). The average notional amount on the deposit auction platform we analyze is large, €81.4 million per deposit. Thus, difficulties in accessing this liquidity for just a few days due to financial difficulties of a bank could cause substantial liquidity problems for some firms. Indeed, the daily unsecured funds from firms' liquidity management are important for banks because these are often cheaper than funds obtained in the interbank market.[3] The average total deposited amount in a quarter via the platform at issue in this paper is very large, €181 billion. For example, these funds might especially be useful in times when the interbank or secured (repo) funding markets are stressed (e.g.; Afonso et al., 2011; Ashcraft et al. 2011; Gorton and Metrick, 2012; Krishnamurthy et al., 2014; Heider et al., 2015).

Central to our analysis are tests as to whether the probability that the deposit interest rate

[2] Note that the setup of a multi-dealer trading platform implies high transparency and allows us to investigate the selection of banks by firms with sufficient statistical power. Furthermore, it ensures that quotes are competitive irrespective of client sophistication (Hau et al., 2017).

[3] In Section 3 of the paper, we provide more institutional details, which show that in case of bank default the (uninsured) deposits in our study are treated equally to claims of bondholders, while they have the same seniority as long-term but lower seniority than short-term unsecured interbank transactions. Note that this is in contrast to the US, where uninsured depositors have first claim over other non-deposit claim holders in the event of bank failure, as regulated in the 1993 National Depositor Preference Law.

bid selected by a firm is concave in the interest rate offered by the bank.[4] While a higher interest rate bid by a bank implies a higher probability of being selected, the increase in probability that the bid is actually successful (i.e. is the winning bid) could be decreasing in the size of the interest rate bid. It is important to keep in mind that Stiglitz and Weiss (1981) determine an *equilibrium* optimal interest rate, which suggests a discrete interest rate threshold of borrower rationing. By contrast, given the empirical nature of our study, we investigate if the probability of a bank being selected as the bid winner in the auction increases at a decreasing rate the higher the bid. We hypothesize that rationing should particularly be observable for interest rate bids of riskier banks, that is, the functional form between bid selection probability and bid interest rate should reflect a stronger concavity for these more risky banks.

Hau et al. (2017) show for foreign exchange (FX) markets on multi-dealer request-for-quote (RFQ) platforms, dealers price competitively.[5] Initially, we perform several tests regarding the competitiveness of deposit bids in our deposit auction environment. In our main tests, we use a bank's interest rate bid as a measure of its risk. We thus first investigate if bank characteristics are monotonically related to bank deposit interest rate bids. Using CDS spreads as a market measure of bank risk we find that banks with higher CDS spreads monotonically bid higher interest rates on the platform. This applies on a given day as well as within an individual auction. It suggests that potential nonlinearities between interest rate bids and banks' selection probability, which we investigate later, do not derive from nonlinearities of the relation between banks' risk and deposit interest rate bids. On average, a one percent higher CDS spread implies a 2.8 basis points (bps) higher deposit interest rate bid within an auction. We also find that smaller

[4] We explain the theoretical framework and its empirical implications in more detail in the following section.

[5] We also use data from a multi-dealer RFQ platform which follows the same setup for deposits as described in Hau et al. (2017) for FX. Interestingly, the authors also show that dealers do not price discriminate even when a client always requests quotes only from the same dealer. The reason is that dealers do not know how many other dealers, if any, are also asked to bid.

banks, banks with higher leverage, and banks with a lower return on equity bid higher interest rates.

We then examine the competitiveness of the deposit auction market more broadly. As to be expected, we observe that firms in general prefer higher to lower interest rates. On average, a 1bp higher interest rate bid in an auction increases the likelihood that a bid is selected by 0.6% and submitting the highest bid in an auction implies a 55% probability of winning the auction. However, we also find that firms do not just select the highest deposit bid. Conditional on bidding the same interest rate, firms select less risky banks. This is confirmed when conditioning on the same interest rate as well as on the same firm-bank relationship. Firms also diversify more when aggregate bank risk increases.

We next test whether a bank's likelihood of being selected is concave in its deposit interest rate bids. Our results show that risky banks are indeed rationed by depositing firms. We observe that the probability of being selected is increasing in the deposit interest rate bid but at a decreasing rate. This is also confirmed when scaling interest rate bids by a bank's risk, comparable to a piecewise linear estimation. Consistent with a rationing effect, credit rationing is more pronounced when bank risk is higher. These results are confirmed (i) in both non-crisis as well as crisis periods, (ii) splitting deposits into amounts above and below €100 million per auction, (iii) including only overnight deposits, and (iv) for deposit interest rates when these are the highest bid in an auction. We also observe that our results on rationing continue to hold when we account for diversification of deposits by firms.

We also investigate rationing using data aggregated at the bank-month level. As a result, we can then examine the percent of auctions in which a bank is not selected in a given month (which we call "failure rate"). If firms ration banks, the relationship between a bank's deposit interest rate bid and this "failure rate" should be decreasing and convex. Our results support this contention. We observe the same pattern when we replace the deposit interest rate bid with the fraction of auctions in which a bank has the highest bid within a month. In further tests, we condition on a bank's auction success probability and investigate the monthly failure rate of banks in auctions of banks that are selected by at least some of the firms and those, which are not selected by any firm, despite bidding for their deposits. In both cases, we again find a decreasing and convex relationship between bid deposit interest rates and auction failure rates. These results provide further empirical evidence that risky banks are rationed by depositing firms.

Our results provide strong support for firms' rationing their deposits to risky banks given the two-step selection process described above. In the first step of firms' selection of banks, firms might not even invite risky banks to bid for their deposits. Thus, we also investigate the extensive margin and examine whether banks exit the market when they become too risky, similar to funding dry-ups as in, for example, Perignon et al. (2018). Our analyses show that banks are indeed more likely to exit the market when their risk is higher. Additionally, we observe that high bank risk is a predictor of bank exit as well as that it remains elevated for several months after the exit. The opposite applies to bank reentry. When bank risk decreases again, banks are more likely to return to the trading platform.[6] Moreover, lower bank risk is also a predictor of bank reentry.

Finally, we investigate the mechanism of a bank's exit from the corporate deposit market in more detail. We examine if banks are more likely to exit unsecured corporate deposit markets when they (have to) bid more often above the interest rate required to obtain funding in

[6] Perignon et al. (2018) observe that banks almost never re-enter the market and conclude that these are no longer perceived as being safe. While this is true for stressed banks which eventually have to restructure or even default, some might only be having difficulties in the short-term. We observe in our data that some are able to re-gain confidence from investors over time and continue regular business again despite the difficulties in the past. However, given the confidentiality of our data we are not able to list these as in Perignon et al.

alternative markets. To examine the latter, we use the interbank market and funding via the central bank. Importantly, the EONIA rate in the interbank market is sensitive to banks' risk while the European Central Bank (ECB) has been following a fixed interest rate regime since October 2008. In other words, the main refinancing operations rate of the ECB has been largely risk-insensitive since then.[7] Our results show that banks are more likely to exit the unsecured corporate deposit market after a period in which they had to bid more often above the interest rate charged by the ECB for short term funding. We do not observe this pattern for the percentage of bids above the interbank market interest rate. This suggests that a largely risk-insensitive refinancing rate, as has been the case for the ECB since 2008, constitutes a ceiling for short-term bank funding. In sum, risky banks exit the corporate deposit market due to rationing as well as a more favorable risk-insensitive central bank refinancing rate.

The paper is structured as follows. Section 2 explains the theoretical framework and its empirical implications as well as the related literature. In section 3, we describe the trading platform and the deposit auction format in more detail and provide institutional details on claim priority. In section 4, we describe the data and provide descriptive statistics. In section 5, we examine the competitive structure of the deposit auction market among banks. Section 6 presents the findings on rationing of banks. Section 7 concludes.

2. Credit Rationing - Theory, Empirical Implications, and Related Literature

2.1. THEORETICAL FRAMEWORK

In Stiglitz and Weiss (1981), a lender selects loan terms such that expected returns are

[7] The full allotment procedure at a fixed interest rate by the ECB implies that in general each bank obtains funds from the ECB at the same interest rate irrespective of its risk. However, the ECB states in its guidelines that "the Eurosystem may also suspend, limit or exclude counterparties' access to open market operations .. on the grounds of prudence" (guideline (EU) 2015/510 of the ECB of 19 December 2014). The same applies to posted collateral.

maximized. Expected returns increase less rapidly than the interest rate charged for the loan due to default risk, implying that expected returns are concave in the interest rate charged for loans. The lender evaluates borrowers' loan applications, however residual imperfect information results in either adverse selection or risk shifting of borrowers. In their model, the interest rate charged for the loan serves two roles. It might be used as a screening device for the lender as borrowers, who are willing to accept a higher rate, indicate that they perceive their probability of repayment to be low (adverse selection). Alternatively, a higher rate might change borrowers' behavior such that they undertake riskier projects (risk shifting). Accordingly, an equilibrium interest rate exists that maximizes a lender's expected return and offers beyond this rate are rejected even though there is a higher demand for loans. Stiglitz and Weiss (1981) additionally show that borrowers' behavior and their distribution might also change depending on the amount of collateral demanded by the lender.

2.2. EMPIRICAL IMPLICATIONS

Stiglitz and Weiss (1981) illustrate that the expected return to the lender is concave in the interest rate charged for the loan. However, lenders' expected returns are not observable. The probability of selecting a borrower's interest rate offer might serve as a proxy variable instead as lenders are concerned about bank default risk. In our study, we investigate firms selecting between interest rate offers of different banks for their deposits. While a higher interest rate bid by a bank implies a higher probability of being selected, the increase in probability that the bid is actually successful (i.e. is the winning bid) may be decreasing in the level of the interest rate bid. One issue of concern is that the relation between a bank's risk and its interest rate offered is itself non-linear. Accordingly, we first have to ensure that bank risk and interest rate offers are non-concave and monotonically related. This would provide evidence that market pricing is competitive and banks are not able to mask their risk by bidding low rates.

The idea is illustrated in Figure 1. As shown in Figure 1A, a bank's interest rate bid increases monotonically in the bank's risk.[8] Once established, we are then able to test if the probability of a bank being selected as the bid winner in the auction increases at a decreasing rate the higher the interest rate bid. The concavity of this relation is depicted in Figure 1B. Two things are important to note. First, in our study, we are only able to test for the adverse selection argument in Stiglitz and Weiss (1981) but not for risk shifting of banks. While the latter is a theoretical possibility, it is rather unlikely that this applies in our setup as we investigate very short-term deposit financing. And second, in a world with no adverse selection, the relationship between a bank's interest rate bid and its selection probability should be monotonic. As shown in Figure 1B, we hypothesize that rationing should particularly be observable for riskier banks, such that the relationship between their selection probability and interest rate bids is (more) concave.[9] For lower risk banks however, the relationship might be relatively monotonic. In Figure 1B, we should not expect to observe cases beyond the maximum, that is, an actual decrease of a bank's selection probability when bidding higher rates. A major reason for this is that the deposit auction market we investigate is not the only funding source for banks and interest rates in other, less risk sensitive, funding markets, such as a fixed rate set for central bank borrowing, might represent a ceiling for short-term interest rates (see Figure 1C). We

[8] Note that banks cannot bid any random interest rate given that some of their characteristics are readily observable to firms via e.g. accounting data or CDS spreads.

[9] One question might be why a bank would bid a higher rate when its observable characteristics are identical to other banks. The reason is that its likelihood to be selected increases by doing so, that is, the probability to receive the funds is higher. Accordingly, in competitive markets banks would bid rates in line with their (observable and unobservable) characteristics reflecting their "true" demand. It might also be related to costly state verification as shown in Williamson (1987). We acknowledge that other factors such as a firm-bank relationship or future business in other areas might also have an impact on deposit interest rate bids. However, we examine the bids of very large banks where it is not obvious that repeatedly interacting with one of these substantially reduces information asymmetries relative to other banks. Furthermore, it is not clear why one bank would bid a higher interest rate than other banks to obtain future business from the firm given that we investigate in general overnight deposits on a trading platform. These might only have very little if any influence on obtaining future business from the firm in other areas.

investigate this in more detail in the final part of our analyses.

[Insert Figure 1 here]

2.3. RELATED LITERATURE

Credit rationing is important for the transmission of monetary policy as well as long-term growth (Calomiris and Longhofer, 2009). Direct empirical evidence on rationing is limited.[10] Some studies provide evidence of rationing using survey data (e.g.; Cox and Jappelli, 1990; Jappelli, 1990; or Chakravarty and Scott, 1999). The challenge with these data however is that self-reported rejections do not necessarily relate to credit rationing (Calomiris and Longhofer, 2009). Berger and Udell (1992) show that loans under commitment do not increase in tight markets and conclude that rationing is not a significant macroeconomic phenomenon. Using data on the recent financial crisis, Campello et al. (2011) find that the overall quantity of credit lines declined only slightly, but terms (maturity, fees, interest rates) became significantly less favorable for borrowers. Additionally, Acharya et al. (2019) show that lenders were less likely to waive a covenant violation on a credit line when their financial health worsened. Finally, Berger et al. (2011a, 2011b) and Cerqueiro et al. (2016) provide empirical evidence on rationing with respect to collateral.

Credit rationing is also related to bank runs and depositor discipline (e.g.; Diamond and Dybvig, 1983; Calomiris and Kahn, 1991; Flannery, 1994; Park and Peristiani 1998; Diamond and Rajan, 2001; Martinez Peria and Schmukler, 2001; Goldberg and Hudgins, 2002; Maechler and McDill, 2003; or Acharya and Mora, 2015). Interestingly, Martin et al. (2018) show that deposit insurance improves banks' funding stability such that it reduces withdrawals and even

[10] A nice overview on the theoretical literature on credit rationing is provided in e.g. Freixas and Rochet (2008).

attracts inflows from new depositors with amounts just under the insured limit.[11] However, they also provide evidence that uninsured depositors exit a bank under stress. This relates to Egan et al. (2017) who document that banks with a larger share of uninsured deposits are less stable due to a higher elasticity of uninsured deposits in times of bank stress. We add to this literature by investigating whether the (uninsured) depositors on our platform ration risky banks, consistent with the notion of depositor discipline.

The study closest to ours is Perignon et al. (2018). They investigate transaction-level data on European wholesale unsecured funding markets and show that banks of a lower quality experience funding dry-ups. These dry-ups predict negative firm performance which the authors interpret as being due to the revelation of negative information. Finally, they observe that banks of a higher quality tend to increase reliance on wholesale funding markets in periods of market stress. We add to their findings by investigating the competitiveness of our market and showing *how* banks obtain unsecured wholesale funding both in times of stress and non-stress. Furthermore, we not only investigate market exit but also reentry. Finally, we take a closer look at the mechanism of market exit accounting for alternative sources of funding in the wholesale funding market we study.

3. Auction Format and Institutional Details

We use data from a European multi-dealer request-for-quote trading platform, which ranks among the three largest platforms in Europe by volume. It was founded in the early 2000s as a multi-product platform and grew substantially over time. Prior to trading, banks and firms agree on a framework agreement. This agreement applies to all of their future trades on the platform.

[11] Martin et al. (2018) also provide a very nice overview on the empirical literature on bank runs.

Firms are able to offer any deposit amount with any maturity on the platform. All banks that have entered a framework agreement with the firm can be invited by the firm to bid.[12] The maximum bidding time in general is two minutes but can be adjusted by the firm prior to the start of the auction. Until the end of this period and briefly afterwards, the firm can select a bid based on its preferences. Banks do not observe other banks' bids but can adjust their offer during the bidding period. This implies that banks adjust their bid during the bidding process idiosyncratically due to, for example, changes in the market interest rate, but not in response to other banks' bids. It is important to note that the platform uses so-called "nice quotation". This implies that for every €1 million that a bank bids for, it has to wait one-third of a second before being allowed to adjust its bid. Accordingly, if a bank bids for €30 million it has to wait for 10 seconds (30 * $^1/_3$) before it is allowed to adjust its previous bid. In our analyses, we only include the last bid a bank makes in an auction since this is the actual information available to a firm when making a decision as to accept (or reject) an offer.

Appendix A1 shows an example of a deposit auction. This auction was executed on November 14, 2005 at 12:35:58 p.m. The maturity was one day, the notional amount was €76,200,000 and six banks bid in this auction. The executed bid is the bank bid where "Status" and "Status of bank bid" both indicate "EXEC", that is, the bid of 2.08% of Bank2 which occurred on November 14, 2005 at 12:35:34 p.m. was the accepted deposit bid in the transaction. The bids of the other five banks, not selected by the firm, are indicated by "LCAN" (list cancel) in the column "Status of Bank Bid". Interest rates on the platform are quoted using an actual/360 day count convention and transactions are settled on the same day. This implies that the amount

[12] The choice to enter a framework agreement with a bank actually constitutes firms' first step in the process of selecting banks. However, we refrain from analyzing this in more detail due to insufficient data. For example, we do not have data on the differences in general availability of banks to firms or the differences in contract complexity. That is, several other factors besides bank risk might have an influence on firms' decision to enter a framework agreement, for which we are not able to test.

of €76,200,000, in the example in Appendix A1, is transferred by the firm on November 14, 2005 to Bank2 and repaid to the firm on November 15, 2005.

To interpret our results, it is important to understand the priority order of deposits in the case of default. Since we exclude all deposit transactions below a notional value of €100,000, we are only including *uninsured* deposits. Furthermore, these Euro-deposits are *uncollateralized*. They have the same seniority as bonds and interbank loans with a maturity of at least one week.[13]

4. Data

We use data from a European multi-dealer request-for-quote trading platform from 2005 until 2015. We include only euro-denominated deposits with a notional amount of more than €100,000. Panel A of Table 1 reports descriptive statistics and Panel B descriptions of variables. It shows that these data include 446,173 observations of 486 firms depositing with 87 banks.[14] Bidding banks are headquartered in 22 countries, with 76% from Europe. We define an auction as an offer where at least two different banks bid. Our data include 64,280 auctions where at least one bank is selected. On average 4.55 banks are bidding in these. The difference to the unconditional average of 3.38 banks bidding for a deposit offer shows that firms also access the

[13] As an illustration of claim priority over the period 2005 to 2015 (which is central in our analyses) we use the case of Germany. The corporate deposits analyzed in this paper are senior to Tier 1 and Tier 2 equity and other instruments but junior to deposits of SME firms and interbank loans with a maturity of less than 7 days. Note that we are not able to exactly assign the deposits in our study to firm size because we do not have firms' identities. The average notional amount of €81.4 million per deposit transaction, however, provides us with confidence that the firms in our sample are rather large. Regarding other European countries, the Bank Recovery and Resolution Directive (2014/59/EU) was published in May 2014 and became effective in January 2015. It was initiated to secure a minimum harmonization of rules and powers for the recovery and resolution of financial institutions. For comparison, in the US, the 1993 National Depositor Preference Law (called "Omnibus Budget Reconciliation Act of 1993") gives uninsured domestic depositors first claim on the assets of a failed bank over other bank claim holders. Thus, these depositors have priority over foreign deposits (that is, deposits payable outside the US), bondholders and interbank funds. In short, uninsured domestic depositors hold "more secured" funds than other claim holders do.

[14] Note that the actual number of observations is much higher in our initial data set but we only include the last bid of each bank for a deposit offer, as explained earlier.

platform when they would like to receive an offer from only a specific bank.[15]

[Insert Table 1 here]

The average maturity of offered deposits is 9 days, with a median maturity of 1 day. As a result, a large proportion of our sample are overnight deposits. Indeed, 79% of all observations and 85.6% of all transactions have a maturity of one week or shorter. The median notional amount offered is €35 million. Figure 2 shows the average notional amount per deposit transaction over time as well as the number of deposit auctions providing evidence that the market is important for participating banks. The total daily outstanding amount is €15bn., which is about one third of the size of outstanding debt in the unsecured interbank market. Figure 2 shows that firms initiate more auctions and allocate smaller deposit amounts per transaction during severe crisis periods as was the case for Europe between 2008 and 2011.[16]

[Insert Figure 2 here]

In our data, we know the bidding banks' names and collect annual bank-specific accounting variables from Bankscope and match these (with a one year lag) to each deposit transaction. The average bank in our sample has €874 billion of total assets in 2005 real terms, with a leverage ratio of 95%, and a non-performing loan (NPL) ratio of 4%. The average return on equity (ROE) is 5% and asset growth is zero. The average spread between loan and deposit interest rates of a bank is 1.19%, and exposure to nominal off-balance sheet items is 19%. Note that several of these measures such as NPL, ROE, or asset growth exhibit substantial across bank variation. This is to be expected given our sample period, which includes the financial as well as the sovereign debt crisis. We measure bank risk via a bank's five-year credit default swap (CDS)

[15] A reason might be favorable interest rates in line with competitive pricing on these platforms (Hau et al., 2017). As described before, dealers do not know how many other dealers, if any, are also asked to bid.

[16] We observe that the average notional amount deposited with banks is rather constant over time. The percentage of auctions in which no bank is selected increases in later periods of our sample, which include both crises as well as negative interest rate offers. This however has no effect on the total notional deposit amount.

spread obtained from Markit. The average 5-year bank CDS spread is 117bps over our sample period and the average deposit interest rate bid is 112bps. Figure 3 compares the weekly average interest rate bid on the platform for overnight deposits to the interbank market using the EONIA interest rate (Panel A), and the Markit iTraxx Europe Senior Financials Index to the CDS spread of banks included in our sample (Panel B). Note that the latter only starts in the third week of June in 2006 due to data availability for the iTraxx index.[17] Figure 3 indicates that both interest rate bids on the platform as well as the risk of the banks in our sample (as reflected in the CDS of banks) are indicative market measures of short-term interest rates and bank risk, respectively. Deposit interest rates start to decline at the end of 2008, when the ECB introduced its full allotment policy and started to substantially reduce its main refinancing interest rate. Moreover, average deposit auction market interest rates become negative from mid-2014 on, in line with the ECB's introduction of a negative deposit facility interest rate in June 2014. In general, overnight deposit interest rates on the platform are slightly lower than the interbank interest rate.

[Insert Figure 3 here]

In Figure 4 we depict the fraction of auctions in which the highest bid was selected, the second highest bid was selected, etc. The figure is consistent with firms in general preferring higher interest rates, in general, as in 70% of the cases firms selected the highest bid. However, in 2011, the number of auctions in which the highest bid was selected declined substantially. Figure 5 shows the fraction of auctions in which the bank with the lowest risk in terms of CDS spread was selected, the second lowest risk, etc. The patterns are much less clear-cut than in Figure 4. It shows that when ordering banks with respect to their CDS spread within an auction, banks with lower risk tend to be selected slightly more often. However, when we investigate the

[17] Adding the average CDS spread of only our sample banks in the period before does not add much value because only a flat line can be observed as is the case in the current figure until mid-2007. The standard deviation of the spreads shown in the figure until this point in time is only about 2bps for both the index and banks in our sample.

difference in CDS spread between banks which are selected and those that are not we only observe 2 (7) weeks where this difference is larger than 50bps (40bps). This indicates an upper bound in terms of risk for banks participating in this market. It might also be reflected in interest rates bids of banks on the platform. We investigate potential explanations for this pattern in more detail in the following sections.

[Insert Figures 4 and 5 here]

5. Deposit Market Competition

In this section, we perform several tests to examine the competitiveness of the auction market for corporate deposits.[18] We first examine the relationship between bank risk and the deposit interest rate that is bid by a bank. This is followed by an analysis of firms' preferences for higher interest rates in general as well as firms' risk management when depositing their excess liquid funds.

5.1. BANK RISK AND THE BID DEPOSIT INTEREST RATE

As illustrated in Panel A of Figure 1, we first establish whether in the corporate deposit market we analyze, interest rate bids monotonically increase with bank risk. For this purpose, we investigate deposit offers where at least two different banks bid and at least one bid is selected by the firm. That is, we only include auctions which result in an actual transaction. We use the following regression specification

$$Interest\ Rate_{ijt} = \alpha + \beta_1 * CDS_{jt} + \beta_2 * CDS_{jt}^2 + \beta_3 * Transaction_{ijt} + \sum_{\gamma=4}^{n} \beta_\gamma * Accounting_{jt_{lag}} + \eta_t + \varepsilon_{ijt} \quad (1)$$

We regress the bid deposit interest rate offered by bank j to firm i at time t, on its 5-year

[18] Hau et al. (2017) show for the foreign exchange markets that on multi-dealer request-for-quote (RFQ) platforms dealers price competitively.

CDS spread on the day of the auction as a measure of the bank's risk, and its squared value, and other bank accounting based risk characteristics using their end of previous year value. We also include a transaction-level variable by using an indicator variable which is one when the bid is the first in the auction and zero otherwise, so as to control for potential preferences of firms for the first observable bid within an auction. η_t are day (auction) fixed effects and ε is an error term. Accordingly, we investigate the relationship between banks' risk and their bid deposit interest rate on a given day (within an auction). In all regressions, we use heteroskedasticity-robust standard errors clustered at the bank and month levels. The results are shown in Table 2.

[Insert Table 2 here]

Columns (1) to (4) include fixed effects for each day, columns (5) to (8) fixed effects for each auction. As can be seen, banks with a higher CDS spread bid higher deposit interest rates. Importantly, in including a squared term to account for possible non-linearity between banks' risk and their bid interest rate, we find that the increase in a bank's bid interest rate is monotonically related to increases in its risk and that the squared term is statistically insignificant in all cases. We also find that smaller banks, banks with higher leverage, and banks with lower returns on equity bid higher rates. Interestingly, the indicator variable for the first bid in the auction is insignificant in all cases. This is consistent with a blind auction and confirms that the first bank's bid does not affect other banks', subsequent, bids.

In Panel B, we regress an indicator variable which is one for the highest bid in an auction on the same control variables as in Panel A. Again, riskier banks are more likely to bid the highest rate in an auction where the relation is again monotonically increasing.[19]

[19] All results are robust to additionally including bank-quarter fixed effects.

5.2. BANK SELECTION

As an additional test of market competitiveness, we investigate firm bid selection in more detail. In other words, we want to ensure that firms behave rationally when depositing using the trading platform. We examine whether firms generally prefer higher interest rates. To do this, we use the following regression specification.

$$I_{selected;ijt} = \alpha + \beta_1 * Rate_{ijt} + \beta_2 * Transaction_{ijt} + \sum_{\gamma=3}^{n} \beta_\gamma * Accounting_{jt_{lag}} + \eta_t + \varepsilon_{ijt} \quad (2)$$

We regress an indicator variable, which is one for a bid of bank j which is selected by firm i in auction t and zero otherwise, on the bid deposit interest rate of a bank in this auction and our transaction-level variable and lagged bank characteristics as in equation (1). In the regressions, we include auction fixed effects η_t and use heteroskedasticity-robust standard errors clustered at the bank and month levels. In doing so, we investigate whether within an auction higher deposit interest rate bids are more likely to be selected. The results are shown in Panel A of Table 3.

[Insert Table 3 here]

Columns (1) and (2) show that a higher interest rate bid by a bank within an auction implies a higher probability that this bid will be selected by a firm. We rerun the regressions including in regression equation (2) an indicator for the highest bid as independent variable instead of the bid deposit interest rate. Columns (3) and (4) show that a bid is more likely to be selected when it is the highest bid in an auction. On average, a 1bps higher interest rate bid in an auction increases a bank's likelihood of being selected by 0.6%, while bidding highest in an auction implies a 55% success probability.

We next test whether firms actively manage risk in their selection of banks. As described earlier, the median notional amount offered is €35 million with an average of €74.4 million. Thus, it is unlikely that firms are unaware of a bank's risk when depositing these large amounts, despite the short maturity of these deposits. We have already shown in Table 2 that riskier banks bid higher interest rates, while depositing firms in general prefer higher rates. As a result, if we simply regressed our indicator variable for bid selection on bank risk we would observe the effect that riskier banks are more likely to be selected. However, to better identify the bank risk effect we investigate instead bank selection within an auction by performing the same analysis as in Table 3A, but replace the bid deposit interest rate with bank risk measured via banks' CDS spread and importantly include (i) only bids with the same interest rate and (ii) only bids with the same interest rate that is simultaneously the highest in the auction. The results are shown in Panel B of Table 3. We find that, conditional on the same bid deposit interest rate, riskier banks are less likely to be selected in an auction. We also observe that this effect becomes even stronger as banks' risk increases. Including indicator variables for bank CDS level intervals ranging from 100 to 200bps, 200 to 300bps, and 300bps and above, both column (2) and column (4) show that firms do not differentiate between banks when their CDS spread is below 200bps. However, banks' bid selection probability substantially decreases above this threshold. Importantly, the effect is non-linear and stronger for higher levels of bank risk.

Next, in Panel C of Table 3 we perform a similar analysis as in Panel B but match bank bids in an auction on the interest rate as well as accounting for the relationship of the bidding firm to the bank. Bharath et al. (2011), for example, show that repeated borrowing from the same lender implies better loan terms over time.[20] Other studies also find that banks charge lower rates for relationship borrowers (e.g.; Bodenhorn, 2003; Ioannidou and Ongena, 2010; López-

[20] Elyasiani and Goldberg (2005) and Degryse et al. (2009) provide nice overviews of the effects of relationship on loan contract characteristics and credit availability.

Espinosa et al., 2017).[21] These patterns might also apply to the deposit auction market, such that interest rates are different between banks with different relationship levels to a firm. We calculate the relationship between a firm and a bank at the trading platform-level via the percentage of the deposited amount between the firm and the bank over the last year divided by the firm's total deposited amount over the last year (following for example Bharath et al., 2007, 2011, and Adam and Streitz, 2016). We again compare bids with the same (highest) interest rate in an auction and additionally only include bids where the relationship level between a firm-bank pair is the same. Relationship level is divided into intervals using steps of ten percent, that is, banks with a relationship to the firm between zero and less than 10% are considered as having the same relationship level. Panel C shows the results. As can be seen, conditional on the same bid deposit interest rate and relationship level, firms select less risky banks. Again, columns (2) and (4) show that selection probability is non-linear and more negative for higher levels of bank risk.

In another test of firms' active liquidity management regarding bank risk, we investigate firm diversification of deposits in more detail. For example, Figure 2 suggests that firms diversify more in crisis periods. It shows that in crisis times, as was the case for Europe between 2008 and 2011, firms initiate more auctions and allocate smaller deposit amounts per transaction. We use the following regression specification to investigate diversification in detail.

$$Y_{it} = \alpha + \beta_1 * \overline{Bank\ Risk_{jt-1|i}} + \sum_{\gamma=2}^{n} \beta_\gamma * \overline{Accounting_{jt_{lag}-1|i}} + \theta_i + \varepsilon_{it} \qquad (3)$$

We investigate diversification of firms across banks using different dependent variables Y_{it}. These are the average amount deposited per auction by firm i in a given period t, the number of banks with which the firm deposits on the platform in a given period, and the total deposited

[21] Ioannidou and Ongena (2010) show that banks eventually increase these loan rates again which relates to hold up.

amount by firm i in period t. Here we define period t by aggregating data for each firm to the weekly, monthly, and quarterly levels, respectively. In these regressions, we calculate the average of banks' CDS spreads in a given period as a measure of bank risk as well as their average characteristics, conditional on the firm depositing with the banks in the previous period, where the bar above these variables in equation (3) denotes the average. Furthermore, we include firm fixed effects θ_i and report significances using heteroskedasticity-robust standard errors clustered at the time period level. Accordingly, we investigate if a firm changes the amount per auction, the number of banks with which it deposits and the total amount it deposits when average bank risk increases.[22] Table 4 shows our results. Irrespective of how we aggregate the data, we observe that firms deposit smaller amounts per auction (columns (1) to (3)) with more banks (columns (4) to (6)) after periods of higher bank risk. Columns (7) to (9) show that this is not related to a change in the total deposited amount of firms. This confirms that firms diversify deposits more after periods of high banking system risk.

[Insert Table 4 here]

Overall, we observe that firms in general prefer higher interest rates. However, we also observe evidence that suggests that firms actively manage risk and do not simply "reach for yield." Conditional on banks bidding the same interest rate, firms select less risky banks. This is further confirmed when additionally conditioning on the same firm-bank relationships. Firms also diversify more after increases in bank risk. These results suggest that the deposit auction market we analyze is competitive and that interest rate bids of banks may serve as a screening

[22] We acknowledge that *Average Bank Risk to Firm* might be influenced by firm selection as we define it as the average bank risk of all deposit transactions of the firm on the platform. That is, we cannot differentiate if our results derive from general increases in bank risk or from firms' selecting riskier banks in certain periods. However, given that we investigate results within a firm and over various time intervals (week, month, quarter) the latter is rather unlikely to substantially affect our results. Note that we deliberately do not use the average CDS spread of all banks as a measure of bank risk as some might never be bidding to a firm what argues for their lower impact on firm decisions. In a robustness check, we use the average CDS spreads of all banks bidding on the platform as measure of bank risk in the previous period and find even stronger results.

device for firms. We test this more formally in the next section.

6. Rationing of Banks

6.1. BANK SELECTION AND BID DEPOSIT INTEREST RATES

As explained in Section 2, if depositing firms rationed banks, we would expect that the probability of a deposit interest rate bid being selected by a firm is concave in a bank's bid interest rate. To test this, we implement the following regression.

$$\mathrm{I}_{selected;ijt} = \alpha + \beta_1 * Rate_{ijt} + \beta_2 * Rate_{ijt}^2 + \beta_3 * Transaction_{ijt} + \sum_{\gamma=4}^{n} \beta_\gamma * Accounting_{jt_{lag}} + \eta_t + \theta_i + \varepsilon_{ijt} \quad (4)$$

We regress an indicator variable, which is one for a selected bank bid of bank j by firm i in an auction and zero otherwise, on banks' bid deposit interest rates. Additionally, we include a squared term for the bid deposit interest rate to test for the concavity in a bank's selection probability as depicted in Figure 1B. If firms rationed banks, we would expect the coefficient of the bid interest rate to be positive and the coefficient of the squared term to be negative. To examine a rationing type effect, we include first all deposit interest rate bids also including deposit offers in which only one bank offers an interest rate. We do this for two reasons. First, the results in Hau et al. (2017) show for FX markets that offers are competitive on multi-dealer trading platforms even when asking for quotes from only a single dealer. And second, firms are able to discard all bank bids for a deposit offer and initiate another auction on the same day. Given this, we include day fixed effects η_t instead of auction fixed effects, which would be too rigid and eliminate large parts of firms' actual time scope of selection.[23] Our second set of tests

[23] As a simplifying example, imagine a firm which offers the same deposit amount in two auctions on a given day. Bank A bids an interest rate for the first offer and the auction is discarded by the firm. Bank B bids for the second offer and is selected. Auction fixed effects would eliminate both offers from our analysis due to insufficient

consists of all bank bids in auctions where at least two different banks bid. One concern might be that there may be some auctions where no bid is selected and no transaction materializes. To address this, we conduct a third set of tests which include only auctions which result in at least one actual transaction. In a final set of tests, we additionally include firm fixed effects θ_i to account for constant firm-specific characteristics such as industry, corporate governance and general selection behavior.[24] In the regressions, we use heteroskedasticity-robust standard errors clustered at the bank and month levels. The results are shown in Table 5.

[Insert Table 5 here]

Columns (1), (3) and (5) show the regression results for the three sets of tests described above including day fixed effects. Column (7) additionally includes firm fixed effects. Our results confirm that risky banks are rationed by corporate depositors. In Table 5, the coefficient of the bid interest rate is positive and the coefficient of the squared term of the bid rate is negative in all cases. However, the statistical significance of the squared term decreases the stricter we are in our definition of the included sample and fixed effects. One possibility is that this might be due to ignoring the level of a bank's risk. As explained in Section 2.2, we hypothesize that rationing should particularly be observable for riskier banks while for low risk banks the relationship between their bid interest rate and selection probability might be relatively monotonic. To examine this further, we divide interest rate bids into CDS spread intervals of the bidding banks, using a piecewise linear regression approach.[25] We use 4 intervals in steps of

variation of the dependent variable; however, day fixed effects allow us to investigate firm selection on this given day. Note that results continue to hold when we include firm-day fixed effects.

[24] As mentioned earlier, we only have a numerical identifier available for each firm but we know that these are non-financial firms.

[25] A piecewise linear estimation would generally imply that we divide interest rate bids into intervals and investigate these separately. However, given our sample period, which includes substantial changes in bid interest rate level as well as standard deviation, we prefer to use bank CDS spreads which we show to be strongly related to interest rate bids on a given day and within a given auction and which retain the same economic interpretation across economic conditions and time periods.

100bps, i.e. [0; 100bps), [100; 200bps), [200; 300bps), and 300bps or larger. The results are shown in the even columns of Table 5. They confirm our hypothesis. In all specifications, the selection probability of banks' interest rate bid is concave when the level of bank risk is higher. Importantly, regarding a bank risk level threshold effect, both the linear as well as the squared term are statistically significant for interest rate bids of banks with a CDS spread of 200bps or more. We also observe that the concavity is stronger for riskier banks. In all specifications, the coefficient of the squared deposit interest rate bid decreases with bank risk.

What do these results imply about the theoretical functional form in Figure 1B which shows a hypothetical maximum bid, beyond which selection probability starts to decline? Using the results and coefficients in column (6) of Table 5, as an example, shows that the selection probability of banks with a CDS spread of less than 100bps increases monotonically with their deposit interest rate bid. For higher risk banks we observe a maximum of 1,040bps for banks in the CDS spread interval [100; 200bps), a maximum of 743bps when their CDS spread is between [200; 300bps), and a maximum of 528bps when banks have a CDS spread of 300bps or larger. Importantly, given that we include day fixed effects, this implies that a risky bank would have to bid a deposit interest rate of 528bps above the average bid rate on a given day, which can be observationally ruled out. This suggests that in the deposit auction market studied here, only the left, increasingly concave, part of Figure 1B is observed. As will be discussed below in Section 6.4, this may be in part due to a fixed alternative borrowing rate offered by the central bank (ECB) well below these maximum levels (see Figure 1C).

6.2. BANK AUCTION FAILURE AND BID DEPOSIT INTEREST RATE

In this subsection, we test rationing of banks by firms from an alternative angle. We investigate whether bid deposit interest rates are non-linearly related to banks' failure to win in an auction. Failure here is defined as a bank not being selected as the winner in an auction by a firm despite bidding. Additionally, we aggregate data to the bank-month level. This allows us to examine the extreme case of auction failure, that is, no selection by a firm of any bid by a bank in a given month. In examining this, we are therefore investigating the intensive as well as the extensive margin in the deposit auction market. We use the following regression specification.

$$Failure_{jt} = \alpha + \beta_1 * Rate_{jt} + \beta_2 * Rate_{jt}^2 + \sum_{\gamma=3}^{n} \beta_\gamma * Accounting_{jt_{lag}} + \eta_t + \kappa_j + \varepsilon_{jt} \quad (5)$$

We calculate a bank's failure rate as the number of auctions in which bank j bids in month t and in which it is not selected over the total number of auctions in which it bids in month t. We regress this variable on the bank's average bid deposit interest rate in month t. In these regressions, we include month fixed effects η_t and bank fixed effects κ_j and use heteroskedasticity-robust standard errors clustered at the bank level. The results are shown in Table 6.

[Insert Table 6 here]

Table 6 confirms that a bank's auction failure rate is negatively related to the level of its interest rate bid. Irrespective of including the bank accounting variables from Table 2 as well as bank fixed effects κ_j to be able to observe changes within a bank, columns (1) and (2) of Panel A show that higher deposit interest rate offers imply that a bank's failure rate in auctions decreases.[26] However, including the squared term of its average bid interest rate in columns (3) and (4) shows that the failure rate is convex to the level of the bid rate. In another test, we replace a bank's monthly bid deposit interest rate with the percent of auctions in which the bank bids highest in a month. The results are shown in columns (5) to (8). They depict the same pattern. Banks which bid the highest in auctions more often in a given month have a lower

[26] The results are robust to excluding bank fixed effects in the even columns of Table 6.

failure rate in auctions, however, the squared term on the percent of auctions in which banks bid highest indicates a convex relationship with banks' auction failure rate.

We are interested in how the results differ between banks which are successful in at least some of the auctions in which they bid and those which are invited by firms to auctions and bid but are never selected in a given month. Note that the latter is a test of the extensive margin as it examines whether banks are excluded from the market by firms despite bidding. In Panel B of Table 6 we show in columns (1) to (4) regression results of a bank's failure rate on its interest rate when at least one of the bank's bids in a month is selected by a firm. In columns (5) to (8) we replace the dependent variable in regression equation (5) with an indicator variable which is one when the bank bids and none of its bids are selected in a month and zero when at least one of its bids is selected. We find our previous results confirmed, a higher bid interest rate implies that banks are less likely to fail in auctions. However, this effect is again convex, irrespective of investigating the intensive or the extensive margin.

6.3. BANK MARKET EXIT AND REENTRY

The results in the previous subsections on the non-linearity between deposit bid interest rates and bank selection provide strong support for rationing of risky banks in the deposit auction market. In general, we would expect that firms do not invite banks to bid for their deposits if they find them to be too risky. In this subsection, we investigate the extensive margin in more detail. Specifically, we analyze the relationship between banks' risk and their participation in the deposit auction market. We are interested whether bank risk is related to both bank exit and reentry, similar to Perignon et al. (2018), which shows that banks' participation in wholesale markets is related to future bank performance.[27] These tests are related to the notion of "redlining" in Stiglitz and Weiss (1981), that is, observationally distinguishable borrowers are excluded from the market because of their high risk.

In a first test, we aggregate data to the bank-month level and define an indicator variable for bank exit, which is one in months when a bank does not participate on the platform, but has participated in earlier periods, and zero when it bids for deposits on the platform. In a second test, we do the same at the firm-bank-month level. Note that in the latter case banks might not be submitting bids to some firms but still submit bids to others.[28] We test this using the following regression specification.

$$Exit_{j(i)t} = \alpha + \beta_1 * CDS_{jt} + \eta_t + \kappa_j(\theta_i \times \kappa_j) + \varepsilon_{j(i)t} \quad (6)$$

We regress our indicator variable for the market exit of bank j (from bidding to firm i) in month t on the bank's risk measured by its average CDS spread in month t. In all regressions, we include month fixed effects η_t and use heteroskedasticity-robust standard errors clustered at the bank level. In regressions using data at the bank-month level we also include bank fixed effects κ_j, in regressions using data at firm-bank-month level also firm-bank fixed effects $\theta_i \times \kappa_j$. The results are shown in Table 7.

[Insert Table 7 here]

Columns (1) to (4) of Panel A of Table 7 show the results using data aggregated to the bank-month level, columns (5) to (8) incorporate data at the firm-bank-month level. In odd columns, we regress bank exit on the average risk of bank j in the same month, in even columns

[27] We do not investigate the first-time entry of banks to the platform as this might be related to self-selection of banks and accordingly endogeneity. Note that several factors besides risk, such as technological affinity, competition, relationships in other business areas, or geographical location, both for banks as well as firms, might have an influence on the decision to enter the platform, for which we are not able to test.

[28] We do so to obtain a full and realistic picture. While some banks could suddenly exit the market, it might be the case that others exit gradually across firms.

on its average risk in the previous month. We are interested if bank market exit is related to bank risk as well as if bank risk predicts exit, both across banks as well as within banks (within a firm-bank relation) when including bank fixed effects κ_j (firm-bank fixed effects $\theta_i \times \kappa_j$). Table 7 confirms both types of exit effects. Banks are more likely to exit corporate deposit markets when their risk is higher. Columns (3) and (4) include bank fixed effects and show that this result also applies to within bank changes in risk. We additionally incorporate firm-bank fixed effects in columns (7) and (8) which account for constant factors between a firm and a bank, and find our result confirmed also at the firm-bank level. Our results in the even columns of Panel A of Table 7 additionally show that bank risk predicts bank market exit in the following month.

We also investigate if a bank's exit from bidding to a firm for its deposits predicts higher bank risk in following periods by running the following regression specification.

$$CDS_{jt+\tau} = \alpha + \beta_1 * Exit_{jit} + \eta_t + \kappa_j \times \theta_i + \varepsilon_{jit} \quad (7)$$

We regress the risk of bank j measured by its average CDS spread in the period $t + \tau$, with τ ranging from 1 to 4 months, on our indicator variable for a bank exiting from bidding to firm i in month t. All regressions include month fixed effects η_t to account for time related constant effects as well as firm-bank fixed effects $\theta_i \times \kappa_j$ to investigate effects within a firm-bank relation and use heteroskedasticity-robust standard errors clustered at the bank level. Panel B of Table 7 shows the results. We observe that the exit of a bank from bidding to a firm predicts higher bank risk up to 4 months into the future. These results indicate that the market exit of a bank reveals new (negative) information to the market about its future risk.

We furthermore examine what determines bank reentry to the deposit auction platform. We define an indicator variable for reentry which is one in a month when a bank bids on the platform but did not bid in the previous month (while having bid on the platform in the past) and zero in months in which a bank does not bid (while having bid on the platform in the past). We estimate the following regression model at the bank-month level.

$$Reentry_{jt} = \alpha + \beta_1 * CDS_{jt-\tau} + \eta_t + \kappa_j + \varepsilon_{jt} \quad (8)$$

We regress our indicator for the market reentry of bank j in month t on its risk measured by its average CDS spread in the period $t - \tau$, with τ ranging from 0 to 4 months. We furthermore include month η_t as well as bank κ_j fixed effects to account for factors which are constant within time and within a bank. Column (1) of Panel C in Table 7 shows that a bank is more likely to re-enter the deposit market when its risk declines. In particular, columns (2) to (5) show that a bank's risk in previous months predicts reentry in the future. It suggests that the reentry of a bank is related to a longer-term decrease in its risk prior to reentry.

The results in this section suggest that bank risk and bank market participation are related. Banks participate in the deposit auction market when their risk is lower and exit when their risk increases. Our results show that banks' market participation is related to longer-term changes in risk, in line with fundamental changes in their performance. Indeed, the average time period to reenter is 4.26 months with a maximum period of 18 months. However, in line with Perignon et al. (2018), we also observe that several banks exit the market and do not reenter. Accordingly, while some banks are able to improve their performance over time, others are not able to do so.

6.4. ALTERNATIVE FUNDING MARKETS AND BANK BIDS

Our results show that bank risk and bank deposit market participation are related. In further tests, we try to shed more light on the mechanism of banks' deposit market exit. Our earlier findings show that riskier banks bid higher deposit interest rates. It is reasonable to assume that banks have access to several other funding markets and are likely to prefer those where interest rates are lower. We therefore compare a bank's bid deposit interest rates on the platform to the interbank market rate as well as to the central bank (ECB) main refinancing operations interest rate at the firm-bank-month level.[29] For the interbank market, we use the EONIA and calculate, in a given month, the percentage of bank deposit bids made to a given firm in a given month in which the bank bids an interest rate higher than the EONIA interest rate. Note that the interbank market interest rate is sensitive to banks' risk as well.[30] For a comparison of bid deposit interest rates on the platform to the central bank interest rate, we investigate data starting in October 2008. In this month, the ECB began to follow a fixed interest rate policy in its main refinancing operations by fully allotting all liquidity demanded by banks, provided they had sufficient collateral, at a fixed rate.[31] This implies that the central bank main refinancing rate has been largely risk-insensitive since October 2008.[32] We calculate the percentage of bids to a given firm in a given month which are higher than the interest rate on the ECB's main refinancing operations. In addition to the fraction of bids above the ECB's main refinancing rate and the interbank market interest rate, we include a banks' auction failure rate at the firm-bank-month level as a proxy for rationing of banks by firms. In sum, we test whether banks exit the market because (i) they are rationed by firms, (ii) alternative markets' interest rates are more favorable, or (iii) both. We run the following regression model.

[29] There are two things to note. First, we observe that the average short-term interest on the deposit auction platform is below the interbank interest rate as well as the ECB main refinancing rate in most periods. This might be an important reason for banks to participate in the deposit auction market. We also observe that deposit volumes are rather constant over time, also when deposit interest rates in transactions on the platform are negative. This suggests that depositing via the platform is also profitable for firms such that firms supposedly are offered lower rates when depositing directly with banks instead of using the platform as intermediary. And second, borrowing from the central bank does not imply a stigma in Europe, in contrast to the US (e.g., Acharya et al., 2017). While borrowing via the main refinancing operations is the common monetary policy tool for the ECB to issue liquidity, even borrowing from the ECB's marginal lending facility, which is in general considered only as a back-up source for funding, does not imply a stigma (Lee and Sarkar, 2018).

[30] Due to data availability, we do not have banks' individual interbank market funding rates available but use the average interbank market interest rate as a proxy variable.

[31] In contrast, the deposits auction market we analyze is uncollateralized.

[32] The ECB substantially eased collateral requirements during the financial crisis to "reduce asset-side constraints" (ECB Monthly Bulletin, October 2010), which argues in favor of the risk-insensitivity of ECB funding.

$$Exit_{jit} = \alpha + \beta_1 * Failure_{jit-1} + \beta_2 * Higher\ than\ ECB\ rate_{jit-1} + \beta_3 * Higher\ than\ Interbank\ rate_{jit-1} + \eta_t + \kappa_j \times \theta_i + \varepsilon_{jit} \quad (9)$$

We use data aggregated to the firm-bank-month level and regress our indicator variable for the exit of bank j from bidding to firm i in month t on these three measures lagged by one month and include time η_t and bank-month $\kappa_j \times \theta_i$ fixed effects to account for factors which are constant within time and within a firm-bank relation. The results are shown in Table 8.

[Insert Table 8 here]

Columns (1) to (3) show the results for each measure individually, including firm-bank and month fixed effects. In columns (4) to (6), we incorporate all measures and use month (column (4)), bank and month (column (5)), and firm-bank and month (column (6)) fixed effects. Table 8 shows that banks are more likely to exit the corporate deposit market when they have a high percentage of auctions in which they bid and are not selected by firms in the prior month. They are also more likely to exit when the percentage of bids they have made with an interest rate higher than the ECB main refinancing rate is larger in the prior month. However, we do not observe any effect on bank exit for the percentage of bids higher than the EONIA interbank market interest rate in the month before.[33]

The results in Table 8 suggest that two factors are important drivers of banks' exit from corporate deposit auction markets: rationing of banks by firms as well as the (level and type of the) interest rate charged by the central bank. Regarding the latter, our findings indicate that the central bank's main refinancing rate constitutes a type of ceiling for short-term interest rates when the central bank follows a fixed interest rate policy.[34] It also suggests that in terms of

[33] The EONIA rate is an uncollateralized rate.

[34] We find this observationally confirmed in our data which shows that after decreases of the ECB main refinancing rate the 99th percentile of deposit market interest rates is above the ECB rate in some of the subsequent weeks but gradually decreases over time to a level below the ECB interest rate.

market competitiveness, liquidity in the deposit auction market is reduced, at least in the tail of high bank risk, due to a central bank fixed interest rate lending policy.

6.5. ROBUSTNESS TESTS

In this subsection, we perform several tests as to the robustness of our results. As our benchmark, we use the sample of all bank bids in auctions, that is, columns (3) and (4) of Table 5 and run regression equation (4). In a first test, we split our sample into the sovereign debt crisis period defined from 2010 until 2012, and the remaining period. As shown in Figure 3B, banks' CDS spreads were at substantially higher levels during the sovereign debt crisis and we investigate whether firms ration banks only in periods of crises, with substantially higher levels of bank risk, or whether rationing applies to all periods.[35] In a second test, we analyze whether rationing only occurs for large deposit amounts. A potential concern might be that firms are more lenient when amounts are smaller and ration banks only when the deposits they need to place are large. We therefore split our sample using a threshold of €100 million per auction. In a third test, we only include overnight deposits made on the platform. Firms might be more lenient when depositing overnight, due to the short maturity and the correspondingly high repayment probability of banks, and not ration banks in these cases. In a fourth test, we exclude all bank bids above the ECB main refinancing rate. As shown in the previous subsection, banks are more likely to exit the market when they (have to) bid more often above the central bank interest rate. We therefore investigate if our results on rationing continue to hold when we "remove" the ceiling for deposit interest rates. The results for these robustness tests are shown in Panel A of Table 9.

[35] In a further test, omitted for brevity, we also investigate only the pre-crisis period, that is, the start of our sample period until August 2007. Our results on rationing in general hold despite no bank in our sample having a CDS spread larger than 100bps prior to September 2007.

[Insert Table 9 here]

Our prior finding of firms rationing riskier banks is confirmed in all cases. Irrespective of how we split the sample, we observe that both the linear as well as the squared term of the bid deposit interest rate are of the predicted sign and statistically significant for bids of banks with a CDS spread of 200bps or more.

In another robustness test, we investigate rationing accounting for diversification of firms. We show in section 5.2 that firms diversify more in crisis periods. We therefore would like to ensure that our results are not driven only by firms' diversification of deposits. In a first test, we include only auctions where a firm selects just one bank, that is, does not diversify within an auction.[36] We find our results on rationing confirmed. Additionally, we re-run columns (5) to (8) of Table 5 but include only those auctions where a firm selects just one bank and this bank is the only bank with which the firm deposits on this given day.[37] This implies that on this given day the firm does not diversify by allocating its total daily deposit amount to several banks. Panel B of Table 9 shows the results. We observe that our result on firms rationing banks continues to hold. Interestingly, the level of the coefficients is largely comparable to our results for columns (5) to (8) in Table 5 despite the much smaller sample.

In a final robustness test, we specifically account for firms' preference for the highest bid in an auction. We show in Figure 4 as well as in columns (3) and (4) of Panel A of Table 3 that bidding highest in an auction implies a higher probability of a bid being selected. However, if banks were rationed by firms we would expect that conditional on bidding highest, a higher interest rate signals higher bank risk to the firm. As in Panel A of Table 9, we use all bank bids

[36] Investigating the differences between auctions where several banks are selected and those where only one bank is selected shows that the level of deposit interest rates is comparable, while auctions with several selected banks in general imply higher total notional amounts as well as more bidding banks.
[37] With this definition, columns (1) and (2) as well as columns (3) and (4) are the same as columns (5) and (6) of Table 5.

in auctions, that is, columns (3) and (4) of Table 5, as our sample. We include an indicator variable which is one when a bid is the highest in an auction and zero otherwise and interact it with a bank's bid deposit interest rate. If firms rationed banks, we would expect a negative coefficient for the interaction term between highest bid and bid deposit interest rate, especially for riskier banks. It would imply that their selection probability decreases in the size of the bid deposit interest rate despite offering the highest interest rate in this auction. Panel C of Table 9 shows the results.

As can be seen, Panel C confirms a rationing of risky banks by corporate depositors, even when we account for firms' preference for the highest bid in an auction. We observe a statistically significant and negative coefficient for the interaction term between bid deposit interest rate and our indicator variable for the highest bid made in an auction. Splitting banks into risk intervals via their CDS spreads, shows this is the case for banks with a CDS spread above 100bps. However, the base effect in Panel C also shows that bidding highest in an auction implies a probability of 44% to be selected in this auction. It again confirms that bidding a higher interest rate per se implies a higher probability to be selected. Our results on the interaction terms nevertheless show that the selection probability of riskier banks is still non-linear in the interest rate bid.

7. Conclusion

In this paper, we investigate firms' depositing behavior using unique data of a FinTech intermediary. Our results provide empirical evidence that firms ration risky banks, consistent with the general idea of rationing in Stiglitz and Weiss (1981). We show that firms' management of deposits is in line with (uninsured) depositors disciplining risky banks. Moreover, risky banks eventually exit the platform and return only when their risk decreases in the long term. Overall, our results provide new insights as to rationing in response to interest rate signals of borrowers.

We also observe that a fixed refinancing rate of the central bank might introduce a type of ceiling on interest rates in alternative bank funding markets, such as the corporate deposit market. While the intention of the central bank might be to ensure funding for risky banks, our results suggest that it might also imply lower returns for firms' deposits. This, in turn, might entail negative effects for firms' working capital and liquidity management. We leave this issue for further research.

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Figure 1

Bank Risk, Interest Rate, and Bank Selection

The figure illustrates in Panel A the relation between bank risk and the bank bid deposit interest rate. Panel B shows the relation between the bank bid deposit interest rate and the selection probability of deposit bid.

Fig. 1A: Bank risk and bank interest rate bid

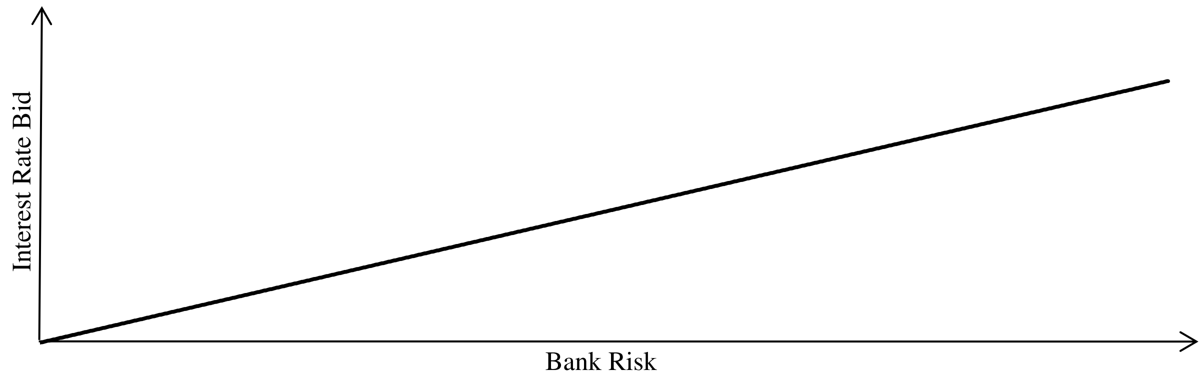

Fig. 1B: Bank interest rate bid and banks' probability to be selected as the winning bidder

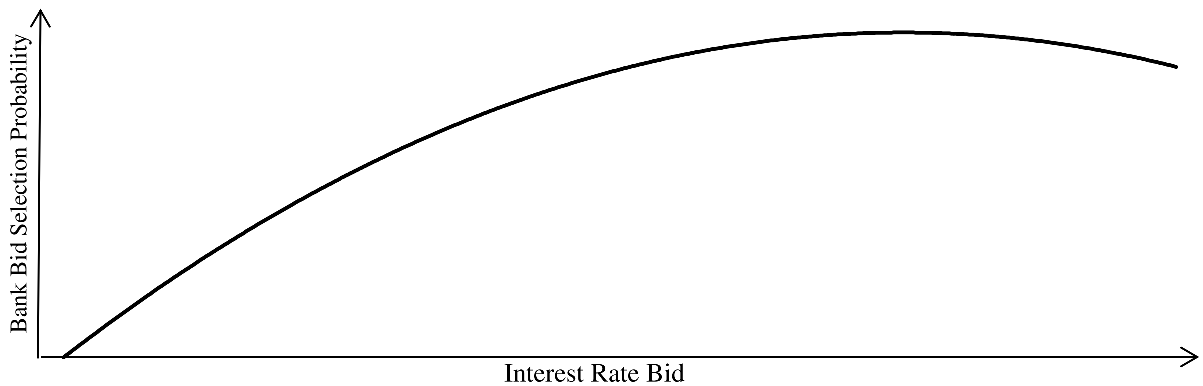

Fig. 1C: Bank interest rate bid and banks' probability to be selected as the winning bidder in the presence of a fixed central bank (ECB) lending rate

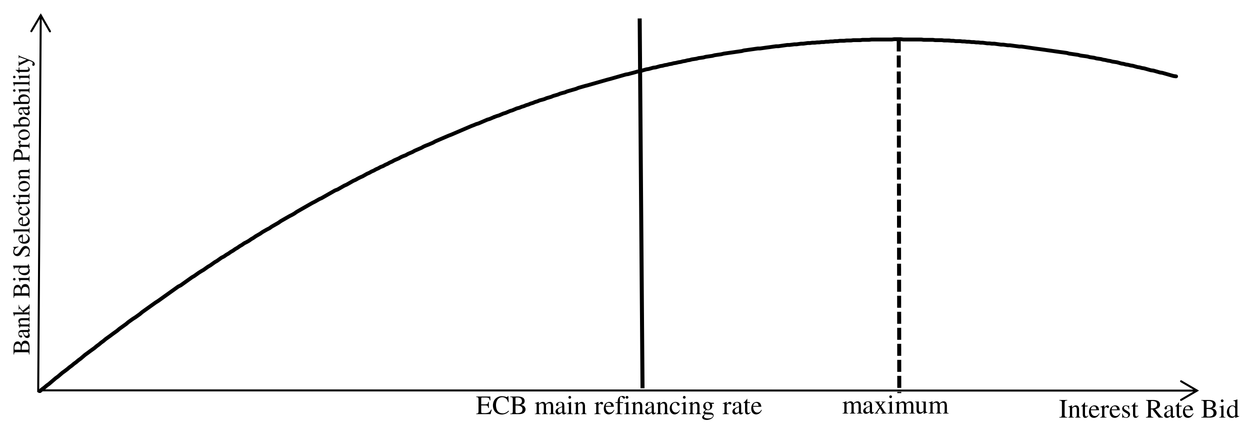

Figure 2

Deposit Volume and Auctions

The figure shows the average notional per auction of traded € deposits on the platform on the left side and the number of auctions in each quarter on the right from January 2005 to December 2015.

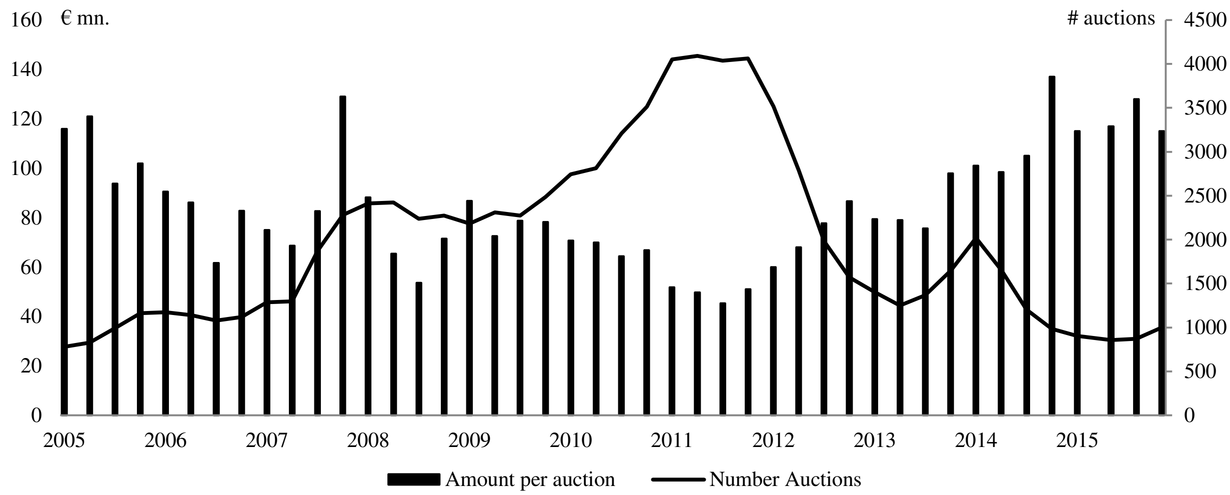

Figure 3

Deposit Interest Rate and Bank Risk

Figure 3A shows the average interest rate on overnight € deposit auctions on the platform and the EONIA interest rate in basis points both aggregated to the weekly level from January 2005 to December 2015. Figure 3B shows in basis points the Markit™ iTraxx Europe Senior Financials Index, starting from the 24th of 2006 due to data availability, together with the average CDS spread of banks on the platform weighted by the number of bids by each bank in each week.

Fig. 3A: EONIA and corporate overnight deposit interest rate

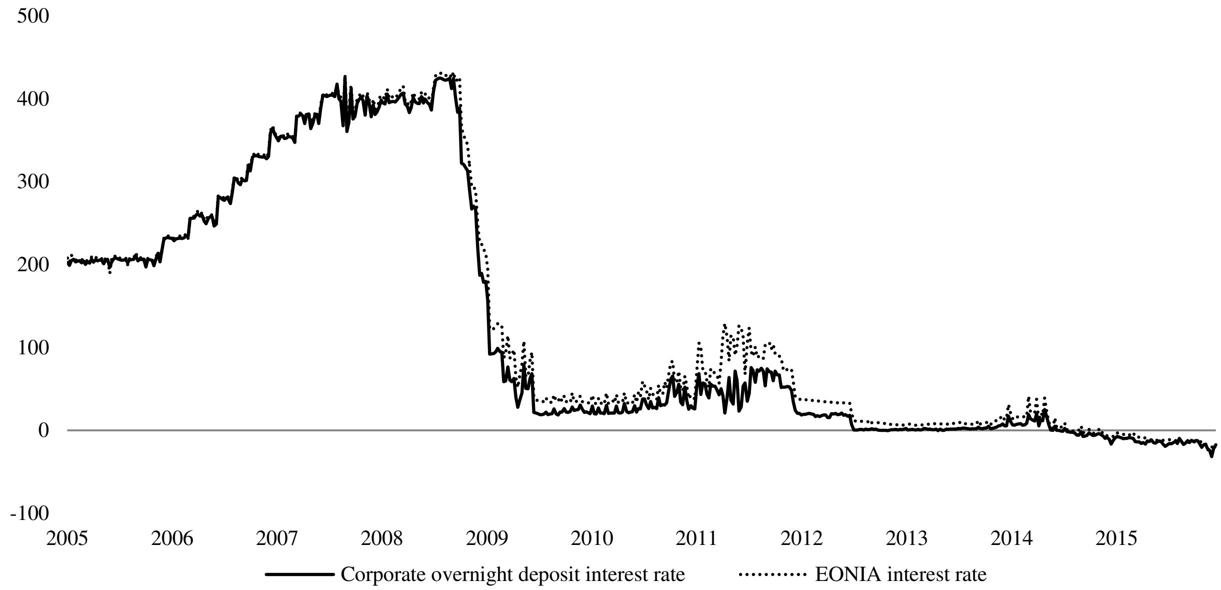

Fig. 3B: iTraxx and average CDS spread of sample banks

Figure 4

Bid Selection within Auction by Interest Rate Bid

The figure depicts the percentage of firms selecting the highest, second highest, third highest, fourth highest, and fifth highest or lower bid in a transaction.

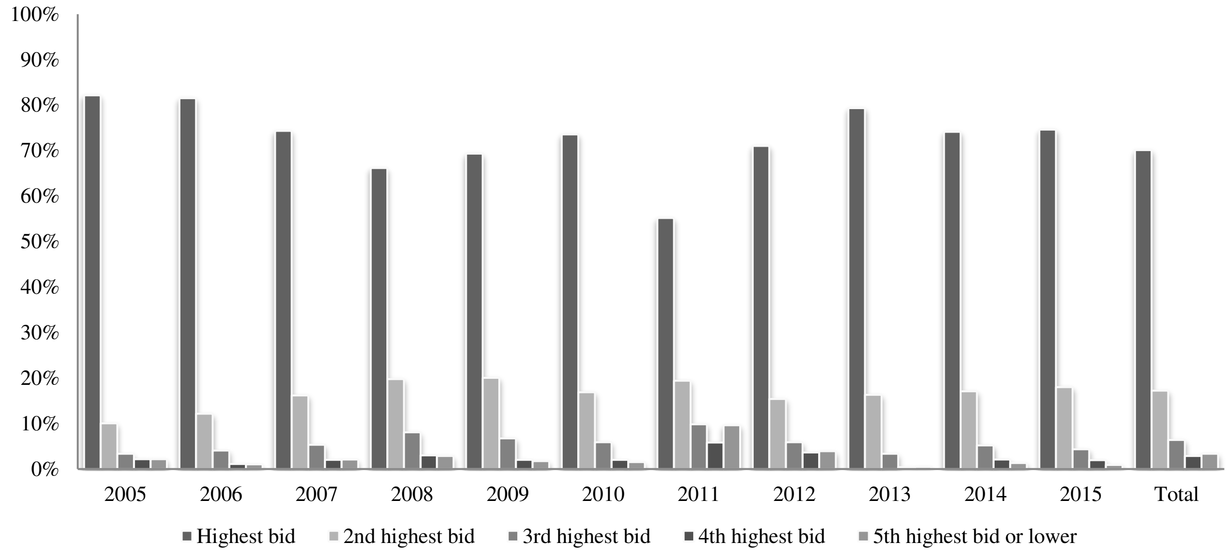

Figure 5

Bid Selection within auction by Bank Risk

The figure depicts the percentage of firms selecting the bank with the lowest, second lowest, third lowest, fourth lowest, and fifth lowest or higher risk in a transaction using banks' CDS spreads at the time of the auction.

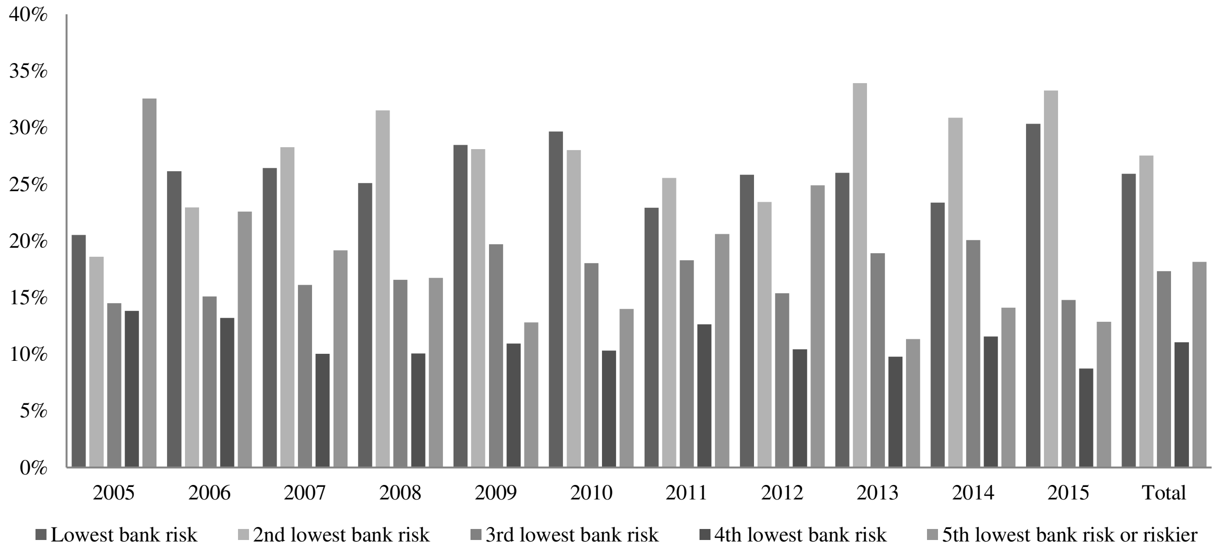

Table 1

Descriptive Statistics

The table shows descriptive statistics using data from January 2005 to December 2015. Bank accounting variables range until 2016 and are matched to the deposit auction data with a one year lag. Bank total assets are measured in real terms with 2005 as the base year using the Consumer Price Index (CPI) as published by the OECD. An *auction* is defined as a deposit offer where at least two different banks bid. Variables are defined in Panel B.

Panel A: Descriptive Statistics

Variable Name	Obs.	Mean	St. Dev.	p(1)	p(50)	p(99)
DEPOSIT AUCTION VARIABLES						
Bid deposit interest rate	446,173	112	144	-19	35	430
Bank Risk (bps)	444,126	117	83	6	103	372
Highest Bid Ratio	4,653	27.98%	0.28	0	0.20	1
BANK ACCOUNTING VARIABLES						
Total Assets (in 2005 € mn.)	445,847	874,682	618,761	1,573	747,571	2,264,468
Leverage	445,847	0.95	0.03	0.86	0.96	0.99
NPL / Total Loans	428,328	0.04	0.03	0.01	0.03	0.11
ROE	445,681	0.05	0.10	-0.43	0.04	0.24
Asset Growth	444,954	0.00	0.09	-0.32	0.00	0.27
Net Interest Margin	444,995	1.19	0.69	0.09	0.98	3.37
OBS Exposure	430,707	0.19	0.13	0.03	0.16	0.61
DEPOSIT OFFERS						
Notional amount (€)	131,932	74,700,000	112,000,000	480,000	35,000,000	500,000,000
Deposit duration (days)	131,932	10.57	28.97	1	1	152
AUCTIONS WITH TRANSACTION(S)						
Notional amount (€)	64,280	81,400,000	128,000,000	700,000	39,000,000	600,000,000
Deposit duration (days)	64,280	9.01	23.81	1	1	115

# Banks	# Firms	# Auctions	Auctions with transaction & min. 2 banks bidding	# Banks bidding	# Banks bidding | min. 2 banks bidding & min. 1 transaction	# Banks selected in auction | min. 1 bank selected
87	486	131,932	64,280	3.38	4.55	1.09

Panel B: Descriptions of variables

Variable Name	Unit	Description
DEPOSIT AUCTION VARIABLES		
Bid deposit interest rate	bps	The deposit interest rate offered by a bank.
Highest bid in auction	0/1	Indicator variable which is one for the highest bid within an auction.
1 = Selected Bid	0/1	Indicator variable which is one for a selected bid.
Bank Auction Failure Rate	%	Number of auctions in which a bank bids and is not selected over the total number of auctions in which a bank bids in a given period.
Bank Risk	%	A bank's 5 year CDS spread on senior unsecured debt as reported in Markit.
First Bid in Auction	0/1	Indicator variable which is one for the first bid within an auction.
Highest Bid Ratio	%	The number of auctions in which a bank bids highest over the total number of auctions in which a bank bids in a given month, aggregating data to the bank-month level.
BANK ACCOUNTING VARIABLES		
log(Total Assets)	ln(€ mn.)	Natural logarithm of a bank's total assets in €-million as recorded in Bankscope.
Leverage	ratio	Ratio of total liabilities to total assets as recorded in Bankscope.
NPL / Total Loans	ratio	Ratio of non-performing loans to gross total loans as recorded in Bankscope.
ROE	ratio	Return on equity calculated as net income over equity as recorded in Bankscope.
Asset Growth	ratio	Annual asset growth as recorded in Bankscope.
Net Interest Margin	%	Net interest margin as recorded in Bankscope.
OBS Exposure	ratio	Ratio of nominal off-balance-sheet items divided by the sum of total assets and off-balance-sheet items, both as recorded in Bankscope.

Table 2

Deposit Interest Rate, Highest Bid and Bank Risk

Panel A of the table reports regression results of the offered deposit interest rate, and Panel B of an indicator variable, which is one for the highest bid in an auction, on control variables. The data range from 2005 to 2015 and include all bank bids of auctions with at least two bids from different banks, which result in at least one transaction. *Bank Risk* is measured via banks' CDS spread. Bank accounting variables are used with their end of previous year value. All variables are defined in Panel B of Table 1. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank and month level. t-statistics are shown in parentheses below coefficient estimates.

Panel A: Bid deposit interest rate and bank risk

Dependent Variable	*Bid deposit interest rate*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bank Risk	3.634***	3.531*	2.645**	2.476	3.078**	2.831**	2.429*	2.325*
	(2.850)	(1.922)	(2.127)	(1.442)	(2.591)	(2.160)	(1.949)	(1.851)
Bank Risk^2		0.022		0.035		0.053		0.022
		(0.080)		(0.136)		(0.221)		(0.091)
Other Transaction Variables								
First Bid in Auction			-0.388	-0.388			-0.137	-0.137
			(-1.004)	(-1.004)			(-0.523)	(-0.523)
Bank Accounting Variables								
log(Total Assets)			-0.751**	-0.751**			-0.478**	-0.478**
			(-2.626)	(-2.627)			(-2.570)	(-2.570)
Leverage			23.869**	23.949*			11.889*	11.947*
			(2.008)	(1.998)			(1.694)	(1.699)
NPL / Total Loans			25.963	26.150			14.663	14.765
			(1.334)	(1.350)			(0.897)	(0.913)
ROE			-0.428	-0.424			-0.813**	-0.810**
			(-0.851)	(-0.841)			(-2.242)	(-2.243)
Asset Growth			-4.483	-4.502			-2.761	-2.771
			(-1.240)	(-1.244)			(-0.969)	(-0.971)
Net Interest Margin			1.146	1.148			1.279	1.280
			(1.054)	(1.054)			(1.520)	(1.520)
OBS Exposure			-3.826	-3.834			-4.086	-4.089
			(-1.057)	(-1.055)			(-1.363)	(-1.362)
Day Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
Auction Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
Observations	291,328	291,328	267,006	267,006	291,159	291,159	264,711	264,711
R-squared	0.989	0.989	0.988	0.988	0.995	0.995	0.994	0.994

Panel B: Highest bid in auction and bank risk

Dependent Variable	*1 = Highest bid in auction*							
	(1)	(2)	(3)	(4)	(7)	(8)	(9)	(10)
Bank Risk	0.115***	0.146**	0.105***	0.129**	0.169***	0.219***	0.150***	0.190***
	(3.282)	(2.260)	(3.341)	(2.252)	(4.235)	(3.241)	(4.399)	(3.289)
Bank Risk^2		-0.007		-0.005		-0.011		-0.008
		(-0.917)		(-0.740)		(-1.455)		(-1.228)
Other Transaction Variables	No	No	Yes	Yes	No	No	Yes	Yes
Bank Accounting Variables	No	No	Yes	Yes	No	No	Yes	Yes
Day Fixed Effects	Yes	Yes	Yes	Yes	No	No	No	No
Auction Fixed Effects	No	No	No	No	Yes	Yes	Yes	Yes
Observations	291,328	291,328	267,006	267,006	291,159	291,159	264,711	264,711
R-squared	0.032	0.032	0.040	0.040	0.173	0.174	0.195	0.196

Table 3

Selection of Banks, Deposit Amount, and Bank Risk

The table reports in Panel A regressions of an indicator variable for the selected bid(s) in an auction on *bid deposit interest rate* in percent (columns (1) and (2)) and an indicator variable for the highest bid in an auction (columns (3) and (4)), and control variables. In Panel B, it shows regressions of an indicator variable for the selected bid(s) in an auction on control variables comparing bids with the same interest rate (columns (1) and (2)) and the same interest rate, which is the highest in the auction (columns (3) and (4)). *Bank Risk* is measured via banks' CDS spread. In columns (2) and (4) bank risk is split via indicator variables for the level of the respective CDS spread of banks. The data range from 2005 to 2015 and include all bank bids of auctions with at least two bids from different banks, which result in at least one transaction. Bank accounting variables are used with their end of previous year value. Panel C follows the setup in Panel B and compares bids with the same interest rate and relationship level (columns (1) and (2)) and the same interest rate, which is the highest in the auction, and relationship level (columns (3) and (4)). Relationship is defined as the amount the firm deposited with a bank on the platform over the last year over the total amount deposited on the platform by this firm. Relationship level is then defined in steps of ten percentage points, that is, banks with a relationship between zero and less than 10% are considered to have the same relationship level, etc. All variables are defined in Panel B of Table 1. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank and month level. t-statistics are shown in parentheses below coefficient estimates.

Panel A: Selection and price

Dependent Variable	*1 = Selected bid*			
	(1)	(2)	(3)	(4)
Bid deposit interest rate	0.625***	0.553***		
	(3.692)	(3.419)		
Highest bid in auction			0.556***	0.555***
			(30.731)	(27.850)
Other Transaction Variables	No	Yes	No	Yes
Bank Accounting Variables	No	Yes	No	Yes
Auction Fixed Effects	Yes	Yes	Yes	Yes
Observations	292,663	266,093	292,663	266,093
R-squared	0.180	0.205	0.428	0.444

Panel B: Selection of banks and bank risk conditional on interest rate bid

Dependent Variable	*1 = Selected bid | Same bid deposit interest rate*		*1 = Selected bid | Same highest bid deposit interest rate*	
	(1)	(2)	(3)	(4)
Bank Risk	-0.032***		-0.092***	
	(-3.605)		(-2.707)	
$1_{Bank\ Risk\ (CDS < 100bps)}$		base case		base case
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		-0.007		-0.018
		(-0.768)		(-0.642)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		-0.045***		-0.114*
		(-2.758)		(-1.727)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		-0.077***		-0.215*
		(-3.355)		(-1.916)
Other Transaction Variables	Yes	Yes	Yes	Yes
Bank Accounting Variables	Yes	Yes	Yes	Yes
Auction-deposit bid rate FE	Yes	Yes	Yes	Yes
Observations	78,098	78,098	19,619	19,619
R-squared	0.521	0.521	0.269	0.269

Panel C: Selection of banks and bank risk conditional on interest rate bid and relationship level

Dependent Variable	*1 = Selected Bid | Same bid deposit interest rate & same relationship level*		*1 = Selected Bid | Same highest bid deposit interest rate & same relationship level*	
	(1)	(2)	(3)	(4)
Bank Risk	-0.023***		-0.148***	
	(-3.317)		(-4.345)	
$1_{Bank\ Risk\ (CDS < 100bps)}$		base case		base case
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		-0.018**		-0.053
		(-2.478)		(-1.378)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		-0.037***		-0.212***
		(-3.288)		(-2.832)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		-0.057***		-0.365***
		(-3.572)		(-3.926)
Other Transaction Variables	Yes	Yes	Yes	Yes
Bank Accounting Variables	Yes	Yes	Yes	Yes
Auction-deposit bid rate-relationship level FE	Yes	Yes	Yes	Yes
Observations	40,848	40,848	6,919	6,919
R-squared	0.605	0.605	0.406	0.405

Table 4

Diversification

The table reports regressions at the firm-time level of the average offered deposit amount per transaction in columns (1) to (3), the number of banks with which a firm deposits in columns (4) to (6), and the total deposited notional of a firm in € million in columns (7) to (9), all in a given period specified at the top of each column. *Average Bank Risk to Firm* is calculated using banks' CDS spreads. Control variables are the same as in Panel A of Table 2. Bank accounting variables are used with their end of previous year value. *Average Bank Risk to Firm* and control variables are used as the average in the previous period using all deposit transactions of the firm. All variables are defined in Panel B of Table 1. The data range from 2005 to 2015 and include auctions, which result in at least one transaction. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the time period level. t-statistics are shown in parentheses below coefficient estimates.

Dependent Variable	*Average amount per auction$_t$*			*Number of banks$_t$*			*Total amount$_t$*		
Time	Week	Month	Quarter	Week	Month	Quarter	Week	Month	Quarter
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Average Bank Risk to Firm$_{t-1}$	-0.053***	-0.047***	-0.058***	0.187***	0.266***	0.228*	0.050	0.123	0.912
	(-11.813)	(-7.559)	(-5.411)	(10.247)	(5.361)	(1.794)	(0.780)	(0.309)	(0.573)
Control Variables$_{t-1}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,648	5,466	2,135	15,648	5,466	2,135	15,648	5,466	2,135
Adjusted R-squared	0.711	0.769	0.828	0.415	0.509	0.606	0.538	0.554	0.572

Table 5

Rationing of Banks – Bank Selection

The table reports regressions of an indicator variable for the selected bid(s) in an auction on control variables. The data range from 2005 to 2015. Column (1) and (2) include all €-deposit bids on the trading platform, columns (3) and (4) include all bids where at least two banks bid for an offered deposit amount, and columns (5) to (8) include all bank bids of auctions with at least two bids from different banks, which result in at least one transaction. In even columns, the deposit interest rate bid of a bank is interacted with indicator variables for the level of the respective CDS spread of banks. Bank accounting variables are used with their end of previous year value. *Bid deposit interest rate* is included in percent. All variables are defined in Panel B of Table 1. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank and month level. t-statistics are shown in parentheses below coefficient estimates.

Dependent Variable	*1 = Selected bid*							
	All bids		*All bids in auctions*		*All bids in auctions with min. 1 transaction*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bid deposit interest rate	0.262***		0.207***		0.322***		0.319***	
	(3.809)		(3.384)		(3.143)		(2.854)	
*Bid deposit interest rate **								
$1_{Bank\ Risk\ (CDS < 100bps)}$		0.233***		0.171**		0.259**		0.239*
		(2.757)		(2.372)		(2.228)		(1.941)
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		0.243***		0.195***		0.312***		0.313***
		(3.648)		(3.263)		(3.057)		(2.840)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		0.321***		0.264***		0.401***		0.402***
		(4.358)		(3.696)		(3.559)		(3.244)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		0.361***		0.300***		0.449***		0.468***
		(3.181)		(3.029)		(3.179)		(3.350)
Bid deposit interest rate^2	-0.048***		-0.026***		-0.028*		-0.017	
	(-4.068)		(-2.728)		(-1.767)		(-1.011)	
Bid deposit interest rate^2 *								
$1_{Bank\ Risk\ (CDS < 100bps)}$		-0.044***		-0.021*		-0.018		-0.004
		(-3.034)		(-1.742)		(-0.968)		(-0.190)
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		-0.046***		-0.027***		-0.030*		-0.021
		(-3.932)		(-2.750)		(-1.835)		(-1.234)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		-0.067***		-0.046***		-0.054**		-0.048*
		(-4.062)		(-2.992)		(-2.435)		(-1.948)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		-0.082***		-0.063**		-0.085**		-0.078**
		(-2.688)		(-2.411)		(-2.184)		(-2.121)
Other Transaction Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Accounting Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	No	No	No	No	No	No	Yes	Yes
Observations	413,670	411,871	371,384	369,740	268,216	267,006	268,214	267,004
R-squared	0.088	0.088	0.021	0.022	0.030	0.031	0.098	0.100

Table 6

Rationing of Banks – Bank Auction Failure

The table reports regressions of the auction failure rate on control variables using data aggregated to the bank-month level using all auctions with at least two bids from different banks, which result in at least one transaction. *Bank auction failure rate* is defined as number of auctions in which a bank bids and is not selected over the total number of auctions in which a bank bids in a given month. In Panel B, columns (1) to (4) include only observations where auction failure rate is not equal to 100% in a month, and columns (5) to (8) use an indicator variable as dependent variable which is one if a bank's auction failure rate is equal to 100% in a month and zero otherwise. *Bid deposit interest rate* is the average monthly interest rate the bank is bidding in percent and *Highest bid ratio* is the number of auctions in which a bank bids highest over the total number of auctions in which a bank bids in a given month. Bank accounting variables are used with their end of previous year value. All variables are defined in Panel B of Table 1. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank level. t-statistics are shown in parentheses below coefficient estimates.

Panel A: Auction failure rate

Dependent Variable	*Bank auction failure rate*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bid deposit interest rate	-0.797***	-0.517***	-1.040***	-0.730***				
	(-7.972)	(-6.580)	(-9.430)	(-8.345)				
Bid deposit interest rate^2			0.091***	0.091***				
			(2.936)	(5.136)				
Highest bid Ratio					-0.713***	-0.665***	-0.871***	-0.818***
					(-20.394)	(-18.852)	(-14.423)	(-14.058)
Highest bid Ratio^2							0.180**	0.178**
							(2.198)	(2.394)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Accounting Variables	No	Yes	No	Yes	No	Yes	No	Yes
Bank FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	4,653	4,181	4,653	4,181	4,653	4,181	4,653	4,181
R-squared	0.208	0.456	0.229	0.468	0.635	0.711	0.638	0.713

Panel B: Auction Failure Rate conditional on Auction Success

Dependent Variable	*Bank auction failure rate | min. 1 bid selected in month*				*1 = No bid selected in month*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bid deposit interest rate	-0.885***	-0.579***	-1.135***	-0.782***	-0.602***	-0.482***	-0.846***	-0.671***
	(-9.728)	(-7.415)	(-9.873)	(-8.255)	(-4.723)	(-5.194)	(-5.725)	(-6.095)
Bid deposit interest rate^2			0.091**	0.104***			0.091***	0.081***
			(2.526)	(3.655)			(3.256)	(3.799)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Accounting Variables	No	Yes	No	Yes	No	Yes	No	Yes
Bank FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	3,729	3,333	3,729	3,333	4,653	4,181	4,653	4,181
R-squared	0.247	0.521	0.264	0.530	0.119	0.437	0.128	0.441

Table 7

Rationing of Banks – Bank Market Exit and Reentry

The table reports regressions of an indicator variable for bank exit in Panel A, bank risk in Panel B, and bank reentry in Panel C on control variables. The data range from 2005 to 2015 and use information on all € deposit bids on the platform. Panels A and C use data at the bank-month level, Panel B data at the bank-firm-month level. *Bank Risk* is measured via banks' CDS spread. *Bank Exit* is defined in Panel A columns (1) to (4) at the bank-month level (Panel A columns (5) to (8) at the firm-bank-month level) and one if a bank is not bidding in a month on the platform (to a firm) while having bid (to the firm) on the platform before and zero when bidding (to the firm) on the platform. Panel B uses data at the firm-bank-month level. In Panel C, *Bank Reentry* is an indicator defined at the bank-month level which is one when a bank bids in a month on the platform but does not bid in the previous month while having bid on the platform before. It is zero in all months when a bank does not bid while having bid on the platform before. All variables are defined in Panel B of Table 1. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank level. t-statistics are shown in parentheses below coefficient estimates.

Panel A: Bank Exit

Dependent Variable	*Bank level*				*Firm-Bank level*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bank Risk$_t$	0.030***		0.040***		0.028***		0.028***	
	(2.782)		(7.039)		(3.172)		(3.063)	
Bank Risk$_{t-1}$		0.031***		0.042***		0.030***		0.028***
		(2.786)		(7.257)		(3.287)		(3.299)
Bank FE	No	No	Yes	Yes	No	No	No	No
Firm-Bank FE	No	No	No	No	No	No	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,339	5,277	5,339	5,277	68,242	65,158	67,590	65,043
R-squared	0.031	0.031	0.464	0.473	0.042	0.036	0.360	0.373

Panel B: Prediction of Bank Risk by Exit

Dependent Variable	*Bank Risk$_{t+n}$*			
	n = 1	n = 2	n = 3	n = 4
	(1)	(2)	(3)	(4)
Bank Exit$_t$	0.028***	0.024***	0.017**	0.015*
	(2.934)	(2.730)	(2.056)	(1.795)
Month FE	Yes	Yes	Yes	Yes
Firm-Bank FE	Yes	Yes	Yes	Yes
Observations	65,058	62,668	60,361	58,156
R-squared	0.836	0.835	0.834	0.834

Panel C: Bank Reentry

Dependent Variable	*Bank Reentry$_t$*				
	(1)	(2)	(3)	(4)	(5)
Bank Risk$_t$	-0.013**				
	(-2.089)				
Bank Risk$_{t-1}$		-0.019**			
		(-2.300)			
Bank Risk$_{t-2}$			-0.019***		
			(-2.820)		
Bank Risk$_{t-3}$				-0.023***	
				(-3.794)	
Bank Risk$_{t-4}$					-0.026***
					(-4.523)
Bank FE	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes
Observations	857	857	851	841	830
R-squared	0.233	0.234	0.236	0.234	0.235

Table 8

The Bank Market Exit Mechanism

The table reports regressions of an indicator variable for bank exit on control variables. The data range from 2005 to 2015 and use information on all € deposit bids on the platform, aggregated to the firm-bank-month level. *Bank Exit* is defined at the firm-bank level and one if a bank is not bidding in a month on the platform to a firm while having bid to the firm on the platform before and zero when bidding to the firm on the platform. *Bank auction failure rate* is defined as the number of auctions in which a bank bids to a firm and is not selected over the total number of auctions in which a bank bids to a firm in a given month. *% bids > ECB rate$_t$* is the number of auctions in which the bank bids above the main refinancing rate to a firm over the total number of auctions in which a bank bids to a firm in a given month using only the fixed interest rate regime of the ECB since October 15, 2008. *% bids > Interbank rate$_t$* is the number of auctions in which the bank bids to a firm above the EONIA interest rate over the total number of auctions in which a bank bids to a firm in a given month. All variables are defined in Panel B of Table 1. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank level. t-statistics are shown in parentheses below coefficient estimates.

Dependent Variable	*Bank Exit$_t$*					
	(1)	(2)	(3)	(4)	(5)	(6)
Bank auction failure rate$_{t-1}$	0.051***			0.058***	0.055***	0.055***
	(5.268)			(5.163)	(4.922)	(5.169)
(% bids > ECB rate)$_{t-1}$		0.071***		0.096***	0.071***	0.082***
		(3.636)		(4.385)	(3.357)	(4.205)
(% bids > Interbank rate)$_{t-1}$			-0.003	-0.002	-0.001	-0.002
			(-0.083)	(-0.064)	(-0.032)	(-0.062)
Bank FE	No	No	No	No	Yes	No
Firm-Bank FE	Yes	Yes	Yes	No	No	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	40,171	30,614	40,171	30,897	30,892	30,614
R-squared	0.241	0.245	0.240	0.022	0.039	0.246

Table 9

Robustness

The table reports regressions of an indicator variable for the selected bid(s) in an auction on control variables. The data range from 2005 to 2015. It includes all bids where at least two banks bid for an offered deposit amount. In even columns, the deposit interest rate bid (and its interaction with an indicator for the highest bid in the auction) of a bank is interacted with indicator variables for the level of the respective CDS spread of banks (in Panel C). Bank accounting variables are used with their end of previous year value. *Bid deposit interest rate* is included in percent. All variables are defined in Panel B of Table 1. *Sovereign Debt Crisis* is defined as the 2010 to 2012 period. *ECB rat*e is defined as the interest rate on the ECB's main refinancing operations since the introduction of a fixed interest rate on October 15, 2008. Panel B only includes auctions where a firm selects only one bank and this bank is the only bank with which the firm deposits on this given day. The statistical significance of results is indicated by * = 10% level, ** = 5% level and *** = 1% level using heteroskedasticity-robust standard errors clustered at the bank and month level. t-statistics are shown in parentheses below coefficient estimates.

Panel A: Sample Splits

Dependent Variable	*1 = Selected bid*													
			Period				*Amount*				*Maturity*		*Alternative Interest Rate*	
	Main		*No Sovereign Debt Crisis*		*Sovereign Debt Crisis*		≤ €100mn.		> €100mn.		*Only Overnight*		*Exclude all bids > ECB rate*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Bid deposit interest rate	0.207***		0.599***		0.223***		0.169***		0.521***		0.461***		0.236***	
	(3.384)		(5.704)		(3.028)		(3.170)		(4.186)		(3.001)		(2.977)	
Bid deposit interest rate *														
$1_{\text{Bank Risk (CDS < 100bps)}}$		0.171**		0.603***		0.116		0.131**		0.477***		0.409**		0.187**
		(2.372)		(5.564)		(0.793)		(2.021)		(3.664)		(2.421)		(2.075)
$1_{\text{Bank Risk (100bps} \leq \text{CDS < 200bps)}}$		0.195***		0.574***		0.202***		0.154***		0.532***		0.458***		0.230***
		(3.263)		(5.187)		(2.765)		(2.954)		(4.127)		(2.931)		(2.859)
$1_{\text{Bank Risk (200bps} \leq \text{CDS < 300bps)}}$		0.264***		0.667***		0.335**		0.232***		0.563***		0.530***		0.311***
		(3.696)		(5.361)		(2.438)		(3.546)		(3.989)		(3.454)		(3.377)
$1_{\text{Bank Risk (CDS} \geq \text{300bps)}}$		0.300***		0.700***		0.328***		0.260***		0.598***		0.509***		0.376***
		(3.029)		(5.170)		(2.808)		(2.864)		(3.089)		(3.287)		(3.041)
Bid deposit interest rate^2	-0.026***		-0.077***		-0.146***		-0.022**		-0.044*		-0.037		-0.061	
	(-2.728)		(-5.248)		(-3.125)		(-2.512)		(-1.908)		(-1.406)		(-1.351)	
Bid deposit interest rate^2 *														
$1_{\text{Bank Risk (CDS < 100bps)}}$		-0.021*		-0.078***		-0.100		-0.016		-0.034		-0.026		-0.049
		(-1.742)		(-5.169)		(-0.687)		(-1.434)		(-1.512)		(-0.918)		(-1.043)
$1_{\text{Bank Risk (100bps} \leq \text{CDS < 200bps)}}$		-0.027***		-0.071***		-0.133**		-0.022**		-0.048*		-0.038		-0.067
		(-2.750)		(-4.485)		(-2.593)		(-2.460)		(-1.883)		(-1.424)		(-1.371)
$1_{\text{Bank Risk (200bps} \leq \text{CDS < 300bps)}}$		-0.046***		-0.096***		-0.233*		-0.043***		-0.061*		-0.059**		-0.097*
		(-2.992)		(-3.982)		(-1.838)		(-2.846)		(-1.908)		(-2.036)		(-1.842)
$1_{\text{Bank Risk (CDS} \geq \text{300bps)}}$		-0.063**		-0.112***		-0.165**		-0.054**		-0.096*		-0.068**		-0.152**
		(-2.411)		(-4.011)		(-2.698)		(-2.160)		(-1.854)		(-2.013)		(-2.255)
Other Transaction Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Accounting Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	371,384	369,740	183,893	183,106	187,491	186,634	290,012	288,578	81,367	81,157	191,621	191,071	289,762	288,644
R-squared	0.021	0.022	0.034	0.034	0.024	0.027	0.020	0.021	0.089	0.090	0.036	0.037	0.021	0.022

Table 9

Robustness cont.

Panel B: Accounting for Diversification

Dependent Variable	1 = Selected bid			
	All bids in auctions with min. 1 transaction			
	(1)	(2)	(3)	(4)
Bid deposit interest rate	0.393***		0.407***	
	(3.196)		(3.008)	
*Bid deposit interest rate **				
$1_{Bank\ Risk\ (CDS < 100bps)}$		0.370***		0.363**
		(2.706)		(2.433)
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		0.375***		0.394***
		(3.012)		(2.915)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		0.459***		0.479***
		(3.247)		(3.199)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		0.497***		0.543***
		(3.060)		(3.174)
Bid deposit interest rate^2	-0.035*		-0.023	
	(-1.755)		(-1.185)	
Bid deposit interest rate^2 *				
$1_{Bank\ Risk\ (CDS < 100bps)}$		-0.032		-0.017
		(-1.438)		(-0.779)
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		-0.031		-0.022
		(-1.449)		(-1.044)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		-0.060**		-0.053*
		(-2.055)		(-1.740)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		-0.077*		-0.074*
		(-1.939)		(-1.748)
Other Transaction Variables	Yes	Yes	Yes	Yes
Bank Accounting Variables	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	Yes	Yes
Firm FE	No	No	Yes	Yes
Observations	100,674	99,988	100,672	99,986
R-squared	0.035	0.036	0.086	0.088

Panel C: Controlling for firms' preference for the highest bid

Dependent Variable	1 = Selected bid			
	(1)	(2)	(3)	(4)
Highest Bid in Auction	0.441***	0.449***	0.436***	0.446***
	(24.547)	(25.262)	(27.684)	(28.331)
*Highest Bid in Auction * Bid deposit interest rate*	-0.012*		-0.002	
	(-1.668)		(-0.391)	
*Highest Bid in Auction * Bid deposit interest rate **				
$1_{Bank\ Risk\ (CDS < 100bps)}$		-0.010		0.000
		(-1.410)		(0.026)
$1_{Bank\ Risk\ (100bps \leq CDS < 200bps)}$		-0.032***		-0.027**
		(-2.962)		(-2.373)
$1_{Bank\ Risk\ (200bps \leq CDS < 300bps)}$		-0.069***		-0.075***
		(-2.708)		(-3.161)
$1_{Bank\ Risk\ (CDS \geq 300bps)}$		-0.086**		-0.119**
		(-2.092)		(-2.528)
Bid deposit interest rate	Yes	No	Yes	No
*Bid deposit interest rate * Bank Risk Interval Indicator Variables*	No	Yes	No	Yes
Other Transaction Variables	Yes	Yes	Yes	Yes
Bank Accounting Variables	Yes	Yes	Yes	Yes
Day FE	Yes	Yes	No	No
Auction FE	No	No	Yes	Yes
Observations	371,384	369,740	368,827	366,977
R-squared	0.233	0.234	0.428	0.430

Appendix A1.

Exemplary Deposit Auction

The table shows an exemplary deposit transaction for illustrative purposes.

Time of trade	Firm ID	Bank Name	Maturity Date	Transaction Start Date	Time of Bank Bid	Product	Currency	Status	Status of Bank Bid	Notional Amount	Quote Value
14-11-2005 12:35:58	xxxxxxxx	Bank1	15-11-2005	14-11-2005	14-11-2005 12:35:43	Deposit	EUR	EXEC	LCAN	76,200,000	2.06
14-11-2005 12:35:58	xxxxxxxx	Bank2	15-11-2005	14-11-2005	14-11-2005 12:35:34	Deposit	EUR	EXEC	EXEC	76,200,000	2.08
14-11-2005 12:35:58	xxxxxxxx	Bank3	15-11-2005	14-11-2005	14-11-2005 12:35:33	Deposit	EUR	EXEC	LCAN	76,200,000	2.07
14-11-2005 12:35:58	xxxxxxxx	Bank4	15-11-2005	14-11-2005	14-11-2005 12:35:35	Deposit	EUR	EXEC	LCAN	76,200,000	2.05
14-11-2005 12:35:58	xxxxxxxx	Bank5	15-11-2005	14-11-2005	14-11-2005 12:35:39	Deposit	EUR	EXEC	LCAN	76,200,000	2.06
14-11-2005 12:35:58	xxxxxxxx	Bank6	15-11-2005	14-11-2005	14-11-2005 12:35:26	Deposit	EUR	EXEC	LCAN	76,200,000	2.07

Trade Number	Identifying number for a specific trade.
Time of Trade	Time when the auction is closed. It shows the date and the exact time in seconds. All transactions are executed on the same day.
Firm ID	Numerical identifier for each firm, anonymized for confidentiality reasons.
Bank Name	Bank names available but changed for confidentiality reasons.
Maturity Date	The maturity of the trade.
Transaction Start Date	The start date of the trade.
Time of Bank Bid	The exact time a bank is bidding for a deposit amount. If a bank provides several bids in a transaction we use the last bid of this bank.
Product	The product which is traded.
Currency	The currency of the product.
Status	The status of the entire auction. EXEC means that the trade is executed.
Status of Bank Bid	The status of each bank's bid in the auction. LCAN means ListCancel, that is, another bank bid was selected by the firm. EXEC depicts the executed trade.
Notional Amount	The notional amount banks bid for.
Quote Value	The deposit interest rate banks are bidding in the auction. Banks bid an annual interest rate in percent using an actual/360 day count convention.