Advantages to Size in Banking: The Price and Management of Reserves[1]

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Abstract

Advantages to Size in Banking: The Price and Management of Reserves

This paper examines the hypothesis that there are economies of scale in banking arising, for example, from large banks being better at "hard" tasks. We focus on reserve management – in particular on what banks pay for reservable funds in ECB repo auctions, which are the main source of euro liquidity. Ours is the first study with access to data on banks' liquidity status (with respect to reserve requirements). Thus, crucially, we are able to control for a bank's liquidity status when examining its auction behavior and performance. We also control for bank type and auction specific conditions such as the level and volatility of the interbank rate as well as auction size. Large banks obtain reserves cheaper than small banks. Studying the reserve data separately, we also find that small banks are more likely than large banks to hold more reserves than necessary, something which is costly. Thus the reserve management evidence is that there are economies of scale in banking.

Keywords: banking, reserve management, liquidity, auctions
JEL: G21, E52, D44

1 Introduction

Berger and Udell (2002) and Stein (2002) argue that small banks, or more generally small organizations, have a comparative advantage relative to large banks in tasks that require processing soft information, such as relationship banking. In support of this, there is evidence that small banks have a higher propensity to lend to small firms [Berger et al (1995) and Peek and Rosengren (1998)]. Additional and more direct evidence supporting the soft information hypothesis is provided by Berger et al (2005). Despite potential advantages to being small, however, there has been considerable consolidation in the banking industry over the last couple of decades. A positive implication is that larger banks have advantages over smaller ones.

Advantages of large banks presumably parallel the advantage of size in other markets; economies of scale and scope and increased market power. Stein (2002) also argues that large banks have an advantage with respect to activities relying on hard information, where the decision process can be made more quantifiable and agency issues are less important than in activities relying on soft information. Sapienza (2002) finds that interest rates charged by consolidated banks fall if the acquisition involves a bank with a small market share. She interprets this as evidence of efficiency gains. In this paper, we use data from German banks to take a direct look at economies of scale in banking. The German banking sector is particularly interesting in this respect because of the sheer number of banks and its diversified nature. At the end of the sample period in December 2001, there were 2,520 deposit taking institutions, including cooperatives and savings banks, owned by their members and municipality, respectively, private banks and foreign banks with German subsidiaries. We investigate a specific function within these banks, namely reserve management. This includes what banks pay for reserves.

The focus on reserve management distinguishes this paper from much of the banking literature, which looks at lending activity. The advantage of examining reserve management performance is that there is homogeneity in the basic activity across deposit taking institutions. Reserves are fungible, loans are not; comparing the rate different institutions pay for reserves is not subject to the same issues of differences in credit risk, term structure,

etc that arise when comparing the terms of loans. Furthermore, reserve management is a "hard" activity. Thus, our paper can be viewed as a clean test of Stein's (2002) hypothesis that large organizations are better at "hard" tasks.

The primary focus of our research is on what banks pay to obtain the funds they are required to hold with the central bank. We investigate this by using individual bank data from the ECB's weekly repo auctions (main refinancing operations), during the period June 2000 to December 2001. In these auctions, banks submit bids for borrowing central bank money against collateral. They are ideal for our purposes for several reasons.

First, the funds obtained in any given auction has maturity of two weeks, meaning that the funds obtained in any given auction will have to be refinanced two auctions later.[1] This stimulates frequent participation by banks. Second, the ECB follows a policy of injecting through these auctions exactly the quantity of liquidity that it calculates that the banking sector needs in aggregate to allow individual banks to fulfill reserve requirements. Thus, while there is an active interbank market where liquidity is reallocated, the auctions are the ultimate source of reservable funds and banks have a need to participate in them.

Third, the auctions are sealed bid and discriminatory (pay your bid). Banks can submit multiple bids, each specifying an interest rate and a quantity, for multiple units. Thus banks pay different rates for the liquidity they obtain, as a function of their bids. Since we have the identity of the bidding banks, we can correlate their performance with the size of their balance sheets.

Fourth, the auctions represent a common market where banks in principle compete on equal footing, whether small or large. Thus the auction provide an excellent setting in which to examine the effectiveness of large versus small banks. It is the fact that the task is so narrow (bidding in the auctions), yet so central to banking, that makes this such a good setting. The fungibility of the basic good also means that there is a high degree of competition. The null hypothesis is that banks do not pay different rates for reserves.

The ECB auctions are open to all institutions in the euro area that face reserve requirements. But not all eligible institutions actually participate. A bank may choose not

[1] In March 2004, the tenor was changed to one week.

to participate in a given auction for example because its current reserves meet its needs for the duration of the reserve maintenance period. In examining the impact of size on performance, we control for banks' need to participate, as captured by its reserve position relative to its reserve requirement (liquidity status). Our dataset also includes the reserve positions of all German financial institutions – not only those that participate in the repo auctions. Thus, we can also examine differences between bidders and non-bidders. Banks that never bid during the sample period tend to be relatively small and have an excess of liquidity relative to reserve requirements.

Our evidence shows that size matters; large banks pay less in the auctions. This is consistent with Stein's (2002) theory that large organizations are better at "hard" tasks. More generally, it is consistent with the view that there are economies of scale in banking. This could arise for example due to increased professionalization of the organization and the staff. Another hypothesis is that the superior performance of large banks in ECB repo auctions reflects that these banks have better access to the interbank market. In this paper, we do not explore which of these hypotheses is the right one, but merely document that large banks do perform better, even after controlling for bank type and liquidity status characteristics. We also control for auction specific conditions, such as the level and volatility of the interbank rate as well as auction size. As an example, we find that the 5% smallest banks pay in excess of 2 basis points (bp) more than the 1% largest banks. In the market for two-week money, 2 bp is a large number – as can be seen by way of comparison to the average auction underpricing in the full sample of around 1.2 bp and the average volatility of the two-week interbank rate on auction days of 5.2 bp.

We are not the first to study repo auctions. But we are the first with access to reserve positions and who study bidders as well as non-bidders. ECB repo auctions were first studied by Bindseil et al (2002), from whose paper one can obtain a number of stylized facts.[2] Of particular relevance to our paper, they find that large bidders pay less than small bidders for funds obtained in the auction. Their evidence also suggests that reserve positions are a key factor in bidder behavior. However, since they do not have access to

[2]Breitung and Nautz (2001) study ECB fixed rate tenders, which were run until June 2000. In these operations, bidding banks submit quantity bids, with the rate being pre-announced by the ECB.

reserve data, they are unable control for reserve positions in their investigation of large versus small banks. Furthermore, they do not have information on non-bidders. Bartzsch, Craig, and Fecht (2005) study a dataset of German bidders and find that different types of financial institutions pay different rates in the auctions. These authors also do not have access to data on reserve positions or on non-bidders. While we corroborate some of the findings in these papers, our focus on reserve management sets our paper apart from them.

We do not only study the rates that bidders bid at and end up paying, but also look at reserve management in a broader sense, for example by investigating the extent to which banks overfulfill reserve requirements. This is interesting because of the euro area remuneration scheme on reserves. Banks receive an interest rate on reserves up to their individual required holdings equal to the average stop-out rate in the weekly repo auctions. Excess reserves, however, only get a rate which is 100 basis points below the minimum bid rate in the auctions. Excess reserves are thus expensive to hold. Nevertheless, we find that some banks hold excess reserves. Small banks generally have higher fulfillments than large banks.

2 Institutional Background and Data

2.1 The Structure of the German Banking Sector

The German banking sector has a three pillar structure. The first pillar, the private domestic commercial banks, made up around 40% of the entire banking sector in terms of balance sheet total by the end of 2000. This pillar contains the four big commercial banks as well as the regional and other commercial banks. Furthermore, this pillar also includes the mortgage banks which are also almost entirely private corporations. The second pillar are the public banks. This group comprises the savings banks and the savings banks' regional head institutions, the Landesbanks, which are jointly owned by the respective state and the regional association of savings banks. While the Landesbanks account for 20% of the German banking sector in terms of balance sheet total, the savings banks had around 16% of the German banking sector's asset under management by the end of 2000.

The cooperative banking sector with the credit cooperatives and the cooperative central banks, which are primarily owned by the regional credit cooperatives, constitute the third pillar. They comprised 12% of the German banking sector of which the credit cooperatives accounted for 9 percentage points. Besides those major banking groups special purpose banks (like the Kreditanstalt für Wiederaufbau) and buildings societies (Bausparkassen) account for 7% and 2% of the banking sector, respectively. Branches of foreign banks operating in Germany made up 2% of the German banking sector by the end of 2000.[3]

This three pillar structure affects the way in which liquidity is reallocated in the banking sector. The public banks as well as the cooperative banking sector form a relatively closed giro system. On balance, the second-tier institutions – the savings banks and the credit cooperatives – typically achieve a significant liquidity surplus due to their retail business structure. Within the giro-systems, they pass this excess liquidity on to the respective (regional) head institution. Consequently, on average in the years 2000 and 2001 savings banks held almost 75% of their interbank overnight deposits with their respective Landesbank. At the same time only slightly more than 50% of savings banks overnight borrowing was obtained from the regional Landesbank. Similarly, credit cooperatives granted more than 90% of their overnight interbank loans to one of the cooperative central banks, while they only received around 30% of their overnight interbank borrowing from the cooperative central banks. Conversely, the cooperative cental banks obtained around 60% of the daily interbank liabilities from credit cooperatives, while Landesbanks, however, received less than 30% of their overnight interbank loans from the regional savings banks. Instead they obtained the waste majority of their short-term interbank funds from foreign banks.[4]. Thus savings (i.e. public) and cooperative banks may have less of a need to participate directly in the market for reserves than private banks. Therefore, when examining the performance of large versus small banks, we will control for bank type.

[3]For a more detailed description of the German banking sector see, for example, Hackethal (2004).

[4]For a broader discussion of the interbank linkages in the German banking sector in general and within the three pillars in particular see Deutsche Bundesbank (2000) and Upper and Worms (2004). Ehrmann and Worms (2004) analyze the implications of the head institution feature of the German banking sector on the monetary transmission process

2.2 Minimum Reserve Requirements

According to ESCB (European System of Central Banks) regulation all German credit institution including subsidies and branches of foreign banks in Germany are subject to a minimum reserve requirement. The required reserves have to be held as average end-of-business-day balances over the maintenance period on the account with the national central bank. During the sample period of this paper, reserve maintenance periods had a length of one month, starting on the 24th of each month and ending on the following 23rd.

The required reserve holdings are remunerated at the average stop-out rate of the auctions studied in this paper, the ECB main refinancing operations, during the respective maintenance period. Reserve holdings that exceed the minimum requirement are not remunerated, but can be transferred to the standing deposit facility which is always 100 basis points below the minimum bid rate in the auctions.

The ECB also operates with a marginal lending facility, where banks can borrow against collateral at a rate which is 100 basis points above the minimum bid rate in the auction. If a bank fails to hold sufficient reserves, for example because it fails to make up a reserve shortfall at the marginal lending facility, the ECB can impose any of the following sanctions: It can require payment of 1) up to 5 percentage points above the marginal lending rate or 2) up to two times the marginal lending rate on the difference between the required and the actually held reserves. Furthermore, the ECB can call for the provision of non-interest bearing deposits up to three times the amount the respective bank failed to provide for. The maturity of those deposits must not exceed the period during which the institution failed to meet the reserve requirement. Moreover, the ECB can impose additional sanctions if an institution repeatedly fails to comply with the reserve requirement.

The basis for the calculation of a bank's reserve requirement is its end-of-calendar-month short-term liabilities,[5] held by non-banks or banks outside the euro area two months

[5]More precisely, these are the overnight deposits, deposits with an agreed maturity up to two years, deposits redeemable at notice up to two years, and issued debt securities with agreed maturity up to two years.

before the maintenance period. For example, a bank's reserve requirements for the maintenance period starting May 24th are determined by its short term liabilities on March 31. The minimum reserve requirement is 2% of these liabilities.[6] Thus banks that are financed primarily with short-term liabilities are required to hold relatively more reserves.

2.3 The Auctions

There is a main refinancing operation every week, each with a tenor of two weeks during the sample period.[7] Thus there are up to five auctions within each reserve maintenance period. Each auction is timed to coincide with the maturity of funds obtained in the second-to-previous auction. The auctions are scheduled well in advance; the intended timing of all regular operations in a year are announced three months before the start of the year. Typically, the auctions are scheduled for Tuesdays, 9:30 am, with terms being announced on Mondays, 3.30 pm. Results are announced on the auction day at 11:20 am. Winning bids are settled the following business day. The auctions are open to all banks in the European Monetary Union.

In each auction, each bidder can submit up to 10 bids which are rate-quantity pairs for two week money. The tick size is 1 basis point and the quantity multiple is 100,000 euros. There are no non-competitive bids. There is a pre-announced minimum bid rate. This rate is determined at the meetings of the ECB's Governing Council, normally held on the first and third Thursday of each month during the sample period. The minimum bid rate was changed six times during the sample period. It started out at 4.25%, changed to 4.5% in time for the 5 September 2000 auction, then increased to 4.75% in time for the 11 October 2000 auction, fell back to 4.50% for the auctions held on and after 14 May 2001, fell further to 4.25% for the auction on and after 4 September 2001, to 3.75% on 18

[6]For a more detailed description of the Eurosystem's minimum reserve system see European Central Bank (2005).

[7]Once a month, the ECB also holds *longer-term refinancing operations* with a maturity of three months. We do not study these auctions. See Linzert et al (2006). The ECB may also hold non-regular, fine-tuning operations with non-standard maturities, for example overnight, but none occurred during the sample period.

September 2001 and to 3.25% on 13 November 2001, at which level it remained until the end of the sample period.

Included with the auction announcements, the ECB publishes an estimate of liquidity needs for the entire euro area banking sector for the following week. Given the ECB's neutral allotment policy, this provides bidders with an unbiased estimate of the auction size. We refer to this liquidity neutral amount as the expected auction size. Deviations may occur because of the lag between the auction announcements (Mondays, 3.30pm) and the allotment decision (Tuesdays, 11.20am). During this period, the ECB may have updated its forecast of the banking sector's liquidity needs. Deviations from the expected auction size also occur in a few instances where banks in aggregate demanded less than the liquidity neutral amount, speculating on decreases in the minimum bid rate in time for the next auction in the maintenance period. However, as documented in Bindseil et al (2002), deviations tend to be very small, averaging to less than 1% of the pre-announced liquidity neutral amount. Thus, bidders face little supply uncertainty in these auctions.

2.4 Data

Our analysis makes use of three datasources supplied by the Bundesbank. First, we have the complete set of bids made by German registered financial institutions, broken down by bidder, in all 78 ECB repo auctions (main refinancing operations) in the period 27 June 2000 to 18 December 2001. This covers 18 reserve maintenance periods. The number of German bidders in an auction varies from 122 to 546.

Second, we have reserve data from *all* 2,520 German registered financial institutions in the period May 2000 to December 2001 that were required to hold reserves with the central bank as of December 2001. The reserve data covers 842 bidders in the main refinancing operations and 1,678 non-bidders. A bidder is defined as a bank that bid at least once and therefore is in the auction data. The reserve data consists of each institution's cumulative reserve holdings within the maintenance period, as well as its marginal (or actual) reserve holding, at the at the end of each business day preceeding an auction. In addition, we have each institution's reserve requirement for each maintenance period over the sample period.

Note that the reserve data is not available for 518 institutions that ceased operating as stand-alone entities during the sample period. 17 of these submitted bids in the auctions.

Third, we have end-of-month balance sheet data for each bank, also supplied by the Bundesbank. These come from bank balance sheet statistics that German banks are required to report to the Bundesbank on a monthly basis. As a measure of size, we thus use the book value of a bank's total assets at the end of each calendar month.

Unique bank codes allow us to track banks over time and correlate bidding decisions with characteristics such as size and fulfillment of reserves. The complete bidding data consists of 59,644 individual bids and 25,345 individual demand schedules from 859 bidders. Deleting the bids from the 17 bidding banks for which we do not have reserve data reduces this to 59,156 individual bids and 25,120 individual demand schedules from 842 different bidders. We lack asset data on 7 bidders, taking the number of bidders for which we have complete data down to 835.

The dataset is pruned further as follows: First, we exclude 45 banks that are registered with zero reserve requirement in every maintenance period during the sample period. Second, we throw out two extreme outliers; the first is a non-bidder that has an average reserve fulfillment (relative to required reserves) of 190,926%. The second is a bidder with an average reserve fulfillment of 3,011%. Without this bank, the average fulfillment of private domestic bidding banks is 100.1%; with this bank, the average is 131.8%. The next highest average reserve fulfillment among private banks is 146.8%. This takes the dataset down to 834 bidders and 1,632 non-bidders. Third, we exclude Bausparkassen and special purpose banks (14 institutions)[8] and head institutions of savings and cooperatives (16 institutions). The analysis below is thus carried out on a final set of 804 bidders (and 22,758 individual demand schedules) and 1,632 non-bidders.

[8]These institutions have very low reserve requirements, averaging to around 0.1% of total assets. This is substantially lower than for other banking sectors, reflecting that they have different functions than typical banks. The Bausparkassen sector also includes several extreme outliers with respect to reserve fulfillment.

3 Descriptive Statistics

The summary statistics we present in this section break our dataset out in several ways. First, we differentiate between bidders, i.e. those banks that submit bids in at least one auction, and on non-bidders. Second, within these two categories, we differentiate between four different types of banks, as described above; private banks (domestic), saving banks, cooperatives, and branches of foreign banks. Finally, we also categorize the banks into size percentiles, by asset value.

3.1 Definitions of Liquidity Status Variables

To measure banks' liquidity status, we focus on the variables "fulfillment" and "normalized net excess reserves", described below. These are different ways of gauging the extent to which a bank is short or long reserves going into an auction.

Fulfillment is a bank's cumulative reserve holdings as a percentage of its cumulative required reserves, within a reserve maintenance period.

$$\text{fulfillment}_{ijp} = \frac{\text{cumulative holding}_{ijp}}{\text{cumulative required reserves}_{ijp}} \times 100, \tag{1}$$

where i refers to the bank, j to the auction, and p to the reserve maintenance period. Multiplying by 100 means that we express fulfillment as a percentage. The fulfillment is measured for each bank using reserve data at the close business the day before each auction. A fulfillment of 100% means that the bank has held reserves thus far in the maintenance period with a daily average exactly equal to the average daily requirement the bank faces this period. Thus, a fulfillment of less (more) than 100% indicates that the bank is short (long).

To define normalized net excess reserves, we start with the "gross excess reserves". This compares the reserves the bank has on deposit with the central bank the evening before the auction with what it needs to hold on a daily basis for the balance of the reserve maintenance period in order to exactly fulfill reserve requirements.

$$\text{gross excess reserves}_{ijp} = \text{holding}_{ijp} - \text{required remaining daily holding}_{ijp}, \tag{2}$$

where

$$\text{required remaining daily holding}_{ijp} = \frac{\text{required total monthly reserves}_{ip} - \text{cumulative holding}_{ijp}}{\text{days left of maintenance period}_{jp}}. \quad (3)$$

The "net excess reserves" nets out from a bank's holding the loan from two auctions ago that matures at the time of the current auction.

$$\text{net excess reserves}_{ijp} = \text{gross excess reserves}_{ijp} - \text{maturing repo}_{ijp} \quad (4)$$

where maturing repo_{ijp} is the amount the bidder won in auction $j-2$. Since this amount matures at the time of auction j, the net excess reserves is what the bank needs to borrow in the auction in order to be even with respect to its reserve requirements. A negative (positive) net excess reserves is indicative of the bank being short (long).

We normalize the net excess reserves for size by dividing it by the average daily required holding:

$$\text{normalized net excess reserves}_{ijp} = \frac{\text{net excess reserves}_{ijp}}{\text{average daily required reserves}_{ip}} \times 100. \quad (5)$$

In a similar way, we also define the "normalized gross excess reserves" by dividing the gross excess reserves by the average daily required reserves.

3.2 Liquidity Status Statistics

Table 1 provides summary statistics on bidding banks, broken down into the four bank categories. We see that private domestic banks are substantially larger on average than the other categories. Mean asset values are: EUR 22,694 million for private banks, 2,091 million for savings banks, 678 million for cooperatives, and 2,256 for branches of foreign banks. So, on average by asset value, private banks are approximately 10 times larger than savings and foreign banks, which in turn are approximately 3 times as large as cooperatives. The smallest asset value in the sample is 25.96 million (a cooperative), and the largest value is 267,591 million (a domestic private bank).

Mean daily reserve requirements are: 132.4 million for private banks, 22.1 million for savings banks, 7.8 million for cooperatives, and 17.1 million for foreign banks. By this

measure, on average, private banks are almost 7 times larger than savings banks, almost 8 times larger than foreign banks, and approximately 17 times larger than cooperatives. The largest average daily reserve requirement is 2,901.6 million (a domestic private bank). This is quite small in comparison to a typical auction size of around 90 billion.

In terms of the liquidity status variables, we see that private domestic banks have a mean fulfillment of 100.25%, measured the day before the auctions. Savings banks and cooperatives have similar mean fulfillments, 102.65% and 102.94%, respectively. The mean fulfillment across foreign institutions is 142.30. So, on the average, as measured by fulfillment, German bidders are slightly long going into the auctions. However, there is substantial variation across banks. The smallest average fulfillment among bidders is 50.85 (a private bank) and the largest is 685.95% (a foreign bank).

The other liquidity status variable we focus on in our analysis is the normalized net excess reserves. This varies from $-3,739.82\%$ (a private bank) to 968.01% (a foreign bank) and is negative as an average across bidders for each bank sector. By this measure, German bidders are short going into the auctions. The difference from the fulfillment measure is that this measures the holdings to date, while the normalized net excess reserves measures what the banks need going forward, taking into account that they may need to refinance a maturing repo. A bank that always has a fulfillment of 100% and borrows in every auction will have a negative normalized net excess reserves measure for every auction.

Table 2 provides summary statistics on non-bidding banks. A comparison with Table 1 shows that non-bidders are smaller than bidders, both in terms of asset values and reserve requirements. An explanation may be that participating in the auctions is costly, perhaps because it requires systems, staff, or simply time to familiarize oneself with the rules and procedures. We see that the fulfillment is approximately the same for bidding and non-bidding savings banks and slightly larger for non-bidding than bidding cooperatives. It is substantially larger for non-bidding private domestic and foreign banks as compared with bidding banks. In sharp contrast to the case of bidders, for each bank sector, the normalized net excess reserves has a positive mean across non-bidders. Thus, non-bidders are comparatively small and long, while bidders are comparatively large and short.

Table 3 examines whether the fulfillment of reserves is different over time for bidders

and non-bidders. Following Bindseil et al (2002) we divide the auctions into four categories, depending on their position within the reserve maintenance period. Auction 1 is the first auction in the maintenance period. Auction 4 is the last, and Auction 3 is the penultimate one. Auction 2 consists of all other auctions; that is, all second auctions in the maintenance period plus all third auctions in maintenance periods where there are five auctions. In the aggregate the table reveals only very small differences in the pattern of fulfillment over the maintenance period. Both bidders and non-bidders have smaller fulfillments going into the first auction than in subsequent auctions; 92.05% (bidders) and 97.55% (non-bidders) in Auction 1 versus average fulfillments varying between 102.59% and 105.42% in subsequent auctions. The table also reports on the fulfillment deviation, the standard deviation around 100% (rather than the mean) across all auctions, calculated for each bank separately and then averaged across banks. While there are differences across bank categories, with private domestic and foreign banks having substantially larger fulfillment deviations than savings banks and cooperatives, there are only small differences between bidders and non-bidders. So there seems to be little relation between a bank's decision to bid in the auction and the extent to which it smooths its reserve holdings over time.

3.3 Bidding and Performance Measures and Statistics

Table 4 reports on various bidding and performance characteristics, by bank type. This table draws on all banks that bid at least once. For each bank, we measure the relevant variables first for each individual demand schedule (i.e. across the bidders' set of bids in a given auction). Then we average across demand schedules for each bank to obtain a population of observations, whose summary statistics are reported in the table.

To benchmark bids and rates paid in the auctions, we follow Bindseil et al (2002) and use the two week Eonia swap rate taken as the midpoint of the bid and ask from Reuters quotations at 9:15 a.m. on the auction day. Our bidding and performance variables are:

- Bidding frequency: percentage of auctions a bank participates in.[9]

[9]This means that, unlike the other variables in this list, bidding frequency is not an average across a bank's demand schedules in different auctions.

- Number of bids: the number of interest rate-quantity pairs.
- Demand to reserve requirement: demand (summed across individual bids) divided by the bank's reserve requirement (in the maintenance period where the auction occurs).
- Award ratio: a bidder's award in an auction as a percentage of his demand.
- Award to total award: a bidder's award in an auction as a percentage of aggregate award in that auction to financial institutions registered in Germany.
- Discount: the swap rate less the bidder's quantity weighted average bid rate.
- Relative discount: a bidder's discount in a given auction less the average discount in that auction across bidders.
- Underpricing: the swap rate less the bidder's quantity weighted average winning bids.
- Relative underpricing: a bidder's underpricing in a given auction less the average underpricing in that auction across bidders (in the sample).
- Ex post normalized excess reserves: similar to normalized net excess reserves, but adds in the bidder's award.

Among the bidding banks, private banks participate more frequently than other banks, specifically they bid on average in 48.95% of the 78 auctions. Cooperatives participate in the fewest number of auctions, only 27.51%. As seen by comparing Tables 1 and 2 the cooperative sector also has the smallest participation rate, as measured by the percentage of banks in the sector that bid at least once. The average number of bids per demand schedule varies from 1.87 (foreign banks) to 2.29 (savings banks).

There are substantial differences across bank categories in performance, as measured by underpricing and relative underpricing. Private banks have an average underpricing and relative underpricing of 1.24 bp and .77 bp, respectively. For savings banks, the corresponding numbers are 1.66 bp and $-.01$ bp; for cooperatives they are 0.78 bp and

−.87 bp; and for foreign banks they are .69 bp and −.18 bp. Thus private banks are the best performers, having a relative underpricing which is 1.64 bp higher than cooperatives, which are the worst performers.[10]

The award ratio measures the relative aggressiveness of a bidder. An award ratio of 100% in a given auction means that all of a bidder's bids won, i.e. all his bids were above the stop-out rate. Thus the bidder can be said to have been highly aggressive relative to other bidders. An award ratio of 0 is indicative of very cautious bidding. We see relatively small differences in award ratios across bank categories. It ranges from 54.90% for private banks to 58.97% for cooperatives. As a measure of bidding aggression, this measure is thus consistent with the smaller relative underpricing we observe for private banks.

The award to total award varies from 0.03% (cooperatives), 0.09% (savings), 0.19% (foreign), and 0.63% (private). The maximum is 11.58% (a private domestic bank). These numbers illustrate how small any bank in this market is compared to the market size.

4 Bank Size, Liquidity Status, and Auction Performance

In this section, we document that bidding performance is related to bank size. We start by tabulating univariate statistics for different size groups. We then present cross-sectional regressions and finally panel regressions, which allow us to control for a variety of relevant factors in examining the relation between size and performance.

[10] A caveat with respect to using the raw underpricing number, instead of the relative underpricing, to gauge performance is that it gives more weight to the early auctions in the sample period, since these auctions had a higher participation rate (see Bindseil et al (2002) for a discussion of the decreasing time trend in the number of bidders). Since interbank rates were higher around these auctions, premia in these auctions were higher than in later auctions.

4.1 Univariate Statistics

We start by studying differences in liquidity status across size groups. We divide the sample of bidders and non-bidders into two sets of 12 size groups, sorted by average asset value. That is, for all bidders, we first calculate each bank's average asset value throughout the sample period and place the banks into the following percentile groupings: 0 - 5, 6 -10, 11 - 20, 21 - 40, 41 - 60, 61 -80, 91 - 95, 96, 97, 98, and 99. We do the same for non-bidders.

We report on liquidity status statistics across auctions for these groups in Table 5. Panel (a) reports on bidders and panel (b) on non-bidders. We will focus on bidders. The average asset value for banks in the 99th percentile is 105,928.50 million euros, while the average size of banks in the 0-5th percentiles is 71.22 million. This illustrates that there is a large heterogeneity in terms of size. The table reveals that larger banks tend to have lower fulfillments going into the auctions than smaller banks; in the 99th percentile the average fulfillment is 94.00%, while it is 111.61% in the smallest group. The 99th percentile is also more short by other measures; for example, the normalized gross excess reserves is -8.11% for the 99th percentile and 39.00% for the smallest group. The normalized net excess reserves is -372.45 for the 99th percentile and -14.70 for the smallest group. Larger banks are also less long among non-bidders. But for all non-bidding size groups, the normalized net excess reserves is positive, illustrating again that bidders tend to be more short than non-bidders.

Table 7 provides statistics on bidding and performance by size. First, we see that large banks participate more frequently. The average number of auctions participated in for the 99th percentile is 68.04, while it is 20.36 for small banks.

Underpricing and relative underpricing are dramatically different across size groups. Underpricing is negative for the three smallest groups (up to the bottom 20 percent), and relative underpricing is negative for the six smallest groups (up to the bottom 80 percent). These differences appear to reflect that larger banks place their bids at lower rates, as evidenced by their larger discounts and relative discounts. The differences in underpricing and relative underpricing, respectively, between the 99th percentile and the

0-5th percentiles are 2.09 bp and 2.06 bp. But the best performing percentile is actually the 97th, which has an underpricing of 1.35bp as compared with .76 for the 99th percentile. The higher bids of small bidders is reflected in their higher award ratios, this is 65.36% for the group of the smallest banks but only 52.40% for those in the 97th percentile.

The smallest group also disperse their bids more, the standard deviation of discounts across bidders within the group is 1.41 bp for the 99th percentile and 3.63 bp for the smallest group. These statistics show clearly that large banks bid less aggressively than small banks even though they tend to have shorter positions, which we would expect to lead to more aggressive bidding, ceteris paribus.

Table 6 provides statistics on the fulfillment by auction position within the maintenance period across the size groups. Among bidders, differences between small and large bidders are not very distinct. However, striking differences are found among non-bidders. The smallest percentile group has a typical fulfillment of 127.37% at the final auction, while the 99th percentile has a fulfillment of 103.18. Given that overfulfillment costs a bank at least 100 bp, this supports the view that small banks manage their reserves less well than large banks. This complements the finding above that small banks pay more in the auctions than large banks.

4.2 Cross Sectional Regressions

In this subsection, we look more closely at the relation between bank size and performance by regressing the bidding and performance measures listed above on asset size. We control for a bank's liquidity status by including its net normalized excess return in the regressions as well as its type (private domestic, savings, cooperative, foreign).

In particular, for each bidder, we consider the following dependent variables, as averages across the auctions (where the bidder participated or won some units): underpricing, discount, award ratio, demand to required reserves, and ex post normalized excess reserves. As independent variables, we employ the bidder's average asset size and net normalized excess reserves over the sample period. We also include bank sector dummy variables for savings, cooperatives, and foreign banks, thus taking private domestic banks as the

benchmark. Standard errors are adjusted for heteroscedasticity by using the Huber/White estimate of variance.

The cross-sectional regression results are reported in Table 8. The findings are consistent with the univariate analysis above; underpricing increases in bank size. The regressions use the natural log of the size of a bank's balance sheet, measured in millions of euros, as a dependent variable. The coefficient on ln(size) in the underpricing regression is .2. In other words, an increase in size by a factor of e leads to a .2 bp increase in underpricing. The coefficient on the normalized net excess reserves is positive, but insignificant. In other words, there is weak evidence that bidders that are "more long" have lower underpricing.

The regression evidence on the underpricing size effect can be compared to the increase in underpricing in the larger size groups as reported in Table 7. Going from the smallest group to the 98th and 99th percentile groups represents an increase in the natural log of the average asset size of approximately 5.8 and 7.2, respectively. According to the regression results, this gives an increase in underpricing from the lowest to the 98th and 99th percentile groups of approximately 1.16 bp and 1.46 bp, respectively. This is lower than the differences reported in Table 7 of 2.21 and 2.06, respectively. This reflects that the smallest group has an exceedingly poor performance. Comparing the second smallest size group (6-10th percentile) to the 98th percentile, we have an increase in ln(asset size) of approximately 5.2, which according to the regression results gives an increase in underpricing 1.04 bp. This is in line with the numbers in Table 7, which shows a difference of 1.19 bp.

The regression results in Table 8 on the discount shows that this measure is not related to bank size. This is surprising given the strong relation between underpricing and bank size. Thus larger banks appear to obtain reserves at lower rates in the auctions than smaller banks without actually bidding at lower rates. An explanation may be that they are better at guessing the stop-out price; they may cluster their bids tighter around the stop-out rate than do smaller banks. In the next version of this paper, we will examine this tighter clustering hypothesis more closely. The cross-sectional regressions also present evidence that short banks are more aggressive in the auctions. They have lower discounts and have larger demand to reserve requirement ratios. A surprising finding, however, is

that this increased aggressiveness does not appear to lead to a statistically significant lower underpricing.

By design, the cross-sectional regressions fail to control for auction specific conditions, such as the size of the auction, the swap rate, and the volatility of the swap rate. These variables are found by Bindseil et al (2002) to impact on bidding and performance. The cross-sectional regressions also do not control for variations in bidders' liquidity status across auctions. To control for these issues, we therefore turn to panel analysis.

4.3 Panel Analysis: Probit

Our first piece of panel analysis is to develop a probit model to study a bank's decision to participate, taking into account not only bank specific variables such as size, liquidity status, and type, but also auction specific variables.

The auction specific variables we use follow Bindseil et al (2002). In particular, we define the swap spread as the two week Eonia swap rate at 9:15 on the auction day (see above) less the minimum bid rate in the auction. The expected auction size is the liquidity neutral amount as announced by the ECB the afternoon before the auction. We also follow these authors in calculating the conditional volatility of the swap rate using a modified GARCH model, based on daily observations at 9:15 as just described (see Appendix 2) in the period 4 January 1999 to 20 December 2001. All these variables are shown by Bindseil et al to impact on bidding in ECB repo auctions. We also use a fourth auction specific variable, namely the *negative swap spread*. This is a dummy variable which is 1 if the swap rate is below the minimum bid rate and zero otherwise. Bindseil et al find that this occurs for some auctions and that it has an adverse impact on bidder's demand.

Summary statistics for the auction specific variables are in Table 9. On auction days, the swap spread has an average of 5.91 bp, with a standard deviation of 8.66 bp. The volatility of the swap rate has an average of 5.32 bp on auction days, with a standard deviation of 1.33 bp. The expected auction size has an average of 84.256 billion euros, with a standard deviation of 28.829 billion.

The dependent variable in the probit model is a dummy variable that takes a value of

1 if a bank submits a bid in a given auction and a value of 0 if a bank does not submit a bid in that auction. With

$$\text{Prob}(Y = 1) = \beta' x \tag{6}$$

and

$$\text{Prob}(Y = 0) = 1 - \beta' x, \tag{7}$$

this gives rise to the following specification under the normal distribution:

$$\text{Prob}(Y = 1) = \int_{-\infty}^{\beta' x} \phi(t)dt = \Phi(\beta' x). \tag{8}$$

where β' is the transpose of β, and ϕ and Φ represent the probability density function and cumulative distribution function, respectively, of the standard normal distribution.

The explanatory variables capture bank and auction characteristics. Bank level variables are the natural log of the bank's total assets in EUR million at the end of the month that immediately precedes the month in which the auction is held, the bank's normalized net excess reserves at the time of the auction, and three bank sector dummy variables (savings, cooperative, and foreign). Auction level variables are the swap spread, the volatility (of the swap rate), the expected auction size, and a negative swap spread dummy variable, all as described above. The probit estimation uses auction fixed effects and is run separately for all sample banks and for bidders only (those banks that submit a bid in at least one auction).

The results are similar whether we run the Probit model on all banks (left column of Table 10) or on bidders only (right column). We see that large banks are more likely than small banks to submit a bid in an auction. The coefficient on size is significantly positive at the 1% level, in both models. This confirms the findings on differences in asset size of bidders versus non-bidders in Tables 1 and 2 as well as the differences in the frequency of participation reported in Table 7.

The coefficient on the normalized net excess reserves is significantly negative at the 1% level, telling us that a bank is more likely to bid the shorter its reserve position is. We also see that banks are less likely to bid when the swap spread is negative, confirming the finding of Bindseil et al (2002) that underbid auctions are associated with negative

swap spreads. The model also includes swap spread itself, whose coefficient is significantly positive. So, after having controlled for the event that the swap spread is negative, we find that larger swap spreads are associated with an increased likelihood of participation. This may be related to the finding in Bindseil et al (and supported in the panel regressions below) that underpricing is increasing in the swap spread; i.e., empirically, participating is relatively more attractive when the swap spread is large.

Finally, the volatility of the swap spread and the expected auction size do not significantly affect the likelihood that a bank participates in the auction. The positive and significant coefficient for savings banks is consistent with the descriptive statistics in Table 1 and Table 2. Savings banks represent the only of the four groups of banks with a larger number of bidding than non-bidding banks. By contrast, foreign banks are less likely to submit a bid in the auctions.

4.4 Panel Regressions

In this section, we run panel regressions with auction fixed effects on underpricing, relative underpricing, discount, relative discount, award ratio and ex post excess reserves. We use the same explanatory variables as in the probit analysis in the previous subsection. Standard errors are adjusted for heteroscedasticity by using the Huber/White estimate of variance.

Table 11 reports the results. Each column represents a different regression. The underpricing and relative underpricing regressions confirm our earlier results that large banks perform better. The coefficients on ln(size) in the underpricing and relative underpricing regressions are both positive, 0.16 and 0.17 respectively, and statistically significant. Along the same lines as in the cross-sectional regressions, however, the coefficient on ln(size) in the discount and relative discount regressions are not significant. Still, in the award ratio regression the coefficient on ln(size) is a significant -0.86, suggesting that large banks are less aggressive than small banks. It is just that this lower aggression is not picked up by the discount.

The regressions also show banks place bids at lower rates when they are short, as ev-

idenced by the statistically significant negative coefficients in the discount and relative discount regressions. Surprisingly, this does not translate into a lower underpricing. However, further evidence that short banks are more aggressive is seen in the award ratio regression, where the coefficient on the normalized net excess reserves is a significant 9.33.

Our findings also confirm the univariate statistics on differences among bank sectors. However, now that we are controlling for a host of other variables, the effect is smaller than previously. In particular, we see that a cooperative pays about 0.4 bp more than a similar domestic private bank for the reserves it obtains in ECB repo auctions.

5 Conclusion

We argue that reserve management is an ideal laboratory to test for the effect of bank size on efficiency, as the basic activity is homogenous across banks and reserves provide the maximum level of fungibility. The results show that large banks do better than small banks. The result is strong, in the sense that it is evident in the univariate statistics as well as in cross-sectional and panel regressions. The result holds after controlling for bank specific conditions, such as the bank's liquidity status and type, and auction specific conditions such as the swap spread, volatility, and auction size. We find that large banks pay less in ECB repo auctions for reserves and also are less likely to hold more reserves than required.

The results in our paper have implications for the discussion of the economic impact of bank size. Our finding that large banks obtain reserves at lower rates than small banks might be driven by an increase in professionalization in larger entities. Our findings could also arise as a result of large banks having better access to the interbank market. Whatever the case, our results show that there are advantages to size in the important banking activity of reserve management.

Our evidence has implications for the discussion on mergers and acquisitions in the financial industry. The existence of efficiency gains in larger entities can be regarded as one important determinant for regulators in assessing the benefits and drawbacks of a further consolidation in the banking industry. The evidence in this paper has also implications

for central banks in their conduct of monetary policy. The results suggest that monetary policy and in particular interest rate decisions are not uniformly transmitted into the financial sector, but rather depend on the distribution of banks' size. Investigating the causes and consequences of this would be an interesting avenue for further research.

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Appendix 1: Tables

Table 1: Liquidity Status by Bank Type: Bidders

Descriptive statistics on the major variables for four types of banks as classified by the Deutsche Bundesbank: Private banks, savings banks, cooperatives, and foreign banks. All variables are collected for each bank the day before each auction and means are calculated for each bank (unconditonally, i.e., not conditional on the bidding decision). The table reports summary statistics of these means across banks within each bank type.

	units	mean	std	s.e.	min	max	N
Panel (a): Private Banks							
Assets	mill	22794.24	52774.34	5472.44	62.13	267591.30	93
Reserve requirement (daily)	mill	132.43	438.16	45.44	0.20	2901.60	93
Holding	mill	130.53	431.59	44.75	0.01	2952.42	93
Fulfillment	%	100.25	15.53	1.61	50.85	157.03	93
Remaining res req (daily)	mill	136.73	443.94	46.03	-0.40	2689.52	93
Gross excess reserves	mill	-6.74	56.54	5.86	-336.59	229.81	93
Normalized	%	14.55	41.83	4.34	-77.78	244.37	93
Maturing repo	mill	188.95	608.30	63.08	0.00	4426.27	93
Norm Net excess reserves	%	-243.82	530.25	54.98	-3739.82	212.39	93
Panel (b): Savings Banks							
Assets	mill	2091.95	2753.98	143.95	169.51	31385.47	366
Reserve requirement (daily)	mill	22.06	27.48	1.44	1.26	314.89	366
Holding	mill	22.07	26.84	1.40	1.25	289.04	366
Fulfillment	%	102.65	6.08	0.32	84.22	133.01	366
Remaining res req (daily)	mill	20.80	29.41	1.54	1.30	395.77	366
Gross excess reserves	mill	1.23	6.42	0.34	-105.98	20.62	366
Normalized	%	7.48	9.35	0.49	-35.88	40.76	366
Maturing repo	mill	22.17	54.64	2.86	0.00	717.68	366
Norm Net excess reserves	%	-81.53	126.12	6.59	-1187.84	25.81	366
Panel (c): Cooperatives							
Assets	mill	677.91	1379.60	76.64	25.96	18582.33	324
Reserve requirement (daily)	mill	7.81	13.25	0.74	0.24	127.10	324
Holding	mill	7.98	14.71	0.82	0.23	171.05	324
Fulfillment	%	102.94	8.15	0.45	74.05	159.71	324
Remaining res req (daily)	mill	7.18	12.16	0.68	0.22	112.85	324
Gross excess reserves	mill	0.78	4.03	0.22	-4.38	69.38	324
Normalized	%	9.42	13.17	0.73	-48.10	70.77	324
Maturing repo	mill	3.63	11.59	0.64	0.00	123.88	324
Norm Net excess reserves	%	-31.90	66.10	3.67	-585.01	44.27	324
Panel (d): Foreign Banks							
Assets	mill	2255.80	2585.97	564.31	30.66	8009.40	21
Reserve requirement (daily)	mill	17.09	18.91	4.13	0.02	62.31	21
Holding	mill	18.77	21.36	4.66	0.28	66.69	21
Fulfillment	%	142.30	139.77	30.50	71.77	685.95	21
Remaining res req (daily)	mill	17.90	20.33	4.44	-0.94	70.42	21
Gross excess reserves	mill	0.99	3.71	0.81	-6.20	12.00	21
Normalized	%	103.94	278.41	60.75	-14.55	965.91	21
Maturing repo	mill	26.28	46.96	10.25	0.00	169.07	21
Norm Net excess reserves	%	-206.53	663.91	144.88	-1950.78	968.01	21

Table 2: Liquidity Status by Bank Type: Non-Bidders

Descriptive statistics on the major variables for four types of banks as classified by the Deutsche Bundesbank: Private banks, savings banks, cooperatives, and foreign banks. All variables are collected for each bank the day before each auction. For non-bidders, there is no difference between gross excess reserves and net excess reserves and there is never a maturing repo.

	units	mean	std	s.e.	min	max	N
Panel (a): Private Banks							
Assets	mill	1477.72	6847.49	665.09	11.11	69252.90	106
Reserve requirement (daily)	mill	6.99	16.73	1.62	0.01	131.21	106
Holding	mill	7.71	17.67	1.72	0.03	134.53	106
Fulfillment	%	169.61	279.13	27.11	26.84	2073.32	106
Remaining res req (daily)	mill	5.96	16.11	1.56	-16.40	111.36	106
Gross excess reserves	mill	1.74	4.33	0.42	-5.77	23.70	106
Normalized	%	208.58	804.73	78.16	-141.00	5452.11	106
Norm Net excess reserves	%	210.83	808.20	78.50	-141.97	5584.70	106
Panel (b): Savings Banks							
Assets	mill	894.65	748.57	55.34	61.38	4573.03	183
Reserve requirement (daily)	mill	10.10	8.59	0.63	0.61	43.16	183
Holding	mill	10.12	8.57	0.63	0.80	41.79	183
Fulfillment	%	102.67	6.24	0.46	88.77	135.04	183
Remaining res req (daily)	mill	9.33	7.99	0.59	0.01	42.26	183
Gross excess reserves	mill	0.77	1.43	0.11	-0.95	9.21	183
Normalized	%	8.13	12.59	0.93	-10.69	126.32	183
Norm Net excess reserves	%	8.30	12.77	0.94	-10.25	129.95	183
Panel (c): Cooperatives							
Assets	mill	234.38	302.07	8.46	11.52	4220.17	1275
Reserve requirement (daily)	mill	2.86	3.58	0.10	0.01	40.26	1275
Holding	mill	2.89	3.59	0.10	0.07	40.78	1275
Fulfillment	%	105.93	79.51	2.23	74.53	2476.16	1275
Remaining res req (daily)	mill	2.70	3.48	0.10	-1.51	41.10	1275
Gross excess reserves	mill	0.19	0.48	0.01	-3.16	6.99	1275
Normalized	%	24.77	318.50	8.92	-120.34	9015.81	1275
Norm Net excess reserves	%	25.33	325.48	9.12	-233.86	9219.97	1275
Panel (d): Foreign Banks							
Assets	mill	1474.30	2976.73	405.08	12.39	15486.32	54
Reserve requirement (daily)	mill	9.61	27.29	3.71	0.00	191.84	54
Holding	mill	11.62	30.18	4.11	0.04	211.32	54
Fulfillment	%	535.17	1414.76	192.52	52.87	8213.70	54
Remaining res req (daily)	mill	7.94	24.78	3.37	-17.23	168.70	54
Gross excess reserves	mill	3.74	7.60	1.03	-2.17	45.32	54
Normalized	%	1687.19	5682.14	773.24	-15.68	35075.25	54
Norm Net excess reserves	%	1697.84	5726.84	779.32	-15.89	35075.25	54

Table 3: Fulfillment Over Time

The table reports on the average fulfillment across bidders and non-bidders for each auction position within the reserve maintenance period. Auction 1 is the first auction. Auction 2 is the second auction and the third auction if there are five auctions in the period. Auction 3 is the penultimate auction. Auction 4 is the final auction in the maintenance period. Fulfillment is in percent. It is calculated for each bank for each auction position. Means across banks per auction position are reported. Fulfillment deviation is calculated first for each bank as follows: average of the tsquare root of the sum of squared deviations of the fulfillment from 100% across all auctions. For each type, we then report the average across banks. Standard deviations across banks within the bank type are in parentheses. All measures are in percentages.

Bank type	**Auction 1**	**Auction 2**	**Auction 3**	**Auction 4**	**Fulfillment Deviation**	**N**
Panel (a): Bidders (bid at least once)						
All	92,05	103,97	105,42	102,59	19,09	833
	(11,73)	(13,93)	(11,90)	(5,41)	(11,22)	
Private	89,88	97,45	100,88	101,70	25,52	93
	(16,47)	(19,93)	(16,99)	(9,20)	(11,13)	
Savings	92,77	106,35	106,36	102,55	16,94	366
	(10,01)	(11,05)	(8,21)	(2,96)	(9,74)	
Cooperative	92,93	104,87	106,67	103,11	18,04	324
	(10,28)	(11,34)	(10,56)	(3,70)	(11,13)	
Foreign	89,15	99,53	105,14	104,18	27,63	21
	(16,10)	(19,15)	(22,15)	(16,04)	(10,24)	
Panel (b): Non-Bidders (never bid)						
All	97,55	103,71	104,75	103,97	14,85	1620
	(12,72)	(11,59)	(10,54)	(8,31)	(10,76)	
Private	96,14	106,77	109,80	109,53	27,04	104
	(20,06)	(21,87)	(22,19)	(18,08)	(13,81)	
Savings	94,88	105,73	105,51	102,54	14,28	183
	(9,18)	(11,04)	(8,77)	(2,79)	(9,13)	
Cooperative	98,01	103,11	104,11	103,42	13,33	1274
	(10,94)	(8,88)	(8,20)	(6,45)	(9,46)	
Foreign	96,89	108,17	107,18	109,77	29,11	48
	(29,43)	(28,72)	(22,24)	(17,57)	(13,84)	

Table 4: Bidding and Performance of Individual Banks by Type: Across Banks
Descriptive statistics on bidding and performance variables for four types of banks as classified by the Deutsche Bundesbank: Private banks, savings banks, cooperatives, and foreign banks. Averaging by bank: Means of each variable are calculated first for each bank. The reported statistics are then calculated across banks for each bank type. Conditional on bidding.

	units	mean	std	s.e.	min	max	N
Panel (a): Private Banks							
Bidding frequency	%	48.95	32.40	3.36	1.28	98.72	93
Number of bids		2.18	0.72	0.07	1.00	4.57	93
Demand to reserve req	%	909.07	1749.32	182.38	15.07	12124.14	92
Award ratio	%	54.90	23.75	2.46	0.00	100.00	93
Award to total award	%	0.63	1.69	0.18	0.00	11.58	93
Discount	bp	3.04	2.07	0.21	-4.50	9.69	93
Underpricing	bp	1.24	1.75	0.19	-5.50	5.58	89
Relative discount	bp	0.14	1.57	0.16	-4.89	5.92	93
Relative underpricing	bp	0.07	0.86	0.09	-3.47	1.65	89
Ex post normalized excess reserves	%	143.78	391.72	40.84	-139.03	2271.65	92
Panel (b): Savings Banks							
Bidding frequency	%	44.43	32.47	1.70	1.28	100.00	366
Number of bids		2.29	0.88	0.05	1.00	5.13	366
Demand to reserve req	%	285.41	228.18	11.93	21.38	1503.59	366
Award ratio	%	57.41	23.62	1.23	0.00	100.00	366
Award to total award	%	0.09	0.17	0.01	0.00	1.97	366
Discount	bp	3.32	2.81	0.15	-5.50	17.50	366
Underpricing	bp	1.66	1.90	0.10	-5.75	9.25	352
Relative discount	bp	-0.09	1.76	0.09	-8.14	12.10	366
Relative underpricing	bp	-0.01	1.09	0.06	-7.71	3.46	352
Ex post normalized excess reserves	%	31.92	60.63	3.20	-134.00	547.72	359

Table 4: (cont.)

	units	mean	std	s.e.	min	max	N
Panel (c): Cooperatives							
Bidding frequency	%	27.51	25.41	1.41	1.28	100.00	324
Number of bids		2.05	1.09	0.06	1.00	9.00	324
Demand to reserve req	%	249.83	280.80	15.60	13.26	3062.99	324
Award ratio	%	58.97	26.29	1.46	0.00	100.00	324
Award to total award	%	0.03	0.06	0.00	0.00	0.77	324
Discount	bp	3.47	4.09	0.23	-14.00	31.25	324
Underpricing	bp	0.78	2.55	0.15	-14.00	8.25	308
Relative discount	bp	-0.18	2.91	0.16	-14.24	21.37	324
Relative underpricing	bp	-0.87	1.80	0.10	-14.13	3.88	308
Ex post normalized excess reserves	%	54.06	143.54	8.07	-125.20	2149.62	316
Panel (d): Foreign Banks							
Bidding frequency	%	34.68	27.90	6.09	1.28	97.44	21
Number of bids		1.87	0.84	0.18	1.00	4.22	21
Demand to reserve req	%	939.11	1218.19	272.40	73.36	4721.26	20
Award ratio	%	58.34	28.36	6.19	0.00	100.00	21
Award to total award	%	0.17	0.32	0.07	0.00	1.15	21
Discount	bp	2.84	4.24	0.93	-4.75	13.25	21
Underpricing	bp	0.69	1.94	0.44	-4.75	3.29	19
Relative discount	bp	-0.15	2.35	0.51	-7.45	4.64	21
Relative underpricing	bp	-0.18	1.42	0.33	-5.71	1.02	19
Ex post normalized excess reserves	%	335.01	743.61	170.60	0.71	3141.72	19

Table 5: Liquidity Status by Assets

We calculate means of each variable for each bank across all auctions. We then report the mean across banks.

		Asset value percentiles											
	Units	0-5	6-10	11-20	21-40	41-60	61-80	81-90	91-95	96	97	98	99
Panel (a): Bidders (bid at least once)													
Assets	mill	71.22	130.60	222.60	434.42	864.10	1,649.05	3,545.54	6,907.01	11,569.87	16,515.70	23,995.47	105,928.50
Reserve req (daily)	mill	0.80	1.52	2.57	4.92	9.74	18.40	36.85	58.60	74.92	106.75	96.82	650.81
Fulfillment	%	111.61	102.70	110.86	104.05	102.31	101.84	102.57	101.56	96.65	97.29	95.91	94.00
Holding	mill	0.81	1.54	2.58	4.96	9.75	18.49	37.66	58.99	76.80	112.73	101.53	626.41
Remn res req (daily)	mill	0.66	1.39	2.33	4.49	9.05	17.13	34.37	56.02	75.18	97.86	102.85	681.74
Gross excess res	mill	0.15	0.15	0.25	0.47	0.70	1.36	3.28	2.97	1.61	14.87	-1.32	-54.76
Normalized	%	39.00	10.55	21.65	11.75	7.43	7.28	9.03	8.45	12.18	3.89	9.50	-8.11
Maturing repo	mill	0.39	0.67	1.12	2.46	7.45	13.60	38.85	102.27	78.65	73.25	86.60	926.53
Norm Net excess res	%	-14.70	-33.96	-40.29	-66.45	-66.39	-75.16	-116.78	-225.22	-82.20	-247.68	-135.94	-372.45
Panel (b): Non-Bidders (never bid)													
Assets	mill	25.14	39.85	60.19	102.94	184.16	328.14	609.59	1,018.87	1,401.83	1,763.59	2,188.70	6,849.52
Reserve req (daily)	mill	0.23	0.42	0.69	1.24	2.33	3.91	7.05	11.99	15.10	18.29	23.16	36.83
Fulfillment	%	127.50	124.71	155.51	119.18	103.09	115.79	110.90	102.84	104.10	126.36	103.58	100.43
Holding	mill	0.27	0.45	0.76	1.34	2.37	3.98	7.08	12.23	15.37	19.22	23.99	39.23
Remn res req (daily)	mill	0.14	0.33	0.52	1.00	2.13	3.55	6.55	11.38	13.83	17.29	20.99	34.93
Gross excess res	mill	0.12	0.11	0.24	0.33	0.23	0.42	0.52	0.84	1.54	1.93	3.00	4.29
Normalized	%	98.29	107.89	153.28	76.88	13.22	103.46	32.61	11.37	13.42	77.80	13.85	21.77

Table 6: Fulfillment over Time by Assets

Table reports on fulfillments for different auctions for bidders and non-bidders.

		Asset value percentiles											
	Units	0-5	6-10	11-20	21-40	41-60	61-80	81-90	91-95	96	97	98	99
Panel (a): Bidders (bid at least once)													
Auction 1	%	105.04	96.97	95.15	96.20	94.01	92.67	93.32	93.19	90.72	84.91	79.74	88.84
Auction 2	%	79.74	88.84	108.56	114.81	132.00	106.60	108.74	105.87	105.95	105.19	103.73	95.42
Auction 3	%	103.73	95.42	85.16	78.64	88.36	151.26	114.13	126.07	106.73	106.80	105.65	106.06
Auction 4	%	105.65	106.06	105.45	104.49	93.16	89.64	84.11	90.24	148.93	111.70	117.66	103.44
Panel (b): Non-Bidders (never bid)													
Auction 1	%	123.28	117.52	147.15	113.61	99.54	110.18	107.63	152.78	97.84	137.05	96.58	87.48
Auction 2	%	129.23	128.64	158.25	119.94	104.26	116.62	114.92	176.58	112.56	120.56	114.01	107.63
Auction 3	%	128.80	127.25	160.12	121.23	104.45	116.77	115.05	170.20	106.22	122.06	112.06	103.99
Auction 4	%	127.37	127.45	151.70	120.49	103.95	119.05	111.13	163.18	102.81	119.45	106.54	103.18

Table 7: Bidding and Performance by Assets

Averaging by auction and by bank. For each size group, means of each variable are calculated first for each auction. The reported statistics are then calculated across auctions for each size group. This corrects for sensoring bias (due to changing composition of bidders over time).

		Asset value percentiles											
	Units	0-5	6-10	11-20	21-40	41-60	61-80	81-90	91-95	96	97	98	99
Bidders (bid at least once)													
Bidding frequency	%	20.36	22.49	24.34	31.16	38.40	42.87	59.25	52.62	56.57	44.71	42.82	68.04
Number of bids		1.65	1.83	1.99	2.13	2.14	2.39	2.24	2.35	2.36	2.13	2.05	2.19
Underpricing	bp	-1.33	-0.39	-0.17	0.17	0.31	0.55	0.72	0.67	1.00	1.35	0.80	0.76
Relative													
Underpricing	bp	-1.88	-0.94	-0.76	-0.41	-0.27	-0.03	0.13	0.08	0.43	0.46	0.32	0.18
Discount	bp	0.78	1.12	1.35	1.25	1.37	1.54	1.50	1.47	2.16	2.23	2.07	1.59
Relative discount	bp	-0.95	-0.61	-0.37	-0.47	-0.35	-0.18	-0.23	-0.26	0.42	0.35	0.39	-0.12
Award ratio	%	65.36	69.23	64.47	69.14	66.69	63.02	64.79	64.32	52.24	52.40	53.60	63.78
Award to													
total award	%	0.01	0.01	0.02	0.02	0.06	0.09	0.20	0.54	0.38	0.34	0.57	3.87
Demand to													
reserve req	%	447.41	287.05	363.37	377.17	303.22	303.56	326.96	850.82	651.73	1,047.59	482.51	833.34
Ex post norm													
excess reserves	%	57.97	30.20	46.20	39.73	22.73	21.77	21.02	79.06	12.37	17.40	57.79	54.71
GROUP													
Number bidders		39.96	39.73	75.38	155.70	158.15	158.67	78.67	38.89	8.00	8.00	7.78	15.73
Fraction winners	%	94.23	95.46	93.87	94.47	92.93	92.03	90.45	92.21	86.37	88.94	87.13	89.71
Std of discount	bp	3.63	2.64	2.58	2.03	1.88	1.68	1.29	1.44	1.47	1.37	1.44	1.41
Award to													
total award	%	0.07	0.09	0.27	1.18	3.46	6.08	8.96	10.29	1.66	1.36	1.71	38.26

Table 8: Cross-Sectional Regression

Each column represents a separate regression. Standard errors are adjusted for heteroskedasticity by using the Huber/White estimate of variance. *, **, *** denote significance (two-tailed) at the 10%, 5%, and 1% level, respectively.

	Units	Underpricing bp	Discount bp	Award Ratio %	Demand to res. req. %	Ex post excess res %
Constant		-0.320	4.242	54.439	407.859	-1,674.467
		(0.50)	(4.67)***	(7.64)***	(2.34)**	(1.44)
LN(Size)	ln(mill.)	0.200	-0.091	-0.383	-1.318	386.906
		(2.89)***	(0.90)	(0.50)	(0.06)	(2.00)**
Norm net excess reserves	%	< 0.001	< 0.001	-0.015	-2.058	-1.754
		(1.40)	(2.62)***	(2.40)**	(4.91)***	(0.95)
Savings Bank		0.568	-0.114	4.517	-280.804	-801.198
		(2.37)**	(0.39)	(1.52)	(3.43)***	(1.66)*
Cooperative		-0.067	-0.175	6.306	-215.982	-305.612
		(0.22)	(0.43)	(1.77)*	(2.57)***	(0.70)
Foreign Bank		-0.288	-0.389	3.463	84.492	445.490
		(0.62)	(0.40)	(0.53)	(0.35)	(0.52)
R2		0.048	0.019	0.093	0.553	0.106
N		768	804	804	802	788

Table 9: Auction Specific Exogenous Variables

Descriptive statistics of exogenous auction specific variables. Swap spread is the difference between the two week swap rate and the minimum bid rate at 9:15 a.m./ on the auction day. Volatility of swap rate is the conditional volatility of the two week swap rate on auction days (see the Appendix). Expected auction size is the liquidity neutral amount, which is computed from the liquidity figures announced by the ECB the afternoon on the day prior to the auctions. Units of measurement are in the second column.

	units	mean	std	s.e.	min	max	N
Swap spread	bp	5.913	8.658	0.980	-9.000	48.250	78
Volatility of swap rate	bp	5.322	1.332	0.151	0.194	9.304	78
Expected auction size	bill	84.256	28.829	3.264	5	177	78

Table 10: Probit estimations

The results for all banks are reported in the left column, the results for the bidding banks are reported in the right column. The probit estimations are run with auction fixed effects. *, **, *** denote significance (two-tailed) at the 10%, 5%, and 1% level, respectively.

	Units	All Banks Bidding = 1	Bidding Banks Bidding = 1
Constant		-3.714	-1.773
		(39.56)***	(13.55)***
LN(Size)	ln(mill.)	0.346	0.159
		(53.35)***	(27.50)***
Norm net excess reserves	%	-0.003	-0.002
		(76.04)***	(16.55)***
Swap spread	bp	0.012	0.018
		(4.98)***	(4.50)***
Neg. Swap spread		-0.214	-0.249
		(4.10)***	(3.68)***
Volatility	bp	-0.005	-0.012
		(0.44)	(0.77)
Exp.Auction Size	bill	0.001	0.001
		(1.22)	(1.53)
Savings Bank		0.455	0.194
		(21.98)***	(6.29)***
Cooperative		0.065	-0.001
		(2.85)***	(0.02)
Foreign Bank		-0.378	-0.265
		(11.29)***	(6.48)***
Pseudo R2		0.344	0.183
Log pseudolikelihood		-44,019.743	-32,310.770
N		171,449	59,465

Table 11: Panel Regression

Each column represents a separate regression. The panel regressions are run with auction fixed effects. Standard errors are adjusted for heteroskedasticity by using the Huber/White estimate of variance. *, **, *** denote significance (two-tailed) at the 10%, 5%, and 1% level, respectively.

	Units	Underpricing bp	Rel. Underpricing bp	Discount bp	Rel. Discount bp	Award Ratio %	Ex post excess res %	Demand to res req %
Constant		-1.80	-1.37	0.45	-0.91	39.50	599.17	393.941
		(1.55)	(5.00)***	(0.35)	(1.51)	(3.37)***	(0.13)	(6.56)***
LN(Size)	ln(mill.)	0.16	0.17	0.05	0.06	-0.86	203.11	9.141
		(8.97)***	(10.56)***	(1.34)	(1.53)	(2.73)***	(0.27)	(1.69)*
Norm net excess reserves	%	< 0.01	< 0.01	< 0.01	< 0.01	-0.01	9.33	-1.014
		(0.77)	(0.33)	(3.65)***	(4.67)***	(6.50)***	(4.55)***	(15.91)***
Swap spread	bp	0.15	0.01	0.29	0.03	-0.86	30.24	5.179
		(2.77)***	(1.07)	(4.11)***	(1.00)	(2.00)**	(1.09)	(6.46)***
Neg. Swap spread		-3.09	-0.09	-3.09	0.17	25.04	621.72	-76.475
		(4.80)***	(0.87)	(4.22)***	(0.61)	(4.56)***	(0.70)	(4.51)***
Volatility	bp	-0.36	0.00	-0.31	0.02	-0.80	-89.08	7.975
		(1.94)*	(0.01)	(1.57)	(0.33)	(0.54)	(0.51)	(1.92)*
Exp.Auction Size	bill.	0.030	-0.001	0.018	0.001	0.341	38.5714	-.755
		(3.64)***	(0.43)	(2.00)**	(0.86)	(3.98)***	(4.20)***	(2.74)***
Savings Bank		0.06	0.01	-0.40	-0.43	8.36	-3381.90	-342.729
		(0.97)	(0.26)	(3.73)***	(4.17)***	(7.99)***	(3.18)***	(11.1)***
Cooperative		-0.37	-0.42	-0.42	-0.44	5.75	-3740.37	-324.711
		(5.61)***	(8.27)***	(4.36)***	(5.24)***	(4.89)***	(5.45)***	(9.64)***
Foreign Bank		0.14	0.17	-0.31	-0.31	6.42	2623.71	26.368
		(1.09)	(1.81)*	(1.94)*	(2.19)**	(3.56)***	(2.24)**	(0.54)
R2		0.52	0.05	0.51	0.02	0.15	0.02	0.3996
N		18540	18540	22758	22758	22758	22758	22758

Appendix 2: Volatility of Swap Rate

To estimate the conditional volatility of the two week swap rate, we apply a modified GARCH(1,1) model (Bollerslev, 1986) to daily rate changes. We have considered various calendar effects, as in Hamilton (1996), but not all are in the final specification. Our model is based on that in Bindseil et al (2006). However, our final specification has a somewhat better fit in the period we are studying as compared to theirs.

Table 12: Conditional Volatility of Swap Rate

This table reports the results of the conditional volatility estimation of the two-week swap rate, using a modified GARCH(1,1) model. Panel (a) gives the coefficients of the mean equation, while panel (b) gives the coefficients of the variance equation.

Slope is the difference between 12 and 1 month Euribor. (-1) stands for the preceding day's observation Downswap takes the value 1 if the swap rate fell the previous day and 0 otherwise. ECBMEET(-1) is 1 if there was a meeting of the ECB Governing Council the previous day. Underbid(-1) is 1 if there was an underbid auction. (An auction is underbid if total demand is less than the liquidity neutral amount. For this purpose, total demand is the demand of all, not only German, bidders. See Bindseil et al (2002) for a discussion of these auctions.) Endmonth takes the value 1 if the day is the last business day of a month and 0 otherwise, Endres takes the value 1 if the day is the last business day of a reserve maintenance period and 0 otherwise. Endres(-1) is a dummy variable for the first business day in a maintenance period. Mainrepo takes the value 1 if the day is an auction day (main refinancing operation) and 0 otherwise.

	Coefficient	z-statistics
Panel (a): Mean equation		
Constant	-0.003	-1.181
Slope(-1)	0.015	2.686
Downswap(-1)×ECBMEET(-1)	0.023	2.289
Downswap(-1)×Underbid(-1)	-0.073	-12.91
Panel (b): Variance equation		
C	0.002	7.982
ARCH(1)	0.123	3.188
GARCH(1)	0.565	8.782
Endmonth	-0.003	-10.657
Endres(-1)	-0.002	-9.215
Endres	-0.002	-6.265
Mainrepo	-0.0005	-4.042