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BIDDING AND PERFORMANCE IN REPO AUCTIONS: EVIDENCE FROM ECB OPEN MARKET OPERATIONS

BY KJELL G. NYBORG, ULRICH BINDSEIL AND ILYA A. STREBULAEV

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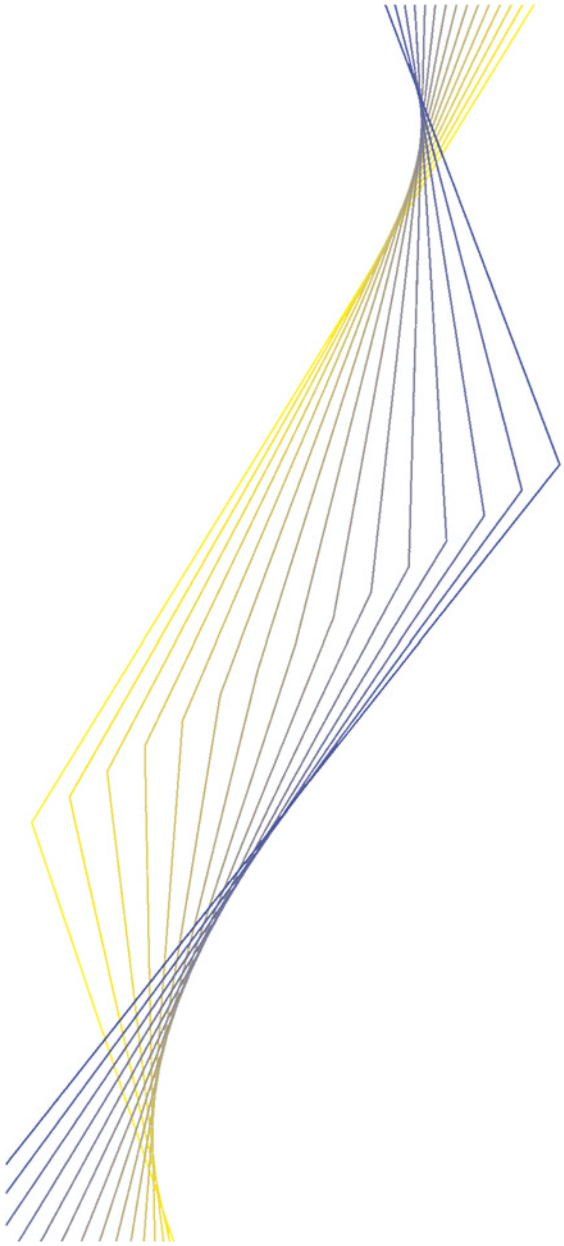

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Abstract

Bidding and Performance in Repo Auctions: Evidence from ECB Open Market Operations

We study bidder behavior and performance in 53 main refinancing operations ("repo auctions") of the European Central Bank (ECB). The data set starts with the first auction after the ECB changed from fixed rate tenders to variable rate tenders. We find that private information and the winner's curse are not important in these auctions. The minimum bid rate and the level of secondary market rates play a crucial role in bidder behavior and auction performance. We also document that large bidders do better than small bidders, apparently because they use "smarter" strategies which involve using more bids and having more kurtosis in their individual bid distribution. The penultimate auction in every reserve maintenance period has less underpricing than the other auctions within the maintenance period. Finally, from the two cases of underbidding covered by the sample period, it appears this was driven by particularly large cutbacks by large, rather than small, bidders.
JEL Classification Numbers: G21, G12, D44, E43, E50.
Keywords: Repo auctions, multiunit auctions, discriminatory auctions, reserve requirements, money markets, central bank, interest rates, collateral, open market operations.

Non-technical summary

Repo auctions play an integral role in the implementation of the ECB's monetary policy. In these auctions, banks submit bids for borrowing central bank funds on a collateralized basis, and they are the primary vehicle used by the ECB for controlling the amount of reservable funds in the banking sector. This contrasts with the Fed which relies primarily on open market operations where it deals directly with primary dealers in the secondary market. The terminology "repo auction" is not used by the ECB itself, which prefers the terminology "refinancing operation." Depending on the country in which the borrowing bank is located, the borrowing is either done as an outright repurchase agreement or as a collateralized loan. Our focus is on the functioning of the main refinancing operations, which are held every week and in which banks submit bids for two week money.

We study bidding and performance in the ECB's repo auctions (specifically, the main refinancing operations), using a unique dataset provided by the ECB. This starts with the first auction after the ECB changed from fixed rate tenders to variable rate tenders and covers one full year. In the language of the auction literature, the repo auctions in our sample are multiunit, discriminatory (pay your bid) auctions. Bidders can submit up to 10 bids consisting of an interest rate and a quantity, where the rates must be at or above the minimum bid rate (reservation rate). The ECB hits the bids with the highest rates first until supply is exhausted. Bids at the stop-out rate (marginal rate) are prorated. The average auction size in our sample is around euro 100 billion nominal. For each of the 53 auctions held during the sample period, the dataset includes each bidder's individual collections of bids. Unique bidder codes allow us to follow each bidder over time.

We find that private information and the winner's curse are not important in these auctions. The minimum bid rate and the level of secondary market rates play a crucial role in bidder behavior and auction performance. We also document that large bidders do better than small bidders, apparently because they use "smarter" strategies which involve using more bids and having more kurtosis in their individual bid distribution. The penultimate auction in every reserve maintenance period has less underpricing than the other auctions within the maintenance period. Finally, from the two cases of underbidding covered by the sample period, it appears this was driven by particularly large cutbacks by large, rather than small, bidders.

1 Introduction

We study the functioning of "repo auctions" in the euro area using a unique dataset provided by the European Central Bank (ECB). For each of the 53 auctions held during the sample period, the dataset includes each bidder's individual collections of bids. Unique bidder codes allow us to follow each bidder over time. Furthermore, in these auctions, each bid placed by a bidder is for his own account. In other words, there are no "customer bids." This allows potentially less noisy inferences on bidder behavior than what has been possible in the literature previously (see, e.g, Nyborg, Rydqvist, and Sundaresan, 2002).

Repo auctions play an integral role in the implementation of the ECB's monetary policy. In these auctions, banks submit bids for borrowing central bank funds on a collateralized basis, and they are the primary vehicle used by the ECB for controlling the amount of reservable funds in the banking sector.[1] This contrasts with the Fed which relies primarily on open market operations where it deals directly with primary dealers in the secondary market.

In the language of the auction literature, the repo auctions in our sample are multi-unit, discriminatory (pay your bid) auctions. Bidders can submit up to 10 bids consisting of an interest rate and a quantity, where the rates must be at or above the minimum bid rate (reservation rate). The ECB hits the bids with the highest rates first until supply is exhausted. Bids at the stop-out rate are prorated. The average auction size in our sample is around euro 100 billion nominal. The loans in the auctions have two week maturity and therefore need to be refinanced. To provide banks with the opportunity to do so, the ECB holds an auction every week. Thus there are up to five regularly scheduled repo auctions within each monthly reserve maintenance period. Each auction is timed to coincide with the repayment of loans from a previous auction.

We use our dataset to contribute in the following areas. First, we document that banks make use of the rich strategy space that is available to them. In particular, bidders tend to submit multiple bids and they adjust their bids in a systematic fashion to exogenous factors such as the level of interest rates, the expected auction size, rate expectations, and the volatility of interbank rates. Furthermore, the auctions are underpriced, in that the quantity weighted rate banks borrow at in the auction is 1.64 basis points below the contemporaneous two week swap rate. Underpricing in primary markets relative to secondary financial markets is a common phenomenon and has been well documented in the IPO and treasury auction literatures. However, the bidder behavior we find is in sharp contrast with what has been documented in the treasury auction literature. In particular, as volatility increases bidders shade their bids less and underpricing falls, which is the opposite of the normal finding in treasury auctions (Nyborg, Rydqvist, and Sundaresan, 2002). It is fair to say that this is inconsistent with bidders adjusting for a winner's curse arising from private information about the post-auction rate. Thus the ECB's repo auctions appear to be

[1]The terminology "repo auction" is not used by the ECB itself, which prefers the terminology "refinancing operation." Depending on the country in which the borrowing bank is located, the borrowing is either done as an outright repurchase agreement or as a collateralized loan. We provide further details below.

very different from treasury auctions in terms of what drives bidder behavior and what determines the level of underpricing.

We find that the level of interbank two week rates relative to the minimum bid rate has significant impact on bidders' discounts, dispersion, and on auction performance. In particular, when two week rates are high relative to the minimum bid rate, bidders shade more, disperse more, and there is more underpricing. Along the same lines, when rates are expected to fall, a bigger difference between forward rates and the minimum bid rate leads to less bid shading, dispersion, and underpricing. However, expectations of rising rates do not affect bidding behavior or underpricing.

Second, we document that there is systematic variation in bid shading and underpricing from auction to auction within the reserve maintenance period. In particular, the penultimate auction within each maintenance period is more aggressively bid than the other auctions, in the sense that it has less bid shading and lower underpricing. The difference between secondary market rates and the minimum bid rate is also smaller for these auctions and may explain the more aggressive bidding.

Third, we find that in terms of intertemporal behavior, bidders use what can best be described as "dampened cycling" strategies. In particular, once a bidder participates in one auction, he tends to also participate in the next auction. However, bidders tend to participate unevenly over time. In particular, most bidders tend to bid more heavily and borrow more in every second auction. At the individual bidder level, this creates negative first order correlation in bid and award quantities and positive second order correlation.

Fourth, we document that large bidders systematically do better than small bidders. This superior performance is not driven by better market timing. Instead, large bidders are able to consistently borrow in the auctions at lower rates than small banks. This is perhaps not surprising, but the striking element of this finding is that larger banks achieve this superior performance without shading their bids more. It appears that they use "smarter" strategies. In particular, they use more bids and have more kurtosis than smaller banks.

Fifth, we shed light on the source of the recent underbidding phenomenon in the ECB's auctions. Starting in February 2001, several auctions have been underbid, in the sense that there have been auctions where banks have demanded less than what they need, in aggregate, to fulfill their reserve requirements. The underbidding has been a result of a combination of expectations of falling rates and the fact that banks cannot bid below the minimum bid rate. The underbid auctions tend to be the penultimate auctions within the maintenance periods, so the resulting deficit in reserve balances could be made up by the ECB holding a particularly large final auction. However, the ECB has been unwilling on most occasions to completely make up the deficit. Thus the underbidding is costly for the banking sector in aggregate, since it leads banks to use the marginal lending facility which is substantially higher than the minimum bid rate in the auction. Standard externality arguments would suggest that the underbidding problem has its roots in smaller banks free-riding on larger banks [Olsen and Zeckhauser (1966), Bergstrom, Blume, and Varian (1986), Shleifer and Vishny (1986)]. However, we find that this is not what is happening. Instead, the two cases of underbidding in our sample were driven by particularly huge cutbacks by the largest twenty bidders.

2 Institutional Framework

The auctions are part of the larger operational framework of the Eurosystem for the implementation of monetary policy.

2.1 Operational Framework of the Eurosystem

The implementation of monetary policy of modern central banks systematically aims at steering with more or less precision short term interbank interest rates.[2] Via the expectations hypothesis of the term structure of interest rates, expected short-term interbank rates impact on longer term rates which are deemed to be fundamental for the transmission of monetary policy into prices and the real economy. The short-term interbank interest rate constitutes at the same time the common valuation element of the good provided by the Eurosystem in its auctions, namely reserves with the Eurosystem, and should hence influence the bidding behavior of banks.

To put the auctions that we study in this paper in a proper context, we will discuss two core elements of the Eurosystem's operational framework. First, like the Fed, the Eurosystem requires banks to hold minimum reserves on average over a maintenance period. The maintenance period is one month long and always ends on a specific calendar day of the month, namely the 23rd. This contrasts with the Fed, whose maintenance period is two weeks long and always ends on Thursdays. A more significant contrast is that minimum reserves are much higher in the Eurosystem. They were around 120 billion euros in the period we analyze (24 June 2000 to 23 June 2001). In contrast, required reserves are only around 15% of this in the US. This large difference is mainly due to the fact that the Eurosystem remunerates required reserves, while the non-remuneration in the US creates strong incentives for banks to circumvent reserve requirements by taking measures to shrink their reserve base. This difference in size gives rise to a fundamental difference in the implementation of monetary policy by the two central banks. In the Eurosystem's case, working balances of banks tend to be systematically below required reserves. Hence, when steering short term rates through the appropriate supply of reserves, the ECB can concentrate on the fulfilment of required reserves and does not have to care about changes in the demand for working balances. In contrast, the Fed has to take into account the demand for excess reserves (Meulendyke, 1998, p. 146).

The second key feature of the Eurosystem's operational framework is the pair of standing facilities. At any time, banks can obtain overnight credit (against collateral) through the marginal lending facility. They can make deposits at the deposit facility. These rates are normally 100 basis points above or below, respectively, the interbank rate the Eurosystem aims at. In contrast, the Fed only offers one credit facility, the discount window.

The logic of the ECBs allotment policy in its weekly auctions, i.e. its actual implementation of monetary policy, can now be summarized as follows: The ECB aims to provide the banks with reserves (i.e. euro overnight deposits with the central bank) through the auctions such that, after taking into account the effects of all other liquidity factors, counterparties can fulfill their reserve requirements as an average over

[2] See e.g. ECB (2001) for the euro area and Meulendyke (1998, p. 139) for the US.

the maintenance period. Overnight interest rates are then determined according to the following very simple model: as long as the central bank has the reputation to steer liquidity conditions in a neutral way, i.e. to allot volumes such that banks can be expected to precisely fulfil their reserve requirements and such that aggregate reserve surpluses and deficits are equally likely, the interbank rate should stay in the middle of the corridor set by the two standing facilities. More generally, the interbank overnight rate should always correspond to the marginal value of reserves at the end of the reserve maintenance period, which is a weighted average of the standing facilities rates at the end of the maintenance period, whereby the weights correspond to the likelihood of being short or long (i.e. to have to take recourse to the marginal lending or deposit facility).

2.2 Open Market Operations: The Auctions

The Eurosystem's open market operations "play an important role in the monetary policy of the Eurosystem for the purposes of steering interest rates, managing the liquidity situation in the market, and signalling the stance of monetary policy" (ECB, 2002a, p.14). All open market operations conducted so far by the Eurosystem have been reverse operations involving a sealed bid procedure. In this paper, we study the main refinancing operations, which during the sample period have been conducted as discriminatory auctions with a minimum bid rate in the middle of the corridor set by the two standing facilities. These operations have a two week tenor and are conducted on a weekly basis, such that there are always two operations outstanding. There are thus up to five of these auctions in a reserve maintenance period.

These main refinancing operations play a pivotal role in pursuing the purposes of the Eurosystem's open market operations and provide the bulk of refinancing to the financial sector (ECB 2002a). The intended timing of all regular operations within a year is pre-announced by the ECB three months before the start of the year. Normally, the definitive terms of the operation are announced on Monday, 3.30 p.m. through wire services. In addition, the ECB publishes with the tender announcement an estimate of liquidity needs in the following week, which gives bidders a precise indication of what the allotment amount should be.

The Eurosystem also holds "longer-term refinancing operations". These have a maturity of three months and are conducted with a monthly frequency, such that there are always three operations outstanding. These operations aim to provide counterparties with additional longer-term refinancing and should not send signals to the market about the stance of monetary policy. Additionally, in the first three years of the euro there were five non-regular auctions with maturity of either overnight or one week. We do not study these auctions in this paper.

The main difference between the Eurosystem and other major central banks' open market operations lies in the predominance of regularity, transparency, and the dominance of auctions (in contrast to direct bilateral transactions with primary dealers, such as done by the Fed). The regularity and transparency of the Eurosystem auctions makes them an ideal and unique object for applying auction theory and bridging it to the theory of monetary policy implementation.

2.3 The Liquidity Management (allotment policy) of the ECB

The ECB normally pursues a liquidity neutral allotment policy (ECB, 2002b). This may be defined as a policy in which the allotment volumes in the auctions are such that they allow banks to fulfill their reserve requirements as an average over the maintenance period. If one disregards the cases of underbidding (see below), the tender volumes indeed appeared to be close to neutral all the time, suggesting that the ECB anchored its allotment decisions in the liquidity needs of counterparties.[3] In a symmetric corridor set by standing facilities around the minimum bid tender rate, a neutral allotment policy is consistent with aiming ex ante at an overnight rate equal to the minimum bid rate.

Under a liquidity neutral policy, deviations of the overnight interest rate from the minimum bid rate should, until the last auction of the maintenance period, reflect expectations of a possible change of interest rates of the standing facilities (and of the minimum bid rate) before the end of the reserve maintenance period. After the last tender of the maintenance period, when the practical likelihood of a rate change within the same maintenance period has reached zero, rate change expectations should no longer play any role to explain the spread between the tender and the overnight rate. Instead, liquidity will matter, since any error made by the ECB in forecasting liquidity needs can no longer be compensated through the following auction. Indeed, the forecasts of liquidity needs of the ECB are not perfect: in the period under review, the standard deviation of the error (forecast one week average versus actual average) was EUR 1.5 billion. Hence, after the last allotment decision of the maintenance period, counterparties will update their beliefs about the likely forecast error of the ECB, and the implied liquidity conditions, when more and more information is revealed on the likely ending of the reserve maintenance period. Overnight rates will move accordingly.

One important exception has to be highlighted with respect to the neutrality of the ECB's allotment volumes: after two occurrences of underbidding within our sample period, the ECB clearly allotted less than the neutral amount. Underbidding refers to the case that total bids submitted by counterparties fall short of the neutral allotment volume. Both cases of underbidding occurred in the penultimate auction in the maintenance period. Thus, the ECB could have allotted sufficient liquidity in the final auction to allow counterparties to completely catch up with required reserves. However, the ECB did not do this, and in both cases total recourse to the marginal lending facilities until the end of the maintenance period exceeded EUR 60 billion and overnight rates moved close to the rate of the marginal lending facility.

[3]Comparing the neutral tender volumes as they can be derived by the liquidity needs the ECB publishes together with its tender volumes, with the actual ones reveals that the standard deviation between the neutral and actual allotment volumes was during the sample period, excluding the tenders affected by underbidding, amounted to EUR 1.7 billion, against a standard deviation of allotment volumes of EUR 38 billion and an average allotment volume of EUR 89 billion. It should also be noted that the EUR 1.7 billion standard deviation also reflects changes of liquidity forecasts available at the ECB between the announcement of the liquidity needs and the allotment decision.

3 Overview of the Data and the Markets

In this section, we provide an overview of the primary and secondary markets for euro reserves. We start by describing the auction (i.e. primary market) data that is the focus of our subsequent analysis. We then move on to briefly describing the secondary market and the interest rate data that we have collected.

3.1 The Auctions

For this study, the ECB compiled a file with individual bidding data and summary statistics for its main refinancing operations (repo auctions) over a one year period, starting with the auction held on 27 June 2000 and ending with the auction held on 26 June 2001. The dataset contains the complete set of bids, broken down by bidder, in all 53 main refinancing operations held during this period. One is held every week, typically Tuesday morning with the bid submission ending at 9:30 am and results announced at 11:20 am. The auctions are always for two week money. Winning bids are settled the following business day. In each auction, each bidder can submit 10 bids which are rate-quantity pairs for two week money. Unlike US Treasury auctions, for example, there are no non-competitive bids. In total, our sample contains 29,833 individual demand schedules from 1,199 different bidders. The auctions are all discriminatory. The first auction in the dataset was also the first auction held by this method. Previously, the ECB had used fixed rate tenders. The data covers 12 complete maintenance periods. The last auction in the dataset is the first auction in the 13th maintenance period.

An important feature of the auctions is the minimum bid rate, which is strictly enforced and announced in advance. Bidders can not submit bids below it. The minimum bid rate tends to be constant for long periods of time. It was changed three 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% for the 11 October 2000 auction, and finally fell back to 4.50% for the auctions held on and after 14 May 2001. During the sample period, the minimum bid rate was always at the mid-point between the ECB's lending and depositing standing facilities, which always were 200 basis points apart. The standing facilities and the minimum bid rate in force throughout the sample period are illustrated in Figure 1. Although the standing facilities and the minimum bid rates were stable for long periods, they were in principle subject to change at the bi-weekly meetings of the ECB's Governing Council.

The day before the auction is held, the ECB publishes an estimate of liquidity needs for the entire banking sector, which can be used to compute the expected auction size needed to maintain liquidity neutrality (see above) in the banking sector. However, the ECB does not commit itself to a particular auction size, and from time to time it happens that the realized auction size differs from the expected size. Figure 2 depicts the expected auction sizes and the difference between it and the realized size. In the 34th and 42nd auctions, the realized size is significantly below the expected size. These auctions, which were the only auctions with bid-to-cover (based on expected size) ratios below 1, are discussed in greater detail in Section 8. The figure also shows that there is a great deal of variation in the auction size, with a range in the expected size from euros 5 billion to euros 177 billion.

The variation in the expected auction size is primarily due to variation in the so-called autonomous factors (see ECB, 2002b). However, some variation is also due to the two "underbid" auctions. These were both the penultimate auctions in their respective maintenance period. As a result, the final auctions in these two maintenance periods were unusually large, to allow the banking sector to "catch up," at least to some extent, with respect to required reserves. Since all auctions are for two week money, the unusually large final auctions were then compensated for by unusually small auctions at the beginning of the next maintenance period. The euros 177 billion auction is the final auction in the maintenance period with the underbid auction 42. The euros 5 billion auction is the first auction in the subsequent period.

The mean expected auction size is euros 89.6 billion and the mean realized size is euros 88.9 billion. The standard deviation of the size surprise is euros 5.8 billion. The absolute value of the difference is euros 1 billion or less in 29 auctions. Thus while there is no guarantee that the realized auction size will equal the expected size, deviations tend to be relatively small.

The number of bidders in each auction is highly variable and goes from 240 to 800. In total, 1199 banks from 12 countries participated in one or more auctions.[4] Our dataset includes individualized bidder codes and we can therefore follow individual bidders over time. 29 bidders participated in all 53 auctions and 101 bidders participated in only one auction. Figure 3 provides a histogram of the number of bidders who participated in a given number of auctions. The average number of auctions per bidder is 24.9. Another way to look at bidder participation is by how many demand schedules were submitted in all auctions in a given maintenance period and how many maintenance periods each bidder participated in. This is shown in Table I, for both bids and awards. Panel (a) shows, for example, that 2938 demand schedules were submitted in the first maintenance period, and 2441 of these had bids at or above the stop-out rate and thus won some award. In total, 949 bidders participated and 865 received a positive allotment in at least one auction in the first maintenance period. Panel (b) shows, for example, that 407 bidders participated in 12 maintenance periods and 327 won awards in twelve maintenance periods (we have dropped the last auction for the purpose of tabulating the lower panel). We also see in Panel (b) that across banks the average number of maintenance periods in which banks bid 7.86 and that the average number of maintenance periods in which banks receive a positive allotment is 7.28. However, slightly more than a third of the banks in the sample bid in every maintenance period and slightly more than a fourth borrow in the auction in every maintenance period. Panel (c) shows that across banks the average number of auctions where they bid is 24.9 and the average number of auctions where they win some units is 20.2.

Table I [Panel (a)] also shows that there is a downward time trend in the number of bidders during the sample period. This time trend is illustrated on an auction by auction basis in Figure 4. In the first auction, there were 800 bidders and in the last auction, there were only 452.

[4] The countries are Austria, Belgium, Finland, France, Greece, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. With the exception of Greece, all countries were in the euro area from the beginning of the sample period. The number of Greek bidders is very small.

The bidders in the auction are small compared with the auction size. The largest award by a single bidder occurred in the 53rd auction and was for 26.6% of the realized auction size. On average, the largest bidder receives 6.8% of awards. In terms of quantity demanded, the average bidder bids for 0.37% of the expected auction size. Despite their relatively small size, bidders appear to act strategically in the sense that they tend to submit multiple bids. The distribution of the number of bids within individual demand schedules is illustrated in Figure 5. The mode is 1, the median is 2, and the mean is 2.4. On average, 64.6% of bidders in a given auction submit multiple bids. Since bidding banks include small cooperatives and large universal banks, there is significant heterogeneity across bidders. This is illustrated by the large proportion of awards won by largest bidders. On average, the 50 largest bidders in each auction receive 72.2% of the realized auction size. Bidder heterogeneity is analyzed in greater detail in Section 7.

3.2 The Secondary Market

As an alternative to borrowing in the auction to satisfy its reserve requirements, a bank may also borrow in the interbank market. Secondary market rates therefore provide a measure of the opportunity cost of borrowing in the auction. The level of secondary market rates with respect to the minimum bid rate, and by implication the standing facilities, may therefore affect bidder behavior. We also need secondary market rates to gauge bid-shading and underpricing. Since the funds obtained in the auctions have a two week tenor, we are particularly interested in two week rates. We are also interested in longer term rates, because we wish to examine the effect of interest rate expectations on bidding behavior and auction performance. Longer term rates are needed to calculate forward rates, from which we can gauge rate expectations.

Since the euro reserves of banks with the Eurosystem have overnight maturity, overnight rates are also important. In addition to borrowing in the auction or in the interbank market using two week contracts, a bank may fulfill its reserve requirements by borrowing in the interbank market on an overnight basis. The EONIA (euro overnight index average) is an effective overnight rate computed as a weighted average of all overnight unsecured lending transactions in the interbank market, initiated within the euro area by 52 panel banks. These are the banks with the highest volume of business in the euro zone money market. The EONIA is calculated on a daily basis by the ECB on behalf of the European Banking Federation. It is a widely used reference rate and is the euro equivalent to the federal funds rate in the US. Like the fed funds rate, the EONIA is highly volatile compared with other short term rates.

Banks can hedge the risk from borrowing overnight over a two week period, matching the maturity of borrowing in the auction, by entering into an EONIA swap. In this swap, cash flows are nominally exchanged every day, but money does not physically exchange hands before the two weeks are up. The counterparty that pays the fixed leg receives the EONIA rate. By going short (paying fixed) the swap, a bank creates a nearly perfect hedge against borrowing on a daily basis in the interbank market. Thus an alternative to borrowing in the auction is to short the swap and borrow on an overnight basis in the overnight market over two weeks. EONIA swaps of different maturities also exist and this market has developed to be one of the most liquid segments of the euro area money markets.[5] Due to the low credit risk, high liquidity, and good hedging properties of the EONIA swap contract, the two week swap rate is arguably the most important two week rate in terms of benchmarking the auction.

There are two other main two week rates; the deposit and repo rates. The deposit rate is the rate of an unsecured loan and is therefore not directly comparable with borrowing in the auction, since the latter is collateralized. The interbank repo rate is also not entirely comparable with the auction, since it is possible to use considerably cheaper collateral in the auction than in an interbank repo. For example, the Bundesbank accepts Pfandbriefe (German mortgage bonds), which are not accepted in interbank repos. Some countries allow bank loans and certain equities to be used as collateral in the auction.[6] The deposit and repo contracts also lack the high liquidity of the EONIA swap market. We will therefore use the two week swap rate as our main benchmark two week rate. This is also consistent with the views expressed by traders that we have talked to.

Bid and ask quotations for these three two week rates were recorded from Reuters pages at 9:15 am every day from 4 January 1999 for the swap and deposit rates and from 26 October 1999 for the repo rates. All series end on 2 July 2001, which is midway between the 53rd auction (for which we have data) and the 54th auction (for which we do not have data). The bid-ask spread for the swap rate tends to vary between 2 and 3 basis points. Deposit and repo spreads are around 5 to 6 basis points. The mid-point of the bid ask quotes is taken to be the best estimate of actual transaction rates. The two week repo contract is not very liquid, something one can see by the infrequent updating of the quotes. Inferences based on the repo rates must therefore be made with caution. This is another reason to focus on the swap rate, as we will do.

Finally, we use EURIBOR (Euro Interbank Offered Rates) to compute forward rates. These rates exist for one week as well as one through twelve month maturities. There is no two week EURIBOR rate. These are important reference rates for interbank term deposits and is computed using the average rates quoted by the same panel banks as for the EONIA. The rates from each bank are collected by asking each panel bank to provide by 10:45 am the rate that it believes that one prime bank is quoting to another prime bank for interbank deposits of the respective maturity. EURIBOR is reported to three decimal places. To gauge rate expectations, in our analysis we use the one and two month rates to calculate the one month forward rate (the one month rate one month from today to two months from today).

Figure 6 depicts the deposit, swap, 1 month forward, and the EONIA rates during the auction sample period. The spikes in the EONIA are related to the end of the reserve maintenance period, and have been well documented by previous researchers [(Hartmann, Manna, and Manzanares (2001), Gaspar, Perez Quiros, Sicilia (2001)].

[5] See the ECB *Euro Money Market* report of 2001, which also documents that the one week to one month maturity range is the one with the highest turnover in the EONIA swap market.

[6] Note that the transactions in the main refinancing operations are conducted with the national central bank, and not the ECB, as the counterparty. Each national central bank therefore has some leeway in deciding what collateral to accept and whether the collateral can be exchanged during the course of the two week tenor of the primary market contract. If one national central bank decides to accept a particular collateral, then that collateral must also be accepted by the other national central banks. See the European Central Bank document *The Single Monetary Policy in Stage Three* for details on admissible collateral and other details.

The figure shows that our sample period covers a period of rising as well as falling rates and rate expectations. This is fortuitous, since it allows us to examine the extent to which bidder behavior and performance is affected by the direction of rate expectations. One might expect this to matter, in part because of the presence of the minimum bid rate.

4 Theoretical Considerations

There has been little theoretical work which directly addresses the ECB's discriminatory repo auctions. As seen from the institutional description these are complicated auctions, particularly since they are embedded in a quite complex structure involving reserve requirements and the sequential auctioning of funds within reserve maintenance periods. Moreover, the maturity of funds obtained in the last two auctions in any reserve maintenance period carry over until the next maintenance period. In this section, we discuss some of the important institutional features of the ECB's repo auctions and what one might reasonable expect their impact to be on bidder behavior and auction performance.

4.1 Winner's Curse and Collateral

On the face of it, the ECB's repo auctions would appear to be common value, since there is a very active and competitive market for overnight reservable funds. There is also an active two week market which matches the maturity of the repos in the auction. However, the wide range of eligible collateral in the auction may introduce a private value component and banks may have different downward sloping demand curves for the auctioned funds. However, since the interbank market is so liquid, different bidders' demand schedules are likely to be highly correlated. As a result, if players have private information about money market rates after the auction is held, we would expect to see bidders adjust for the resulting winner's curse (Milgrom and Weber, 1982) by responding to increased volatility by reducing the rates at which they bid, reducing quantity demanded, and dispersing more, as has been found in discriminatory treasury auctions (Nyborg, Rydqvist, and Sundaresan 2002). If the amount of the cheapest collateral that players can use in the auction is smaller than the largest auction size in our sample, we would expect to see an increases in the auction size to lead to more cautious bidding, lower rates, lower demand, more dispersion, and more underpricing.

4.2 Reserve Requirements: Shorts and Longs

The purpose of the auctions is to inject reservable funds into the banking sector. If no banks bid, the banking sector will suffer because banks will have to go to the lending standing facility, which is 100 basis points above the minimum bid rate in the auction. Clearly banks that are short liquidity have a stronger incentive to bid than banks that are long liquidity. However, it is difficult to assess the loss function of a short bank, if it does not obtain the amount it needs, because it may also cover its reserve requirements by borrowing from other banks in the secondary market. As explained by Nyborg and

Strebulaev (2001), this carries the risk that the short bank may be " squeezed" in the sense that they will end up being charged above "fair" rates by other banks who know of the short bank's predicament. Short banks may therefore have "target" amounts that they would prefer to borrow in the auction, so as to not put them in a position to be squeezed. The idea is that banks bid so that they do not end up being overly reliant on the secondary market for their reserve needs.[7] Nyborg and Strebulaev (2001) show that short banks tend to be more aggressive than long banks. Since we do not have reserve balances of individual banks, it is difficult for us to test this explicitly. However, if the dispersion of shorts and longs is increasing in money market volatility, then we would expect to see a higher volatility leading to more aggressive bidding. This is the opposite of what is predicted by a private information/winner's curse model.

4.3 Collateral, Auction Cycle, and Minimum Bid Rate

A key consideration in the ECB's repo auctions is that they are part of an auction cycle within the reserve maintenance period. Specifically, the ECB holds a two week repo auction every week. There are therefore up to five auctions within each reserve maintenance period, and, at any given time, there are always two sets of repos outstanding and the dates of repos in consecutive auctions overlap. This means that collateral which has been pledged in the first auction of the maintenance period, for example, will not be available to a bank in the second auction. However, it will be available again in the third auction, etc. As a result, banks may face an intertemporal tradeoff between using their collateral in consecutive auctions within the reserve maintenance period. If bidders are constrained by the amount of collateral that they have, we would expect to see a time pattern in individual bidding behavior. In particular, we should see a negative first order and positive second order autocorrelation in bidder behavior.

When rates are expected to fall (rise), bidders have a preference for doing the bulk of their borrowings of central banks funds late (early) in the reserve maintenance month. Therefore, one might expect the aggressiveness of bidding in auctions to be positively related to the slope of the yield curve. However, sequential auction theory (e.g. Weber, 1983) shows that when participating in a sequence of auctions, bidders adjust their bidding so that expected profits from winning in different auctions are equated.[8] In our setting, one might also expect expectations of rising rates to have a negligible effect on underpricing because of the high liquidity of the secondary market. Disregarding costs from being short liquidity, when rates are expected to rise it is not so important how much a bank borrows in the auction, what is important is what that rate is relative to the contemporaneous secondary market rate. The situation may be different when rates are expected to fall, because of the floor on bid rates imposed by the minimum bid rate. In this case, bidders cannot adjust their bids down, which may be a necessary requirement to keep expected profits (or underpricing) the same across

[7] A trader told us that in his bank, they usually operate with a "target" amount in the auction. They were concerned about receiving much less than their target, not necessarily because they would be squeezed in the short term, but in the long term if they consistently needed "large" amounts of liquidity from the interbank market, other banks would cotton on to this and start asking heavy rates.

[8] A decreasing price pattern arises in some models (Bernard and Scoones, 1994) and sometimes in practice (Ashenfelter, 1989).

auctions under a falling rate regime.

5 Cross Sectional Analysis

In this section, we provide an overview of the bidding and auction performance variables and how they vary with the exogenous parameters across auctions. We also test some of the implications of the theories reviewed above and identify the key drivers behind bidder behavior and auction performance.

5.1 Descriptive Statistics

Table II provides three panels with summary statistics on the exogenous and endogenous variables. The exogenous variables include variables that capture interest rate volatility, levels, and expectations. The endogenous variables include bid-shading and underpricing measures as well as the standard higher order moments of bidders' demand schedules [Nyborg, Rydqvist, and Sundaresan (2002), Bjønnes (2001), Keloharju, Nyborg, and Rydqvist (2002)]. We also include a number of participation and award concentration measures.

The exogenous variables are summarized in Panel (a). We start by discussing the volatility, which we include because empirical works on treasury auctions have found that this is the most significant variable in terms of describing bidder behavior and auction performance [Nyborg, Rydqvist, and Sundaresan (2002), Bjønnes (2001), Keloharju, Nyborg, and Rydqvist (2002)]. We have computed the daily conditional volatility of the swap rate using a GARCH(1,1) model with dummies to capture key events within the reserve maintenance period (see the Appendix for details). On auction days, the volatility has an average of 4.27 basis points (bp), which is practically the same as in the sample period as a whole. It varies from 1.176 bp to 8.538 bp. By way of comparison, during the sample period the average daily volatilities of 1 and 12 month EURIBOR were 2.7 bp and 3.6 bp, respectively.[9] The relatively large volatility of the swap rate reflects the high volatility of the underlying EONIA (which has an average daily volatility of around 14 bp).

Panel (a) also contains statistics on the level of interest rates relative to the minimum bid rate. The swap spread is the two week swap rate less the minimum bid rate. The forward spread is the 1 month forward rate minus the minimum bid rate. When the swap spread is small, it may be relatively more attractive to fulfill reserve requirements by going short the swap and borrowing in the overnight market. When the forward spread is small, banks may hold back on bidding in the current auction, in the expectation that the minimum bid rate and the standing facilities will have been reduced by the next auction in the maintenance period. The forward spread has an average of around 15.5 bp and varies from -26.7 bp to 62.7 bp. Further inspection (details not reported here) reveals that it is consistently positive in our sample in the first six maintenance periods and mixed thereafter. The smallest forward spread occurs on the auction held on 10 April 2001 in the 9th maintenance period (auction 42). The swap spread follows a similar pattern, since it tends to be large when rates are

[9] Computed as standard deviations of the first differences time series.

expected to rise. The average swap spread is 8.2 bp and the range is from -5.5 to 48.2 bp. In our sample, the swap spread was nonpositive in 4 cases. Two of these auctions led to bid-to-cover ratios below 1. The ranges of forward and swap spreads show that our sample period covers times of both rising and falling rate expectations.

We also see in Panel (a) that there is considerable variation in the expected auction size, which we discussed in Section 3. The last exogenous variable displayed in Panel (a) is the projected number of bidders. This is included to capture the falling time trend discussed in Section 3. Because of the overlapping nature of the auctions, there is one auction every week for two week money, the projection has been computed by first regressing the number of bidders in auction j on the number of bidders in the two previous auctions. Letting N_j denote the number of bidders, the estimated regression equation is

$$\begin{array}{cccccccc} N_j & = & 127.67 & + & 0.22N_{j-1} & + & 0.53N_{j-2} \\ & & (1.96) & & (1.85) & & (4.59), \end{array}$$

where t-statistics are reported in brackets below the regression coefficients. The regression has been adjusted for first order autocorrelation using the Cochrane-Orcutt transformation. This equation is then used to calculate the projected number of bidders. This is not meant to be the best model for forecasting the number of bidders, but is a simple solution for dealing with the time trend we see in the data. Comparing the summary statistics for the projected number of bidders to the statistics for the actual number of bidders (Panel (c)), we see that the projection captures the mean (as it should) but underestimates the actual variability.

The bidding variables are summarized in Panel (b). Three discount measures are reported, one for each of the three two week rates. As in Nyborg, Rydqvist, and Sundaresan (2002), all variables are representations of intra-bidder behavior. To calculate discounts, we first calculate the quantity weighted bid rate in each of the 29,833 demand schedules. We then subtract this number from one of the three two week rates on the auction day the demand schedule was submitted. The higher order moments are computed along similar lines. For each individual demand schedule, the standard deviation is the quantity weighted average bid rate. Skewness and kurtosis are also quantity weighted within each individual demand schedule. In cases where a bidder submits only 1 bid, we define the skewness to be 0 and kurtosis to be 1, as in Keloharju, Nyborg, and Rydqvist (2002). Panel (b) reveals that the bidders tend to submit demand schedules whose mid-points tend to be below all contemporaneous two week rates. The discount relative to the deposit rate is the highest, followed by that of the swap rate. This reflects that deposit rates tend to be higher than swap rates and repo rates, due to higher credit risk. The average swap rate discount is 3.352 bp, with a standard deviation of 4.476 bp. The average intra-bidder standard deviation, intra-bidder skewness, and intra-bidder kurtosis are 0.704 bp, -0.018, and 1.529, respectively. However, there is a considerable variation across bidders. Finally, Panel (b) also contains statistics on the relative quantity bid (as percentage of expected auction size) by individual bidders and the number of bids in individual demand schedules. As discussed in Section 3, we see that bidders tend to be quite small, but submit multiple bids. The average bidder bids for only 0.367% of the auction and submits 2.397 bids.

Panel (c) contains variables measuring auction performance and participation. There are three underpricing measures, one for each of the two week rates. Underpricing is defined as the two week rate minus the quantity weighted average winning rate. Underpricing is 2.96 bp relative to the deposit rate and 1.66 and -0.93 relative to the swap and repo rates, respectively. In other words, the average winning bidder pays a rate which is between the swap and repo rates. That the auction rate is above the repo rate probably reflects that banks use cheaper collateral in the auction than what they can use in the interbank repo market. That it is below the swap rate is more of a true measure of underpricing and shows that it is typically cheaper for bidders to borrow in the auction than in the interbank market. Since, in a given maintenance period, banks earn interest on their reserves equal to the average stop-out rate, it is also interesting to see how winning rates compare to stop-out rates. We see that the banking sector tends to pay around 1.64 bp more for their reservable funds than they earn from the ECB. Coupled with the numbers above, this also tells us that the quantity weighted average rate paid is typically at the mid point between the swap rate and the stop-out rate. The stopout spread is defined as the stop-out rate minus the marginal bid rate and averages to 6.5 bp. The relative large magnitude of the stopout spread reflects that the secondary market rates were much larger than the minimum bid rates for long periods over the sample period, as seen in the swap spread statistics.

The average underpricing relative to the swap of 1.66 bp is relative to the mid-point of the swap bid-ask spread, which is normally around 2 to 3 basis points. This means that bidders in the auction are, roughly speaking, obtaining the funds at the bid rate. This confirms conversations we have had with traders who told us that banks generally do not bid in the auction with a view to resell, because that is not a profit making activity.

The average number of bidders across auctions is 563 and 459 typically win some units. However, the variation in participants as well as winners is large, going from 240 to 800 and 154 to 705, respectively. Award concentration is measured by the Herfindahl index and averages to 2.10. This is approximately what it would be if we had 50 equal bidders. This is another way of seeing the considerable size variation that exists across bidders. Award/ demand concentration is the Herfindahl index based on award divided by the Herfindahl index based on demand. The average of this ratio is 1.36, showing that award tends to be more concentrated than demand. The average bid-to-cover ratio is 2.05, but varies from 0.47 to 166.61. The highest bid-to-cover occurred in the smallest auction, which was only for euros 5 billion. Finally, we see that the largest (by award) 1, 10, and 50 bidders typically receive 6.8%, 34.3%, and 72.2% of the auction. Keeping in mind that more than 500 banks typically participate in each auction and the average bank demands less than 0.4% of the auction, this is further illustration of the large variation in size among participating banks.

5.2 Regression Analysis

In this section, we regress the endogenous variables on the exogenous variables. We wish to examine the extent to which bidder behavior and auction performance varies with swap volatility, expected auction size, the level of rates, and the expectation of rate changes. To allow for the possibility that bidders behave differently when rates are expected to rise as compared to when rates are expected to fall, we break the forward spread up into two new variables. In particular, we define the "forward sp(-)"

to be equal to the forward spread if this is negative, and 0 if the forward spread is positive. Similarly, the "forward sp(+)" is the forward spread if this is nonnegative and 0 otherwise. We do not break the swap spread up in the same manner because there are only 4 auctions where the swap spread is negative.

Not surprisingly, the swap spread is highly correlated with both the forward spread (0.69) and the forward sp(+) (0.68), but less so with the forward sp(-) (0.39). The reason for the lower correlation with the forward sp(-) is that the swap spread very rarely goes below the minimum bid rate, perhaps because if a player quotes a swap rate below the minimum bid rate he affords other players the possibility of obtaining funding below the rate in the auction. The four cases where we have a negative swap spread reflect strong views held by some players that the ECB would drop rates. The high correlation between the swap spread and the forward sp(+) precludes us from running regressions with both variables. We report the results from using the swap spread, since this more accurately captures the level of rates. Later, we will discuss an alternative to the forward-sp(+) as a measure of rising rate expectations, which has a lower correlation with the swap spread.

The regression results are reported in Table III. To correct for autocorrelated errors, all regressions have been run with the Cochrane-Orcutt transformation. Where errors are heteroscedastic, t-statistics are reported using the Newey-West adjustment. In the regressions, we have used the average bidder variable for each auction instead of running stacked regressions across the auctions. This is done for two reasons. First, it is to correct for possible correlations in errors within auctions. This is particularly a concern in the discount and underpricing regressions. Second, it is to place equal weight on each auction. If we used the individual bidder numbers, we would have 29,833 observations on discounts, intra-bidder standard deviation and the other moments, but we would weigh the earlier auctions more heavily since more bidders participated in these auctions.[10]

Panel (a) in Table III contains the regressions on the bidder variables and Panel (b) contains the regressions on the performance and participation variables. Bidding variables are equally weighted within auctions, unless otherwise specified.

Looking down the swap spread column, we see that the swap spread has a significantly positive impact on the price levels at which bidders place their bids and on underpricing. In particular, for each basis point increase in the swap spread, the discount (swap) increases by 0.278 basis points. In other words, for each basis point the swap rate moves above the minimum bid rate, bidders' bids move up only by approximately 0.722 bp. Similarly, a basis point increase in the swap spread increases underpricing by 0.107 bp. This suggests that the minimum bid rate serves an important role by restricting bidders' ability to shade their bids. Without the minimum bid rate, the rate paid in the auction would quite likely be lower in many cases. The

[10] By running the regressions on an auction-by-auction basis, we may well end up overstating standard errors. However, results from running stacked regressions are qualitatively the same as reported in Table III. Because of the minimum bid rate, discounts and underpricing should perhaps be run as Tobit regressions. Since correcting for autocorrelation and heteroscedasticity is notoriously complicated in the Tobit model, we prefer to report the results using the standard regression model as explained in the text. However, Tobit regressions on discounts and underpricing produce results which are qualitatively the same as, and quantitatively very close to, the results reported in Table III.

swap spread has a smaller impact on dispersion: standard deviation increases by 0.031 bp per bp increase in the swap spread, skewness decreases by -0.001, and the equally weighted kurtosis increases by 0.013. The quantity weighted kurtosis increases by 0.075 bp, which tells us that big bidders behave differently from small bidders with respect to kurtosis.

That a larger swap spread leads bidders to disperse their bids more can also be seen by from the winrate-stopout regression. This shows that quantity weighted average winning rate in the auction minus the stop-out rate increases by 0.075 bp per increase in the swap spread. We also see that more banks bid in the auction as the swap spread increases. This may be because of an expectation of a larger underpricing, or it may be because players with relatively expensive collateral find it worthwhile to participate. The swap spread has no notable effect on the quantity variables, including award concentration and bid-to- cover (the latter is weakly positive).

Looking down the forward sp(-) column in Table III, we see that as the forward spread gets more negative, bidders shade less. For each basis point the forward spread falls, the discount with respect to the swap falls by 0.131 bp. The effects on standard deviation and skewness are also statistically significant, but economically small. For example, a 1 basis point drop in the forward sp(-) decreases the intra-bidder standard deviation by only 0.007 bp. Moving down to the performance variables, we see that a 1 basis point drop in the forward spread(-) translates into a 0.148 bp decrease in underpricing. In other words, when rates are expected the fall, then the stronger these expectations are, the regression results tell us that discounts and underpricing gets smaller. This is counterintuitive.

We believe the "strange" effect of a negative forward spread is due to the minimum bid rate. What is happening is that as the swap rate edges towards the minimum bid rate, discounts and underpricing are squeezed towards zero. At the same time, the forward spread is getting more and more negative. However, since there is considerable resistance among market participants to lend at swap rates below the minimum bid rate, the swap spread does not react as strongly to falling rate expectations as the forward spread. This creates a positive regression coefficient on the forward sp(-) in the discount and underpricing regressions. This is augmented, but not driven by, the four cases where the swap spread is negative.[11]

We see from the number of bidders regression that when the forward spread is negative and falls, banks tend to drop out of the auction. This is consistent with the view that when bidders expect rates to fall, they cut back their bidding, in the hope of borrowing more cheaply in the next auction. Players with limited amount of cheap collateral, may also not find it worthwhile to participate. It is puzzling why anybody would bid in the auction when the swap rate is below the minimum bid rate. However, traders that we have spoken to have expressed concern about being overly reliant on the secondary market to satisfy reserve requirements. Of course, it could not be equilibrium for swap rates below the minimum bid rate to be available for as large a quantity as the expected auction size. If nobody were bidding in the auction, the banking sector would be in a serious liquidity deficit and overnight rates would soar, taking swap rates with them. In this case, it would be desirable to bid in the auction

[11] We have run the regressions without these four cases. There are no notable changes.

after all.[12] Those that actually stay in the auction when the swap spread is negative are most likely predominantly banks that have particularly large liquidity needs, since these "very short" players may value the auctioned units higher than other players (Nyborg and Strebulaev, 2001).

Although the high correlation between the forward sp(+) and the swap spread means that we cannot use them in the same regression, we are still interested in the question of whether rising interest rate expectations lead banks to bid more aggressively. This cannot be addressed unequivocally from the regressions in Table III. To examine this, we need a variable that captures rate expectations but is less highly correlated with the swap spread. Analogously to the forward sp(+), we therefore create a variable which is equal to the forward rate minus the swap rate if this is positive, and zero otherwise. Including this as an explanatory variable, we find that it is insignificant across the board, with three exceptions. Rising rate expectations tend to decrease the quantity weighted skewness, increase the quantity weighted kurtosis, and increase the number of bids per bidder and the proportion of players who submit multiple bids.

That rising rate expectations are not important for discounts and underpricing is somewhat surprising, since one might expect banks to be more aggressive in a regime of rising rate expectations since they should be more keen to get reserves today rather than next week. However, because banks also can obtain reserves in the interbank market, there may be little reason for them to bid more aggressively when rates are expected to rise.

Moving on to the expected auction size, we see that it impacts positively on standard deviation. This supports the view that players will start to use more expensive collateral, and so spread their bids more as the auction size gets larger. The effects on discounts are weakly positive, which is also supportive of this view. The effect on underpricing is strongly significant, albeit economically small. A 100 billion increase in expected auction size increases underpricing (swap) by 0.024 bp. Expected auction size also decreases relative bid quantity, bid-to-cover, and award concentration. Again, this supports the view that some bidders are collateral constrained. It is also consistent with the view that bidders have targets regarding the amount they want to obtain in the auction.

Finally, the swap volatility impacts negatively on underpricing and discounts. In other words, banks apparently find the auction more attractive when volatility is high. This is the opposite of what previous research has documented for treasury auctions [Nyborg, Rydqvist, Sundaresan (2002), Bjønnes (2001), Keloharju, Nyborg, and Rydqvist (2001)], and is the opposite of what one would expect from winner's curse based arguments. There is also no evidence that bidders cut back demand when volatility is high. It therefore seems that the private information and the winner's curse plays at best a small role in this market.

The finding on volatility is a puzzle. Why should bidders want to bid more aggressively in the auction when volatility is high? One possibility may be that when volatility is high, the depth of the swap quotes is low, thus making the auction relatively more attractive. However, since the relative bid quantity and bid-to-cover is unaffected by swap volatility, this is an unlikely explanation. Another possibility is

[12] This has been studied by Bindseil (2002).

that when volatility is large, there is more dispersion across banks with respect to their reserve balances. If so, volatility may be positively correlated with the number of players that are short and we know from Nyborg and Strebulaev (2001) that short players tend to value units higher than long players and bid more aggressively, thus leading to lower average discounts and underpricing. This could also explain the increase in standard deviation, since short bidders would be expected to disperse more (Nyborg and Strebulaev, 2001).

To summarize, the regression evidence points to the level of rates relative to the minimum bid rate as a significant variable when it comes to explaining bidder behavior and the performance of the ECB's repo auctions. In particular, bidding is less aggressive relative to swap rates when the swap spread is large and underpricing tends to be larger. There is also some evidence that when rates are expected to fall, bidders tend to drop out of the auction. However, when rates are expected to rise, there is little effect on bidding and performance. Large auctions have more underpricing than small auctions, supporting the view that more expensive collateral starts to be used. Finally, there is little evidence of the winner's curse playing an important role in this market. The projected number of bidders play a relatively small role in most regressions.[13]

6 Intertemporal Behavior and Performance

In this section we examine the frequency of bidder participation by looking at the time difference between auctions for individual bidders. We provide some further descriptive statistics to complement those in the previous section to gauge whether there have been any systematic difference across maintenance periods. Finally, we examine whether the position of an auction within the maintenance period affects bidder behavior and auction performance.

6.1 Behavior

Table IV shows the distribution of the frequency with which bidders participate in auctions. We measure the frequency by the *run*, which is the time difference (in weeks or auctions) between consecutive auctions in which a particular bidder has participated. We measure the distribution of "runs" for bids as well as for awards. To make this more clear, consider a hypothetical bidder who placed bids in auctions 1, 5, 6, 7, 8, 45, 47, 49, and 50. The *run* between the two first auctions he bid in is 4. The run between the third and second auction he participated in is 1, etc.. For this bidder, the distribution of bid runs is

Run length	1	2	4	37
Number (bids)	4	2	1	1

Runs based on awards are defined similarly. For example, if the above bidder received a positive allotment in auctions 1, 5 , 6, and 49, the distribution of award runs is:

[13] We have also run the regressions without the projected number of bidders, with no notable changes.

Run length	1	4	43
Number (award)	1	1	1

Table IV shows that bidders overwhelmingly tend to participate in consecutive auctions. Once they are "in the market" they tend to stay in the market. Out of 28,633 bid runs, we see that 22,477 are runs of 1. There is some anecdotal evidence that banks play "cycling" strategies, where they participate in every other auction. This could also arise if bidders are very constrained by their collateral and tend to use all their collateral at once, thus precluding them from participating in the next auction, unless they obtain additional collateral in the secondary market. Indeed, a run of 2 is the second most frequent run. However, the number of bid runs of 2 is 4,206, which is small compared with the number of bid runs of 1. The numbers are very similar for award runs. This suggests that either bidders are not collateral constrained, or they budget their collateral, using only a portion of it in each auction. It also suggests that bidders prefer to participate in each auction, perhaps to reduce risks.

To investigate this further, we have also calculated the autocorrelation of bid and award sizes for bidders who participated in every maintenance period. This reduces the number of bidders to 407. In particular, for each bidder we first calculate the relative bid size (relative to expected auction size) and relative award size (relative to realized auction size) for each auction. Then we compute the two first autocorrelations of these two measures. Finally, we average across all 407 bidders. The results are in Table V. We see that both bidding and award have negative first order autocorrelation but positive second order autocorrelation. Furthermore, the number of bidders with negative autocorrelation outweigh those with positive autocorrelation. This is reversed for the second order autocorrelation. This shows that while these bidders tend to participate in most auctions, they participate more heavily in every other auction. In other words, the strategy of the most frequently participating bidders can be described as a "dampened cycling" strategy. This is consistent with bidders being collateral constrained or having targets with respect to how much they want to obtain in the primary market.

This suggests that we can divide bidders in any auction up into categories depending on their refinancing needs. Bidders with strong refinancing needs are those who were very active in the auction two weeks ago and bidders with weak refinancing needs are those who were more active in previous week's auction. Our findings here suggest that bidder behavior depends on refinancing needs; specifically, those with stronger needs are more aggressive.

6.2 Performance Across and Within Maintenance Periods

Table VI provides some descriptive statistics on some of the key variables across maintenance periods. Each column represents a new period. We report statistics on the swap volatility, swap spread, forward spread, expected auction size, discount (swap), underpricing (swap), the higher order intra-bidder moments, winrate-stopout, stopout spread and bid-to-cover. Each statistic represents the mean across the auctions in the given maintenance period. Standard errors are in brackets. In terms of the exogenous parameters, we see that the swap and forward spreads have been falling over time.

This has induced a parallel fall in discounts and underpricing. Looking further down the table, we also see that the quantity weighted average winning rate less the stop-out rate (winrate-stopout) has fallen over time. This is an interesting variable since it captures the loss to banks from holding reserves. For example, the table shows that in maintenance period 1 of our study, banks paid approximately 1.58 bp more for their reserves than what they earned on them from their deposits with the national central banks.[14]

In Table VII, we have broken the auctions up into the position they have in the maintenance period. Position 1 represents the first auction; position 2 represents auction 2 out of 4 or auction 3 out of 5; position 3 represents the penultimate auction; and position 4 represents the final auction.[15] The variables are the same as in Table II. The table reveals some striking results. In particular, it can be seen that underpricing is lower in the penultimate auction than in other auctions. Furthermore, this auction has a lower swap spread than the other auctions. Means tests for underpricing, discounts, and swap spreads for auctions in position 3 versus the other positions is carried out in Table VIII. This shows that auctions in position 3 indeed have a lower underpricing than the other auctions. This is not driven by outliers.[16] The penultimate auction had the lowest underpricing in 8 out of 12 maintenance periods and the second lowest in 3 maintenance periods. It had the lowest swap spread in 6 maintenance periods and the second lowest swap spread in 2 maintenance periods. This is strong evidence that during our sample period, there was something different about the auctions in position 3. In particular, they have lower underpricing. This is quite puzzling. Sequential auction theory would suggest that players' expected profits should be the same in each auction (Weber, 1983), or possibly falling over time (Bernard and Scoones, 1994).

The finding that the swap spread tends to be lower at the time of the penultimate auction could be a pure reflection of expectations. For example, an anticipated rate hike early in the maintenance period could have failed to materialize, thus pushing the swap rate down towards the minimum bid rate. Another possibility is that a rate hike did take place early in the maintenance period, thus pushing the minimum bid rate up towards the swap rate. Finally, the market might expect rates to be revised downwards at the first Governing Council meeting after the penultimate auction. A problem with this explanation is that it implicitly assumes that *ex ante* rate hikes were more likely to occur early in maintenance periods while rate cuts were more likely to occur towards the end of maintenance periods. As it turned out, *ex post* all rate changes during our sample period occured before the penultimate auction.

While it is not clear that the penultimate auction should play a special role in terms of expectations, it is nevertheless true that it plays a special role within the maintenance period and this may have an impact on swap spreads as well as on bidder behavior. Focusing first on bidding in the auction, note that liquidity obtained in the first two or three auctions within a maintenance period mature within that period. In contrast, the tenor of the penultimate auction extends into the next maintenance period. It

[14] This is only an approximation since reservable funds borrowed in the last two auctions in a maintenance period carry over until the next.

[15] Each maintenance period has either 4 or 5 auctions.

[16] We have carried out the same test when dropping the highest and lowest observations within each auction position. The results do not change.

therefore offers the first chance for banks to complete their reserve management for the duration of the maintenance period, with the exception of the fine tuning required by unexpectedly large in- or out flows in the final days of the maintenance period. This may lead banks to bid more aggressively in the penultimate auction, thus causing discounts and underpricing to fall.

Turning now to swap spreads, note that in common with the final auction the penultimate auction covers the period when the volatility of overnight rates is at its highest; namely the period around the end of the maintenance period. This increased risk may cause swap rates to fall if lenders, who receive fixed and pay floating, are in relatively large supply as compared with borrowers. This situation could arise if conservative liquidity management leads some banks to bid particulary aggressively in the penultimate auction, as suggested above. To summarize, while it is hard to say what lies behind our findings on swap spreads and underpricing within the maintenance period without the benefit of a fully fledged model, we suspect it is driven in part by rate expectations and in part by the unique role played by the penultimate auction in terms of liquidity management and the higher overnight volatility at the end of the maintenance period.

7 Size

In this section, we examine the performance of large versus small bidders. One might expect large bidders to do better, since by virtue of being large, they have more to gain from investing time and effort etc in the bidding process. Furthermore, there is some anecdotal evidence that smaller banks submit their bids well before the deadline, thus giving themselves a competitive disadvantage since their bids do not fully incorporate market conditions (e.g. the swap rate) at the time of the auction.

To investigate this, we first examine the stability of the relative bid size of banks across auctions. We do so by making twelve size based groups for each auction, where we categorize bidders according to their relative bid size. For each auction, group 12 consists of the largest 8.33% bidders and group 1 consists of the smallest 8.33%. The choice of 12 groups is arbitrary. Table IX is a "Markov" table to gauge the stability of these groups across auctions. In the table, the rows and columns represent the size groups. The numbers in each cell are the number of banks that were in size group i and j in consecutive auctions, where the columns represent the previous auction and the rows represent the current auction. The numbers in the cells are aggregates for the entire sample. For example, row 12, column 12 represents the number of players that were in the largest group in auction n that were also in the largest group in auction $n-1$, where n goes from $2,\ldots,53$. Some migration is to be expected because the number of bidders in each auction varies. However, the table shows that there is a great deal of stability in these groups. Banks tend to be in the same size group from auction to auction and the number of migrating banks is decreasing in the migration distance (group n − group m).

Next we break the sample up into 12 fixed groups of 100 banks each (99 in the smallest group) based upon the average relative bid size for each bank across all auctions that the bank participated in. Given the stability of the auction-by-auction size groups, we think comparisons between these new fixed groups will be representative for differences between "large" and "small" banks.[17] In terms of cross-sectional differences between large and small bidders using sorting on an auction-by-auction basis or using our fixed sorting, we have seen no notable qualitative differences. We therefore report statistics only for the fixed size groups. One advantage of working with fixed rather than auction-dependent size groups is that any differences that we find in terms of performance, for example, can be attributed to systematic differences among specific groups of banks rather than differences in private information, refinancing needs, collateral portfolios, etc at given points in time. Another advantage is that by working with fixed groups, we can also examine the extent to which differently sized banks are able to "time" their purchases. For example, we can address the question as to whether large banks buy less in penultimate auctions than small banks, or vice versa. This is an interesting question, since penultimate auctions have less underpricing than other auctions.

Table X reports summary statistics on each of the 12 size groups (standard errors in brackets). The first row in the table is the average relative bid quantity for each bidder in the group. The second row shows the mean quantity won by the group as a whole across auctions. We can see that there is a very large size variation among the groups. Banks in the largest size group typically bid for 1.991% of expected auction size and receive 0.958% of the realized auction size. In contrast, banks in the smallest size group typically bid for 0.002% and receive 0.001%. So in terms of amounts bid for and amounts awarded, the largest size group is about 1,000 times larger than the smallest size group.

The table reveals a discernable difference in the behavior and performance of large and small banks. For example, comparing the largest group (number 12) with the smallest group (number 1), we see that underpricing is higher for large banks. In other words, large bidders tend to obtain liquidity cheaper than small bidders. This is perhaps not surprising. However, the striking thing is that large banks have larger underpricing without having a larger discount. In terms of bidding behavior, the difference between large and small banks is in the number of bids and the kurtosis. In particular, large bidders tend to submit more bids and have more kurtosis. Unless large bidders time their auction borrowings better than small bidders, it appears that it is the larger kurtosis that allows them to borrow cheaper in the auction. Kurtosis can be increased, keeping standard deviation the same, by using three bids and placing more quantity on the middle bid and adjusting the upper and lower bids appropriately.

In Table XI, we formally test the hypothesis that large and small banks perform differently. The table contains means tests on underpricing. It reports the differences in mean underpricing between pairs of groups, with p-values in brackets. For example, row 12 column 1 shows that the difference in average underpricing between banks in group 12 and group 1 is 1.65 bp. The difference is significant at better than the 1% level. We can also see that group 12 has a significantly bigger underpricing than all other groups, with the exception of group 10 and 8 and, to a smaller extent, group 11. Groups 1 and 2 have a significantly smaller underpricing than all other groups.

[17]Note our categorization of "large" and "small" banks is based on bid sizes rather than on balance sheets. What one normally would think of as a large bank, may well be a small bank in terms of bid size, and vice versa.

The table demonstrates that larger banks tend to have less underpricing than smaller banks.

To examine whether large banks time their purchases better or whether they simply are better due to "smarter" strategies within auctions, we look at the amounts the different size groups borrow in auctions in different positions within maintenance periods. This is motivated by the result in the previous finding that penultimate auctions are more expensive. If large banks time their borrowing better, we would expect to see them borrow relatively less in these auctions. Results on relative quantities purchased for each size group for each auction position are reported in right-hand panel of Table XII. We see some evidence of the dampened cycling strategies documented earlier, and group 1 tends to buy more heavily in the first and penultimate auctions of maintenance periods, while group 12 tend to buy less. However, the differences are not dramatic. Moreover, group 10, which has the same high underpricing as group 12, buys more in penultimate auctions than in any other auction position. Thus the right hand panel of Table XII offers little evidence that larger banks time their borrowings better.

The left hand panel of Table XII reports on underpricing by auction position for the twelve groups of banks. The table shows that all groups do worse in auctions in position 3 than in other auctions. Each group shows the same variability in underpricing across auctions over the maintenance period. However, there is little evidence of a systematic difference between underpricing of different groups across auction positions.

Another approach for testing whether large bidders are able to time their auction borrowings is to see whether they borrow more in auctions that have large underpricing. We examine this by, for each size group, regressing the group's relative bid quantity, b_{ji} and the group's relative award quantity, a_{ji} on underpricing, u_j, where j denotes auction j and i denotes size group i. Note that in these twelve regressions, there is one underpricing number for each auction, regardless of the size group. We thus obtain two underpricing "betas" for each size group. If large banks can time their purchases, we should see their beta being positive and that of smaller banks being negative. The findings are reported in Table XIII. For the "bid" betas, only the one for group 2 is significant. For the "award" betas, only the one for group 11 is significant, and it is negative. We conclude that there is no evidence that large banks time their purchases better than small banks. The difference in underpricing between groups that we documented above is therefore due to large banks consistently borrowing cheaper than small banks. Since their discounts are the same, the higher underpricing for large banks must be due to "smarter" strategies. In terms of strategies, from Table X it seems that the most significant differences between small and large banks lie in the larger number of bids and higher kurtosis by larger banks. It may well be that this lies behind the higher underpricing they achieve.

8 Underbidding

In this section, we study the two underbid auctions in greater detail. Studying these auctions is important because several auctions held after the end of our dataset have also been underbid. Thus, from time to time, there is a breakdown in the ability of the auctions to bring to the banking sector the liquidity it needs to maintain reserve requirements. Understanding this breakdown is therefore important.

Table XIV provides some summary statistics from the two underbid auctions. These were held on 13 February 2001 and 10 April 2001 and are the 34th and 42nd auctions, respectively, in our dataset. In these two auctions, bidders demanded only 74.2% and 47.1%, respectively, of the expected auction sizes. The expected auction sizes were euros 88 billion and euros 53 billion, so the underbidding was not driven by these two auctions being unusually large. Indeed, auction 42 is substantially smaller than average. The striking information in Table XIV is that the swap spread for these two auctions were less than zero. For auction 34, the swap rate at the time of the auction was 0.5 bp below the minimum bid rate in the auction. For auction 42, it was 5.5 bp below. This means that a bank could get cheaper funding by shorting the swap (paying fixed) and borrowing on an overnight basis for two weeks as compared with borrowing in the auction.

We will examine whether the underbidding were driven by large or small banks. For this purpose, we break our sample up into different size groups than in the previous section. In particular, we break it up into the top 20, 21-50, 51-100, 101-200, and 201-1199. In Table XV [Panel (a)] we report summary statistics on amount bid for, amount awarded, and number of bidders for these size groups, excluding auctions 34 and 42. Standard errors are in brackets. We see that, on average, 16.8 of the top 20 banks participate in an auction and they bid for a total of 75.3% of the auction. Of the bottom 999 banks, 415.6 normally participate and as a group they bid for 30.0% of each auction. Panel (b) reports on the same variables for the two underbid auctions. The comparison with the "normal" auctions is striking. While the top 20 banks normally buy 34.7%, in the two underbid auctions they buy only 25.3% percent. In contrast, the bottom 999 banks normally buy 14.5%, but in the two underbid auctions they buy 18.7%. Similarly, the 101-200 largest banks normally buy 12.7%, but in the two underbid auctions they buy 16.3%. In other words, the top 20 banks normally buy about 7.6 percentage points *more* than the bottom 1099 banks. In the two underbid auctions, the top 20 buy 9.7 percentage points *less* than the bottom 1099.

As a robustness check, in Table XVI, we report summary statistics on the eight auctions straddling auction 34 [Panel (a)], and the eight auctions straddling auction 42. We see that the top 20 banks reduced their purchase in both of the underbid auctions relative to what they were buying in the auctions before. Furthermore, the top 20 banks increased their purchases in the auctions after the underbid auction.

A means test which confirms that large banks cut back their borrowings more than small banks is carried out in Table XVII. The top row compares auction 34 with all other auctions, for each size group. The second row compares auction 34 with the eight auctions straddling in. The next two rows repeats the exercise for auction 42. The table shows unequivocally that the top 20 banks reduced their borrowing in the underbid auctions while bottom 1099 banks increased theirs.

In conclusion, there is strong evidence that underbidding in auctions 34 and 42 was caused by large banks cutting back demand rather than by small banks free-riding on larger banks. This supports the conclusion from the previous section that larger banks use "smarter" strategies than small banks. It also suggests that to deal successfully with the underbidding problem, it may be necessary to address the bidding of the top twenty or so largest banks. It would be interesting to see whether larger players also cut back more than smaller players in the more recent underbidding cases.

That large banks are the "worst" underbidding culprits is surprising, since underbidding is fundamentally a free-riding problem. The banking sector suffers as a result from it, since the ECB keeps the subsequent auction "tight"; it's policy has been to increase the size of the subsequent auction but not by as much as the banking sector needs to be liquidity neutral. This is illustrated by the banks' use of the marginal lending facility, net of the deposit facility, after the two underbid auctions for a total amount of above euros 60 billion. Thus these two underpricing episodes have been costly for the banking sector as a whole, since the marginal lending facility is 100 bp above the auctions' minimum bid rates. In some cases, unsecured overnight transactions were even above the ECB's standing facility. Normally, one would expect small players to be the "worst" free-riders [Olsen and Zeckhauser (1966), Shleifer and Vishny (1986)]. The fact that the large banks act as free-riders suggests that they consider themselves fairly small in the big picture. The largest bank in an average auctions buys only around 6% of the auction. Our finding may also be driven by larger banks having better access to the swap market. In principle, this should not be the case, but smaller banks often lack the resources, "sophistication," and will (e.g. at board level) to make use of derivative contracts.

9 Conclusion

In this paper we have provided an overview of individual bidder behavior and performance in the European Central Bank's repo auctions. With respect to what drives bidder behavior, our findings stand in contrast with the growing literature on treasury auctions. In particular, we have found no evidence that bidders react to increased volatility by reducing their bids. Instead, they increase their bids, and this results in a lower underpricing when volatility is larger. Thus, it appears that private information about post-auction value and the winner's curse plays little role in ECB repo auctions. Our findings point to individual bidders' reserve balances being an important factor in how they bid. While we expect that the banks running the largest reserve deficits are the most aggressive bidders, we cannot confirm this hypothesis since we do not have access to reserve balance data. A key driver behind bidder behavior and performance is the level of secondary market rates relative to the minimum bid rates. When this "spread" is large, bidders tend to shade more and significantly larger underpricing results.

A unique feature of ECB repo auctions is the sequential and overlapping auction cycle. Furthermore, since there are up to five auctions within each maintenance period, this provides banks with an opportunity to time their borrowings to take advantage of the direction that interest rates are expected to move. For example, when rates are expected to rise, banks would prefer to fulfill the bulk of their reserve requirements early in the maintenance period. However, we find that expectations of rising rates do not affect bidding behavior or performance. This is consistent with sequential auction theory, which predicts that the expected profits to players in sequential auctions are constant across the auctions. What is happening in our case is that the expectations of rising rates are already factored into the current level of interest rates. However, when rates are expected to fall, the presence of the minimum bid rate comes into play and the expectation of falling rates therefore has an impact on bidder behavior and underpricing. This suggests that building in reservation prices into theoretical work on sequential auctions may be a fruitful exercise. A puzzling finding, however, is that the penultimate auctions in each maintenance period appear to have less underpricing than the other auctions. At the same time, secondary market rates relative to the minimum bid rates also seem to be lower at the time of these auctions.

Another important feature of ECB repo auctions is that there is substantial heterogeneity among players. Bidders include large commercial banks as well as small cooperatives. We document that larger bidders do better, in the sense that they manage to obtain lower borrowing rates in the auction than smaller bidders. The remarkable thing about this result is that they do so without actually bidding at lower rates, on average. In terms of bidder behavior, the only substantial difference between large and small bidders is that the larger ones use more bids and have a higher kurtosis. Since we find no evidence that large banks are able to time their borrowings, we can only conclude that larger banks achieve their superior performance through "smarter" strategies, which include using more bids.

Finally, our dataset includes two underbidding episodes, where banks demanded less than the liquidity neutral amount. This happened when the secondary market rate was below the minimum bid rate and there were strong expectations that the ECB would reduce rates. Since this underbidding is costly for the banking sector as a whole, this appears to be a free-rider problem. Surprisingly, we find that large bidders cut back their demand and reduced the relative quantity they borrowed in the auction by more than small bidders. To address underbidding in the future, it therefore seems important to create incentives for large players, in particular, not to try to free-ride when they expect rates to fall.

10 Appendix: Conditional Volatility Estimation

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. As in Hamilton's (1996) study of the Fed funds rate, we use calendar effects to capture the effect of fixed events, such as the end and beginning of the maintenance period, Governing Council meetings, the end and beginning of the month, and main and longer term refinancing operations. Since interest rates tend to be mean-reverting and since conditional volatilities sometimes react asymmetrically to increases and decreases in rates, we also introduce stochastic variables to capture this. In particular, we use a dummy variable which takes the value 1 when the swap rate fell the previous day and 0 otherwise. We also use the "short-end" slope of the term structure of interest rates.

The final model specification and our results are in Table XVIII. The final specification has been chosen based upon a variety of diagnostic tests. In particular, we examine closely the joint distributions of standardized residuals and standardized squared residuals (see, e.g., Engle and Ng (1993)). We reject the hypothesis that the residuals or squared residuals could be autocorrelated. It should be noted that our empirical results are robust to many other model specifications for the process of conditional volatility.

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Table I
Participation

Panel A presents the following statistics for each of the 13 maintenance periods for which we have data: the number of demand schedules submitted in all auctions within the maintenance period, the number of bidders who participated in at least one auction, the number of demand schedules that won some award, and the number of bidders who won some award. Panel B tabulates the number of banks that participated and won some award in from 1 to 12 maintenance periods. (This panel excludes the 53rd auction in our sample, since this is the only auction we have data for in the 13th maintenance period). Panel C tabulates the number of banks that participated in and won some award in from 1 to 53 auctions. N is the total number of banks who bid and won in our sample.

Panel A: Demand schedules and bidders per maintenance period

	1	2	3	4	5	6	7	8	9	10	11	12	13
Demand schedules	2938	3608	2606	2362	2954	2302	2033	2601	2190	1620	2353	1814	452
Bidding	949	919	850	822	796	841	779	774	738	680	662	623	452
Winning schedules	2441	2427	1957	1906	2482	2084	1986	2407	1724	1423	1687	1524	262
Winning	865	843	767	746	758	812	772	737	678	604	576	577	262

Panel B: Number of maintenance periods per bank

	mean	std	1	2	3	4	5	6	7	8	9	10	11	12
Bidding	7.861	4.068	120	85	64	55	50	68	63	72	59	75	81	407
Winning	7.279	4.202	125	78	62	66	52	70	62	69	79	79	83	327

Panel C: Number of auctions per bank

	mean	std	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-53	N
Bidding	24.861	17.557	254	89	114	81	100	87	69	86	94	225	1199
Winning	20.258	16.034	268	120	122	106	98	87	72	87	84	108	1152

Table II
Descriptive Statistics

This table reports descriptive statistics on the exogenous variables (Panel A), the bidding variables (Panel B), and the participation and performance variables (Panel C). The symbol s.e. denotes the standard error of the mean, and N is the number of observations. 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 prior to each auction. Forward spread is the difference between the EURIBOR forward rate from 1 month to 2 months and the minimum bid rate. Swap spread is the difference between the two week swap rate and the minimum bid rate. Projected number of bidders is obtained by a regression as described in the text. Discount and underpricing are the differences between the secondary market rates (deposit, swap, and repo) and the quantity-weighted average bid rate within each demand schedule and the quantity-weighted average winning rate, respectively. Standard deviation, skewness, and kurtosis are all quantity-weighted intra-bidder measures. Relative bid quantity is the quantity demanded by a single bidder relative to the expected auction size. Relative auction size is the quantity allotted in a given auction relative to the expected auction size. Largest 1, 10 and 50 is the alloted share of the 1, 10 and 50 largest (by award) bidders in a given auction. Manybids is the percentage of bidders who submit more than 1 bid in a given auction. Stopout spread is the difference between the stopout rate and the minimum bid rate. Winrate-stopout is the difference between the quantity-weighted average winning rate and the stopout rate. Award concentration is the Herfindahl index. Award/demand concentration is the Herfindahl index based on awards divided by the Herfindahl index based on demand. Bid-to-cover is the quantity demanded in a given auction divided by the expected auction size. Units of measurement are in the second column.

	units	mean	std	s.e.	min	max	N
a) Exogenous Variables							
Volatility of swap rate	bp	4.273	1.217	0.167	1.176	8.538	53
Expected auction size	bln	89.585	31.669	4.350	5	177	53
Swap spread	bp	8.132	8.775	1.205	-5.500	48.250	53
Forward spread	bp	15.530	22.077	3.032	-26.652	62.657	53
Projected number of bidders		555.588	78.848	11.041	391.241	711.357	50
b) Bidding Variables							
Discount (deposit)	bp	4.651	4.372	0.025	-60.500	51.500	29,833
Discount (swap)	bp	3.352	4.476	0.026	-59.500	48.250	29,833
Discount (repo)	bp	0.487	5.342	0.031	-67	42	29,833
Standard deviation	bp	0.704	0.901	0.005	0	28.284	29,833
Skewness		-0.018	0.482	0.003	-4.984	13.712	29,833
Kurtosis		1.529	1.709	0.010	1	189.005	29,833
Relative bid quantity	%	0.367	1.491	0.009	0.001	80	29,833
Number of bids		2.397	1.434	0.008	1	10	29,833
c) Performance and Participation							
Underpricing (deposit)	bp	2.959	2.545	0.350	-4.645	10.064	53
Underpricing (swap)	bp	1.643	2.492	0.342	-5.645	6.762	53
Underpricing (repo)	bp	-1.347	3.096	0.425	-10.488	5.564	53
Stopout spread	bp	4.849	6.951	0.955	0	43	53
Winrate-stopout	bp	1.640	1.404	0.193	0.145	6.468	53
Number of bidders		562.925	116.188	15.960	240	800	53
Manybids	%	64.574	14.325	1.968	13.750	80.571	53
Number of winners		458.679	115.100	15.810	154	705	53
Award concentration		2.124	1.424	0.196	1.122	8.875	53
Award/demand concentration		1.368	0.627	0.086	0.928	4.615	53
Bid-to-cover		2.064	2.178	0.299	0.471	16.661	53
Largest 1	%	6.819	4.302	0.591	3.131	26.598	53
Largest 10	%	34.340	9.312	1.279	23.848	64.763	53
Largest 50	%	72.201	7.409	1.018	61.973	94.450	53
Relative auction size	%	99.410	8.698	1.195	47.073	109.434	53

Table III
Cross-Sectional Analysis

This table reports cross-sectional regressions on the following dependent variables: discount (swap), standard deviation, skewness, kurtosis, quantity-weighted kurtosis, relative bid quantity, number of bids per bidder, underpricing (swap), winrate-stopout, number of bidders, manybids, largest10, bid-to-cover. The following regressors are used: volatility swap (conditional volatility of the two week swap rate), expected size (expected auction size), forward spread(-) (forward rate from 1 to 2 months if negative, otherwise 0), swap spread (difference between swap rate and minimum bid rate), projected # bidders (projected number of bidders). For manybids, largest10, number of bidders and bid-to-cover, the two step Cochrane-Orcutt procedure is implemented. The other regressions include a third step: at the third stage the Newey-West standard errors are produced for Cochrane-Orcutt transformation of the initial regression to correct for heteroscedasticity. *t*-statistics are in parenthesis.

	units	C	volatility swap bp	expected size bln	forward spread (-) bp	swap spread bp	proj # bidders 100's	Adj R^2	N
(a): Bidding variables									
Discount (swap)	bp	1.715	-0.377	0.016	0.131	0.278	-0.106	0.733	49
		(0.685)	(-2.261)	(1.777)	(4.076)	(5.063)	(-0.330)		
Std	bp	0.331	0.043	0.001	0.007	0.031	-0.037	0.827	49
		(1.408)	(2.543)	(2.740)	(1.973)	(11.855)	(-1.011)		
Skewness		-0.053	-0.004	-0.001	-0.004	-0.001	0.013	0.559	49
		(-1.043)	(-1.152)	(-4.944)	(-3.856)	(-2.029)	(2.313)		
Kurtosis		1.028	0.013	0	-0.002	0.005	0.049	0.395	49
		(12.084)	(1.328)	(0.398)	(-0.550)	(2.229)	(3.440)		
QW kurtosis		1.569	0.075	0.002	-0.003	0.016	-0.049	0.280	49
		(3.862)	(2.421)	(1.614)	(-0.368)	(2.074)	(-0.792)		
Relative bid quantity	%	2.884	-0.026	-0.010	0.015	0.009	-0.214	0.339	49
		(1.821)	(-0.603)	(-2.132)	(1.674)	(1.097)	(-1.471)		
Number bids per bidder		1.632	0.040	0.003	0.028	0.029	0.003	0.693	49
		(3.558)	(1.401)	(3.334)	(3.623)	(6.103)	(0.054)		
(b): Performance and participation variables									
Underpricing (swap)	bp	-0.434	-0.538	0.026	0.148	0.107	0.207	0.671	49
		(-0.267)	(-3.540)	(3.802)	(4.553)	(3.158)	(0.942)		
Winrate-stopout	bp	2.129	0.077	0.013	0.031	0.075	-0.359	0.384	49
		(1.378)	(0.847)	(2.811)	(1.439)	(3.654)	(-1.987)		
Manybids	%	51.819	0.535	0.085	1.419	0.497	0.195	0.693	49
		(3.459)	(0.670)	(3.510)	(6.029)	(3.706)	(0.103)		
Largest 10	%	76.678	1.082	-0.175	-0.050	0.094	-4.474	0.456	49
		(7.321)	(1.297)	(-5.117)	(-0.278)	(0.716)	(-3.718)		
Number of bidders	100's	1.054	0.027	0.011	0.051	0.037	0.447	0.722	49
		(1.339)	(0.438)	(5.109)	(6.101)	(2.878)	(4.169)		
Bid-to-cover		11.457	-0.115	-0.041	0.075	0.045	-0.766	0.315	49
		(4.093)	(-0.528)	(-4.810)	(1.562)	(1.303)	(-2.348)		

Table IV
Runs Table

This table reports the distribution of runs (for bids and awards) for our sample. Run is defined as the number of auctions between any two auctions in which a bidder participated (bid run) or won (award run). Thus, a run of length 1 corresponds to two consecutive auctions.

	median	mean	std	1	2	3	4	5	6-10	11-25	26-51	N
Bid	1	1.504	1.976	22477	4206	750	421	185	315	248	31	28633
Award	1	1.726	2.190	15766	4892	1032	521	254	414	254	25	23158

Table V
Autocorrelation of Bids and Awards

This table reports on the first and second autocorrelation coefficients for bids and awards (relative to the expected auction size and allotted quantity, respectively) for bidders who participated in each maintenance period in our sample. The reported mean across bidders is equally weighted. % positive is the percentage of bidders with positive autocorrelations.

	mean	t-stat	% positive	min	max	N
bids, 1st	-0.028	-3.843	31.695	-0.644	0.561	407
bids, 2nd	0.126	12.765	68.796	-0.144	0.846	407
award, 1st	-0.114	-10.106	27.273	-0.721	0.804	407
award, 2nd	0.300	26.278	91.155	-0.432	0.842	407

Table VI
Descriptive Statistics: Maintenance Periods

This table provides descriptive statistics for each maintenance period covered by our sample (period 13 is excluded). The following variables are reported: volatility swap, swap spread, forward spread, expected auction size, discount (swap), underpricing (swap), standard deviation, skewness, kurtosis, winrate-stopout, stopout spread, bid-to-cover (see Table II).

		1	2	3	4	5	6	7	8	9	10	11	12
Vol swap	bp	4.12	4.06	4.36	4.19	4.07	4.14	4.11	4.04	4.63	4.51	4.63	4.09
		(0.06)	(0.02)	(0.15)	(0.07)	(0.03)	(0.09)	(0.04)	(0.02)	(0.38)	(0.27)	(0.36)	(0.04)
Swap sprd	bp	8.75	15.85	18.81	11.87	9.60	10	5.50	3.90	4.13	2	5.10	2.37
		(1.59)	(4.19)	(9.83)	(5.88)	(1.47)	(1.78)	(2.79)	(2.65)	(0.75)	(5.33)	(0.43)	(1.43)
Forw sprd	bp	25.02	44.15	39.48	24.88	43.56	25.96	4.17	-1.75	0.52	-19.80	2.78	-2.77
		(0.74)	(4.42)	(7.80)	(5.60)	(4.75)	(6.10)	(4.60)	(1.14)	(0.98)	(5.21)	(1.36)	(2.85)
Exp size	bln	73.50	88	83.75	86.75	94	108	98	109.40	90.50	99.25	64.80	80.50
		(12.43)	(16.71)	(11.74)	(5.51)	(3.83)	(9.64)	(1.47)	(15.34)	(31.49)	(30.36)	(15.11)	(5.19)
Disc (s)	bp	4.70	7.46	3.98	3.65	3.06	3.79	2.08	2.46	2.19	0.53	2.22	0.08
		(0.07)	(0.08)	(0.11)	(0.11)	(0.07)	(0.07)	(0.07)	(0.08)	(0.05)	(0.16)	(0.05)	(0.05)
Under (s)	bp	3.17	4.59	1.37	2.02	1.95	3.39	1.92	1.65	1.39	-2.14	0.80	-0.61
		(1)	(0.78)	(0.41)	(1.26)	(1.08)	(0.74)	(1.08)	(1.12)	(0.89)	(1.84)	(0.40)	(0.65)
Std	bp	1.04	0.78	1.09	0.75	0.69	0.74	0.59	0.46	0.47	0.69	0.53	0.44
		(0.02)	(0.01)	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)
Skewness		0.02	-0.02	-0.02	-0.02	-0.04	-0.06	-0.02	0.03	-0.01	-0	-0.04	-0.03
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Kurtosis		1.67	1.66	1.58	1.56	1.54	1.52	1.44	1.38	1.44	1.54	1.46	1.46
		(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.13)	(0.02)	(0.02)
Win-stp	bp	1.58	1.66	1.94	1.61	1.65	3.36	2.33	1.45	0.73	1.39	1.30	0.99
		(0.63)	(0.51)	(0.37)	(0.47)	(0.23)	(1.22)	(0.92)	(1.01)	(0.07)	(1.12)	(0.33)	(0.24)
Stp spr	bp	4	9.60	15.50	8.25	6	3.25	1.25	0.80	2	2.75	3	2
		(0)	(3.23)	(9.19)	(4.50)	(1.10)	(1.65)	(0.95)	(0.58)	(0.41)	(2.75)	(0.32)	(1)
Bid/cov		2.64	2.57	2.08	1.66	1.57	1.29	1.24	1.14	2.41	1.05	4.92	1.78
		(0.32)	(0.47)	(0.22)	(0.18)	(0.08)	(0.12)	(0.09)	(0.14)	(0.73)	(0.21)	(2.94)	(0.17)

Table VII
Descriptive Statistics: Auction Positions

This table provides descriptive statistics for auctions in different positions within the maintenance period. Position 1 is the first auction in any maintenance period. Position 2 is the second auction in a period with 4 auctions or the second and third auctions in a period with 5 auctions. Position 3 is the third auction in a period with 4 auctions or the fourth auction in a period with 5 auctions. Position 4 is the last auction in any maintenance period. Definitions of all variables are given in Table II.

	units	1	2	3	4
Volatility of swap rate	bp	4.351	4.127	4.264	4.269
		(0.133)	(0.040)	(0.164)	(0.111)
Swap spread	bp	12.208	6.953	4.021	10
		(3.872)	(1.301)	(1.556)	(2.498)
Forward spread	bp	18.088	17.235	12.633	15.753
		(6.685)	(5.578)	(6.856)	(6.078)
Expected auction size	bln	5.083	95.188	74.250	112.250
		(9.799)	(6.640)	(5.063)	(10.108)
Discount (swap)	bp	5.233	2.547	1.341	4.318
		(0.064)	(0.029)	(0.044)	(0.061)
Underpricing (swap)	bp	2.556	1.745	0.042	2.319
		(0.960)	(0.395)	(0.701)	(0.617)
Standard deviation	bp	0.848	0.618	0.557	0.815
		(0.014)	(0.007)	(0.008)	(0.012)
Skewness		-0.001	-0.017	-0.005	-0.042
		(0.006)	(0.005)	(0.006)	(0.006)
Kurtosis		1.538	1.526	1.484	1.570
		(0.030)	(0.015)	(0.020)	(0.015)
Winrate-stopoutrate	bp	1.819	1.270	1.145	2.514
		(0.414)	(0.238)	(0.209)	(0.585)
Stopout spread	bp	7.833	3.937	2.833	5.167
		(3.384)	(1.127)	(0.936)	(1.762)
Bid-to-cover		3.182	1.787	1.788	1.612
		(1.250)	(0.199)	(0.245)	(0.157)

Table VIII
Means Tests

This table reports the results of means tests for underpricing (swap), discount (swap), and swap spread between auctions in position 3 and auctions in the other positions (see Table VII). Means are given in basis points. P-values are in parenthesis.

	1	2	4
Underpricing	-2.513	-1.703	-2.277
	(0.046)	(0.033)	(0.023)
Discount	-3.684	-1.509	-3.115
	(0.028)	(0.137)	(0.042)
Swap spread	-8.187	-2.932	-5.979
	(0.063)	(0.158)	(0.054)

Table IX
Bid-Size Markov Table

This table reports on the stability of 12 bid-size groups from auction to auction. For each auction, twelve groups ordered by bid-size are created. The groups are ordered from smallest to largest, that is, Group 1 consists of the 8.33% smallest bidders and Group 12 consists of the 8.33% largest bidders. The (i,j)th cell in the table shows how many bidders who were in group j last auction are in group i this auction. i refers to rows, j to columns.

	1	2	3	4	5	6	7	8	9	10	11	12
1	1018	366	97	45	19	14	5	3	4	0	1	0
2	347	611	321	183	97	38	12	8	6	2	0	0
3	94	320	594	395	188	94	51	18	12	3	2	0
4	37	164	392	567	360	159	99	38	18	4	0	0
5	20	85	183	358	503	333	205	92	49	20	1	1
6	11	38	88	165	313	510	400	197	95	43	9	2
7	6	10	37	90	175	378	551	377	173	69	15	4
8	3	8	17	42	91	188	352	615	383	156	57	4
9	2	9	14	15	47	80	160	389	627	408	161	23
10	0	0	3	3	16	42	62	133	419	786	476	83
11	1	1	2	1	2	11	14	56	134	454	1025	349
12	0	0	0	0	1	1	3	6	29	73	343	1685

Table X
Descriptive Statistics: Fixed Groups

This table provides descriptive statistics for 12 fixed groups based on bid-size. Each bidder is placed in group from 1 to 12 based upon his relative bid quantity throughout the total sample for auctions he participated in. The groups are ordered by size, that is, Group 1 consists of the 99 smallest bidders and Group 12 consists of the 100 largest bidders.

	1	2	3	4	5	6	7	8	9	10	11	12
Re	0.002	0.006	0.010	0.016	0.025	0.037	0.054	0.079	0.121	0.208	0.436	1.991
	(0)	(0)	(0)	(0)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.005)	(0.010)	(0.057)
Disc	3.234	3.193	2.958	2.956	3.330	3.435	3.397	3.781	3.238	3.545	3.451	3.309
	(0.216)	(0.145)	(0.134)	(0.104)	(0.094)	(0.089)	(0.083)	(0.083)	(0.081)	(0.073)	(0.068)	(0.056)
Under	0.580	0.879	1.173	1.391	1.781	1.812	1.934	2.118	1.843	2.210	2.108	2.231
	(0.196)	(0.096)	(0.102)	(0.079)	(0.070)	(0.068)	(0.063)	(0.061)	(0.063)	(0.056)	(0.055)	(0.047)
Std	0.421	0.790	0.692	0.703	0.785	0.708	0.633	0.753	0.732	0.680	0.676	0.726
	(0.032)	(0.031)	(0.025)	(0.023)	(0.022)	(0.017)	(0.015)	(0.016)	(0.017)	(0.014)	(0.014)	(0.013)
Skew	-0.014	-0.045	-0.020	-0.033	0.004	0.009	-0.028	-0.006	-0.041	-0.040	0.007	-0.014
	(0.004)	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)	(0.011)	(0.009)	(0.010)	(0.010)
Kurt	1.060	1.296	1.340	1.411	1.450	1.483	1.426	1.515	1.689	1.536	1.643	1.807
	(0.006)	(0.012)	(0.018)	(0.019)	(0.013)	(0.015)	(0.012)	(0.017)	(0.045)	(0.017)	(0.060)	(0.034)
N bids	1.411	2.037	2.166	2.312	2.500	2.421	2.286	2.566	2.570	2.403	2.450	2.622
	(0.024)	(0.030)	(0.037)	(0.031)	(0.031)	(0.025)	(0.026)	(0.028)	(0.028)	(0.025)	(0.024)	(0.025)
Award	0.001	0.004	0.006	0.010	0.014	0.019	0.028	0.039	0.063	0.104	0.206	0.958
	(0)	(0)	(0)	(0)	(0)	(0)	(0.001)	(0.001)	(0.001)	(0.002)	(0.005)	(0.021)
A rat	0.626	0.662	0.670	0.661	0.622	0.605	0.618	0.568	0.628	0.589	0.573	0.588
	(0.015)	(0.010)	(0.010)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.006)
Wr-stp	3.211	2.751	2.336	2.104	1.853	1.829	1.729	1.610	1.682	1.490	1.384	1.324
	(0.142)	(0.071)	(0.077)	(0.057)	(0.048)	(0.046)	(0.043)	(0.040)	(0.042)	(0.034)	(0.032)	(0.028)
P part	3.920	6.210	6.040	7.420	7.230	8.420	8.530	8.470	8.850	8.940	9.810	10.490
	(0.327)	(0.395)	(0.394)	(0.401)	(0.406)	(0.387)	(0.378)	(0.371)	(0.375)	(0.379)	(0.302)	(0.298)
A p	9.090	16.570	15.680	21.890	22.280	26.150	26.540	27.300	29.270	30.260	33.500	39.800
	(1.111)	(1.440)	(1.392)	(1.601)	(1.743)	(1.637)	(1.643)	(1.661)	(1.776)	(1.740)	(1.506)	(1.442)
Runs	1	1	1	1	1	1	1	1	1	1	1	1
	(0.153)	(0.052)	(0.168)	(0.254)	(0.092)	(0.096)	(0.062)	(0.377)	(0.060)	(0.191)	(0.214)	(0.046)

Table XI
Means Tests on Underpricing Between Fixed Groups.

This table reports on means tests for differences in underpricing (swap) between the 12 fixed groups (see Table X). The groups are ordered by size, that is, Group 1 consists of the 99 smallest bidders and Group 12 consists of the 100 largest bidders. The (i, j)th cell is the difference in underpricing (swap) between groups i and j, where i represents rows and j columns. Differences are in basis points. P-values are in parenthesis.

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	-0.30	-0.59	-0.81	-1.20	-1.23	-1.35	-1.54	-1.26	-1.63	-1.53	-1.65
	(1)	(0.12)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
2	0.30	0	-0.29	-0.51	-0.90	-0.93	-1.06	-1.24	-0.96	-1.33	-1.23	-1.35
	(0.12)	(1)	(0.04)	(0.00)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
3	0.59	0.29	0	-0.22	-0.61	-0.64	-0.76	-0.95	-0.67	-1.04	-0.94	-1.06
	(0)	(0.04)	(1)	(0.09)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
4	0.81	0.51	0.22	0	-0.39	-0.42	-0.54	-0.73	-0.45	-0.82	-0.72	-0.84
	(0)	(0)	(0.09)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
5	1.20	0.90	0.61	0.39	0	-0.03	-0.15	-0.34	-0.06	-0.43	-0.33	-0.45
	(0)	(0)	(0)	(0)	(1)	(0.75)	(0.10)	(0)	(0.51)	(0)	(0)	(0)
6	1.23	0.93	0.64	0.42	0.03	0	-0.12	-0.31	-0.03	-0.40	-0.30	-0.42
	(0)	(0)	(0)	(0)	(0.75)	(1)	(0.19)	(0)	(0.74)	(0)	(0)	(0)
7	1.35	1.06	0.76	0.54	0.15	0.12	0	-0.18	0.09	-0.28	-0.17	-0.30
	(0)	(0)	(0)	(0)	(0.10)	(0.19)	(1)	(0.04)	(0.31)	(0)	(0.04)	(0)
8	1.54	1.24	0.95	0.73	0.34	0.31	0.18	0	0.28	-0.09	0.01	-0.11
	(0)	(0)	(0)	(0)	(0)	(0)	(0.04)	(1)	(0)	(0.27)	(0.90)	(0.14)
9	1.26	0.96	0.67	0.45	0.06	0.03	-0.09	-0.28	0	-0.37	-0.27	-0.39
	(0)	(0)	(0)	(0)	(0.51)	(0.74)	(0.31)	(0)	(1)	(0)	(0)	(0)
10	1.63	1.33	1.04	0.82	0.43	0.40	0.28	0.09	0.37	0	0.10	-0.02
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0.27)	(0)	(1)	(0.20)	(0.77)
11	1.53	1.23	0.94	0.72	0.33	0.30	0.17	-0.01	0.27	-0.10	0	-0.12
	(0)	(0)	(0)	(0)	(0)	(0)	(0.04)	(0.90)	(0)	(0.20)	(1)	(0.09)
12	1.65	1.35	1.06	0.84	0.45	0.42	0.30	0.11	0.39	0.02	0.12	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0.14)	(0)	(0.77)	(0.09)	(1)

Table XII
Fixed Groups: Underpricing and Award by Auction Position

This table reports on underpricing (swap) (left panel) and relative award (right panel) for the 12 fixed groups (see Table X) by auction position (see Table VII). Group 12 consists of the largest bidders. Underpricing is in basis points and relative award is in percent.

	Underpricing (swap)				Award			
	1	2	3	4	1	2	3	4
1	1.933	0.085	-1.556	1.733	0.027	0.020	0.027	0.023
2	2.590	0.705	-0.953	1.168	0.107	0.099	0.107	0.099
3	2.337	1.255	-0.560	1.571	0.184	0.138	0.183	0.153
4	2.688	1.330	-0.434	1.920	0.364	0.362	0.391	0.372
5	3.389	1.677	-0.059	2.127	0.581	0.535	0.635	0.519
6	3.313	1.619	-0.038	2.339	0.878	0.886	0.905	0.807
7	3.570	1.759	0.162	2.399	1.418	1.416	1.535	1.212
8	3.667	1.880	0.302	2.649	2.130	1.986	2.112	1.836
9	3.353	1.538	0.091	2.544	3.451	3.448	3.596	3.130
10	3.636	1.934	0.477	2.917	5.797	5.835	6.251	5.713
11	3.386	1.928	0.498	2.783	12.836	12.982	13.219	12.347
12	3.592	1.995	0.653	2.833	72.227	72.294	71.040	73.789

Table XIII
Fixed Groups: Regressions of Underpricing on Bid Quantity and Award

This table reports the results of ordinary least squares regressions of underpricing (swap) on (i) a constant and relative bid quantity, and (ii) a constant and relative award. Both regressions are run for each of the 12 fixed groups (see Table X). Bid and award are relative to the expected auction size and allotted quantity, respectively. Constants are not reported. t-stats are given in parenthesis. Group 12 consists of the 100 largest bidders.

	bid	Adj. R^2	award	Adj. R^2	N
1	0.003	0.049	-0	0	53
	(1.624)		(-0.065)		
2	0.015	0.081	-0.001	0.002	53
	(2.113)		(-0.278)		
3	0.010	0.005	-0.007	0.011	53
	(0.524)		(-0.750)		
4	0.018	0.005	-0.017	0.044	53
	(0.501)		(-1.528)		
5	0.039	0.011	-0.011	0.018	53
	(0.762)		(-0.975)		
6	0.069	0.007	-0.021	0.015	53
	(0.599)		(-0.889)		
7	0.137	0.022	-0.002	0	53
	(1.083)		(-0.072)		
8	0.297	0.051	0.063	0.037	53
	(1.651)		(1.399)		
9	0.132	0.002	-0.043	0.014	53
	(0.327)		(-0.857)		
10	0.384	0.007	0.003	0	53
	(0.583)		(0.039)		
11	0.042	0	-0.396	0.135	53
	(0.024)		(-2.822)		
12	-0.303	0	0.430	0.028	53
	(-0.034)		(1.207)		

Table XIV
Underbidding Case Study: Descriptive Statistics

This table provids descriptive statistics for the two underbid auctions, 34 and 42, in our sample. Definitions of all variables are given in table II.

	units	Auction 34	Auction 42
Date		13 Feb 2001	10 Apr 2001
Tender id		20010007	20010018
Maintenance period		8	10
Auction position		4	3
Expected size	bln	88	53
Bid-to-cover		0.742	0.471
Number of bidders		401	240
Relative bid quantity	%	0.185	0.196
Discount (swap)	bp	-0.944	-5.743
Underpricing(swap)	bp	-0.700	-5.645
Standard deviation	bp	0.138	0.070
Skewness		0.043	0.054
Kurtosis		1.150	1.371
Stopout spread		0	0
Winrate-stopout	bp	0.200	0.145
Volatility of swap rate	bp	4.425	4.536
Swap spread	bp	-0.500	-5.500
Forward spread	bp	-3.476	-26.652

Table XV
Underbidding Case Study: Descriptive Statistics for Five Fixed Groups

This table provides some descriptive statistics for five fixed bid-size based groups. The groups have been constructed analogously to those in Table X. Group 1-20 consists of the 20 largest bidders (by average relative bid quantity), etc. Panel A excludes auctions 34 and 42. Panel B is for auctions 34 and 42 only. Means are reported.

	1-20	21-50	51-100	101-200	201-1199
(a): All auctions excluding 34 and 42					
Rel. bid quantity: group	75.286	46.205	32.352	28.240	30.047
Award (realized): group	34.692	23.497	14.659	12.682	14.471
Number bidders	16.824	23.824	35.667	64.196	431.863
Number winners	14.804	20.216	29.059	51.235	348.765
Number of bids	2.963	2.524	2.601	2.480	2.373
(b): Auctions 34 and 42					
Rel. bid quantity: group	14.948	15.304	9.092	10.018	11.280
Award (realized): group	25.311	25.289	14.415	16.285	18.700
Number bidders	9	14.500	20.500	38	238.500
Number winners	9	14.500	20.500	38	238.500
Number of bids	1.111	1.103	1.073	1.118	1.289

Table XVI
Underbidding Case Study: The Straddling Auctions

This table provides some descriptive statistics for auctions 34 and 42 and the four auctions preceding and succeeding these auctions. Top 20 refers to the 20 largest bidders and Bottom 999 refers to the smallest 999 bidders (see Table XV). Panel A covers auction 34 and panel B covers auction 42.

	-4	-3	-2	-1	34	+1	+2	+3	+4
Expected size	101	104	85	101	88	169	25	153	49
Swap spread	4.500	2	4	0	-0.500	14	2.500	3.500	4.500
Bid-to-cover	1.363	1.140	1.619	1.034	0.742	1.187	4.385	1.241	2.658
Rel. bid quantity: top 20	44.581	41.954	57.950	36.840	19.999	41.193	176.528	44.794	111.445
Award (realized): top 20	28.859	36.566	30.600	35.305	26.948	34.673	33.855	32.114	44.426
Rel. bid quantity: bottom 999	21.889	16.919	22.610	15.318	14.060	15.626	62.076	15.660	35.856
Award (realized): bottom 999	16.748	14.971	15.417	15.009	18.946	13.272	21.307	12.985	14.367
	-4	-3	-2	-1	42	+1	+2	+3	+4
Expected size	49	135	49	118	53	177	5	80	79
Swap spread	4.500	6	-4.500	0.500	-5.500	17.500	5.500	3.500	5.500
Bid-to-cover	2.658	1.349	1.174	1.094	0.471	1.456	16.661	1.842	2.088
Rel. bid quantity: top 20	111.445	47.956	35.546	50.517	9.897	65.484	611.664	90.232	86.603
Award (realized): top 20	44.426	36.049	28.577	45.528	21.026	49.037	8.755	48.320	40.948
Rel. bid quantity: bottom 999	35.856	18.855	13.779	11.479	8.500	17.433	210.864	19.061	19.793
Award (realized): bottom 999	14.367	13.230	12.124	10.604	18.057	10.114	25.541	11.102	8.881

Table XVII
Underbidding Case Study: Means Tests

For each underbid auction and for each of the five fixed groups (see Table XV) , this table provides means tests between the award in the underbid auction and the eight straddling auctions as well as all other auctions. Means are in basis points. P-values are parenthesis.

	1-20	21-50	51-100	101-200	201-1199
all vs 34	-7.352	2.038	-1.583	2.811	4.086
	(0)	(0.003)	(0)	(0)	(0)
8 straddling vs 34	-7.602	3.607	-1.433	1.992	3.436
	(0.003)	(0.025)	(0.165)	(0.003)	(0.008)
all vs 42	-13.275	1.570	3.590	4.917	3.198
	(0)	(0.019)	(0)	(0)	(0)
8 straddling vs 42	-16.680	4.914	3.636	3.317	4.812
	(0.010)	(0.013)	(0.006)	(0.051)	(0.036)

Table XVIII

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 gives B the coefficients of the variance equation. Slope is the difference between 12 and 1 month EURIBOR. Downswap takes the value 1 if the swap rate fell the previous day and 0 otherwise. 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. Mainrepo takes the value 1 if the day is an auction day (main refinancing operation) and 0 otherwise. (-1) stands for the preceding day's observation. For example, endres(-1) is a dummy variable for the first business day in a maintenance period.

	Coefficient	z-statistics
(a) Mean equation		
Constant	-0.003	-1.790
Slope(-1)	0.012	3.592
Downswap(-1)	0.004	2.065
(b) Variance equation		
C	0.0009	4.892
ARCH(1)	0.147	3.326
GARCH(1)	0.594	7.028
Endmonth	-0.002	-6.283
Endres(-1)	-0.001	-5.758
Endres	-0.002	-5.192
Mainrepo	-0.0004	-5.080

Fig. 1: Standing Facilities and Minimum Bid Rate

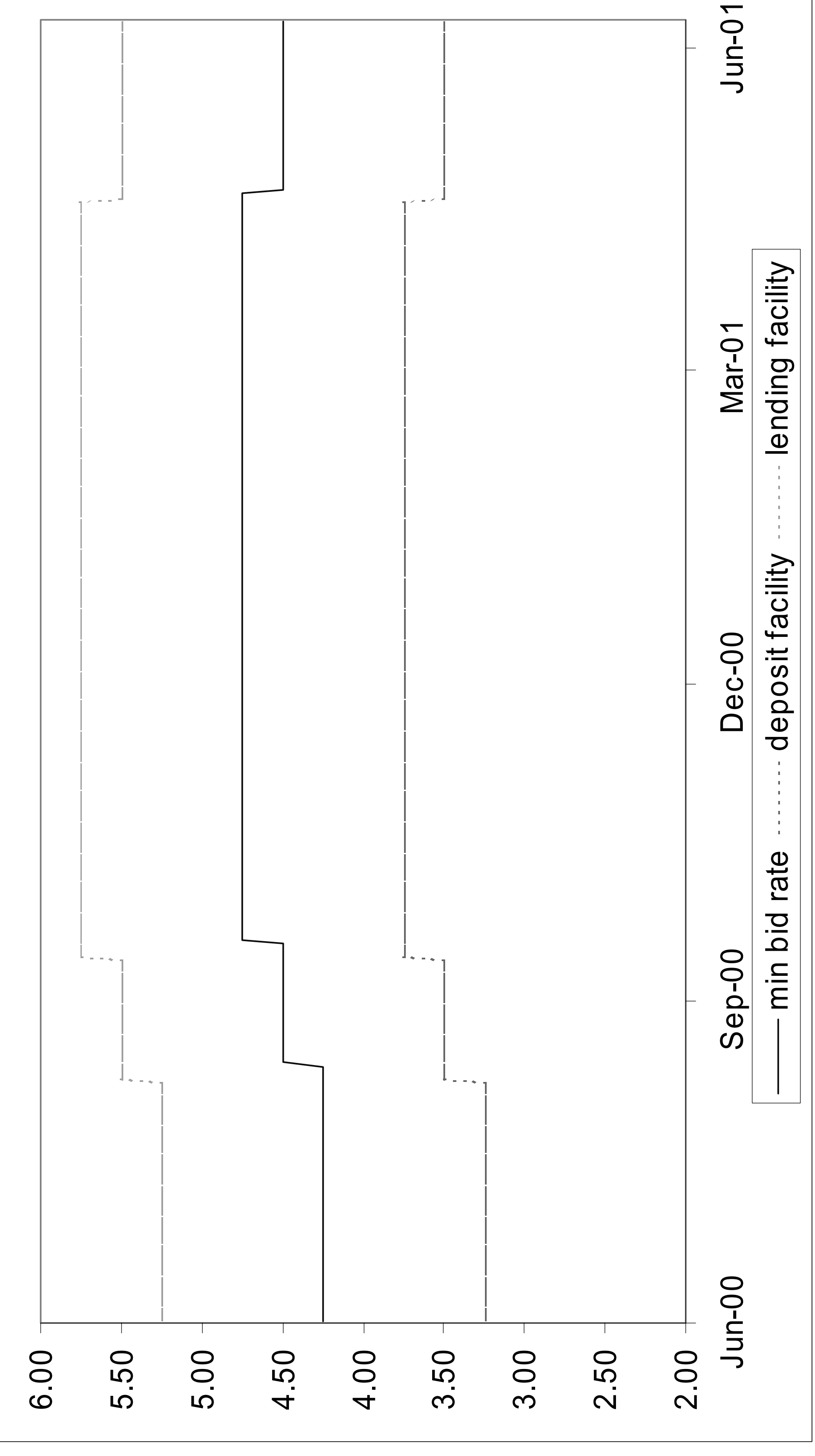
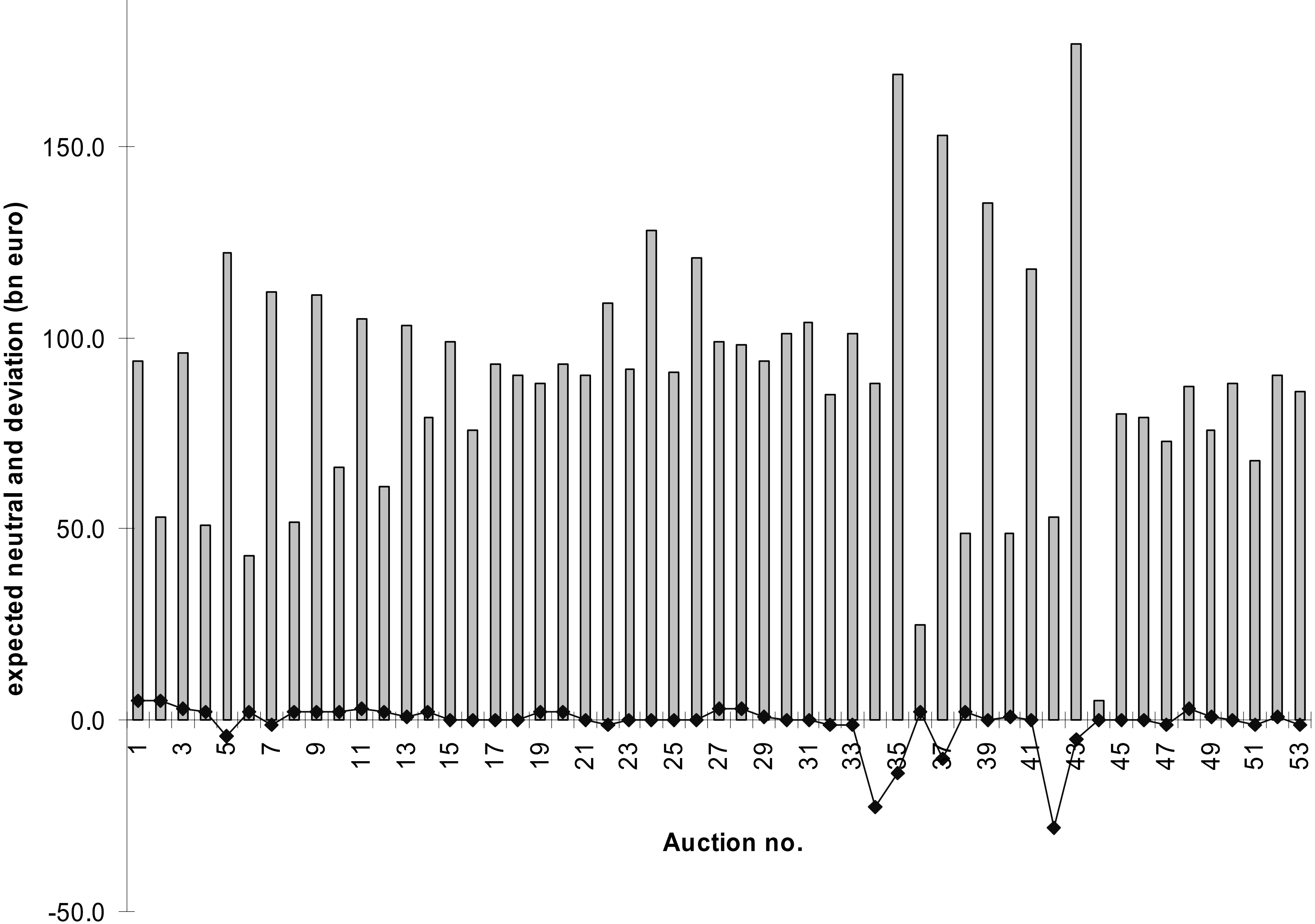


Fig.2: Expected neutral allotment amount and difference to actual allotment amount



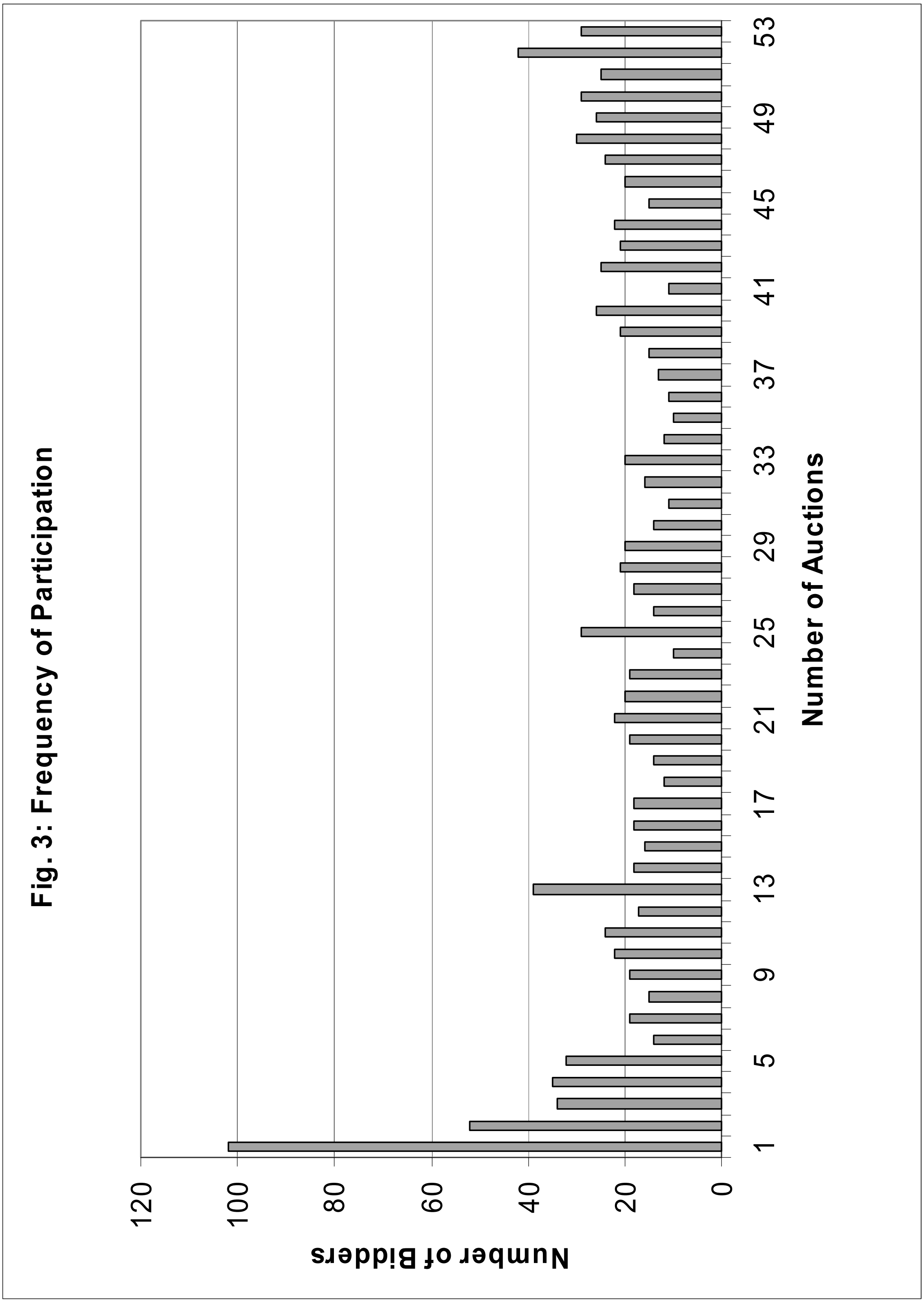


Fig. 3: Frequency of Participation

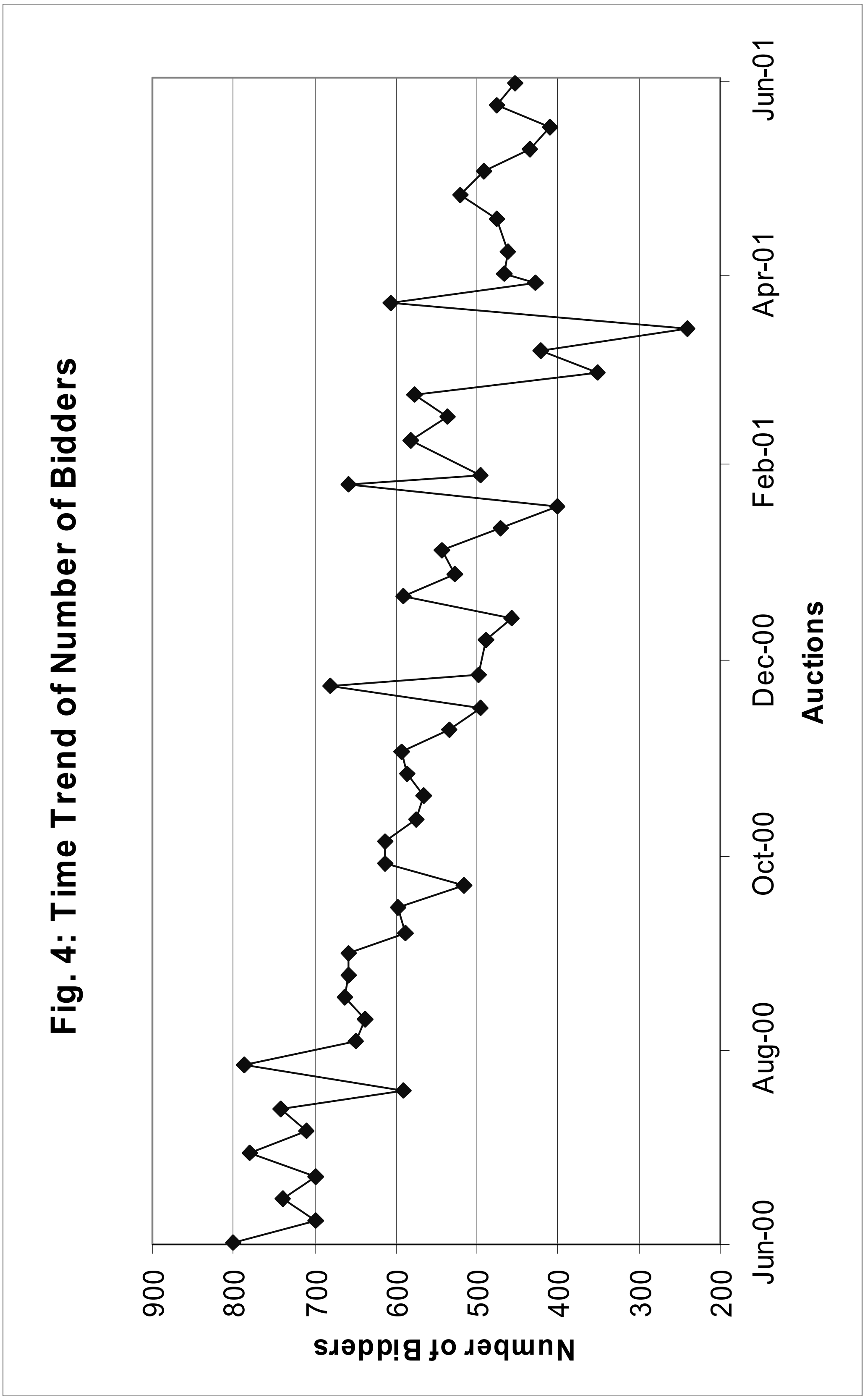


Fig. 4: Time Trend of Number of Bidders

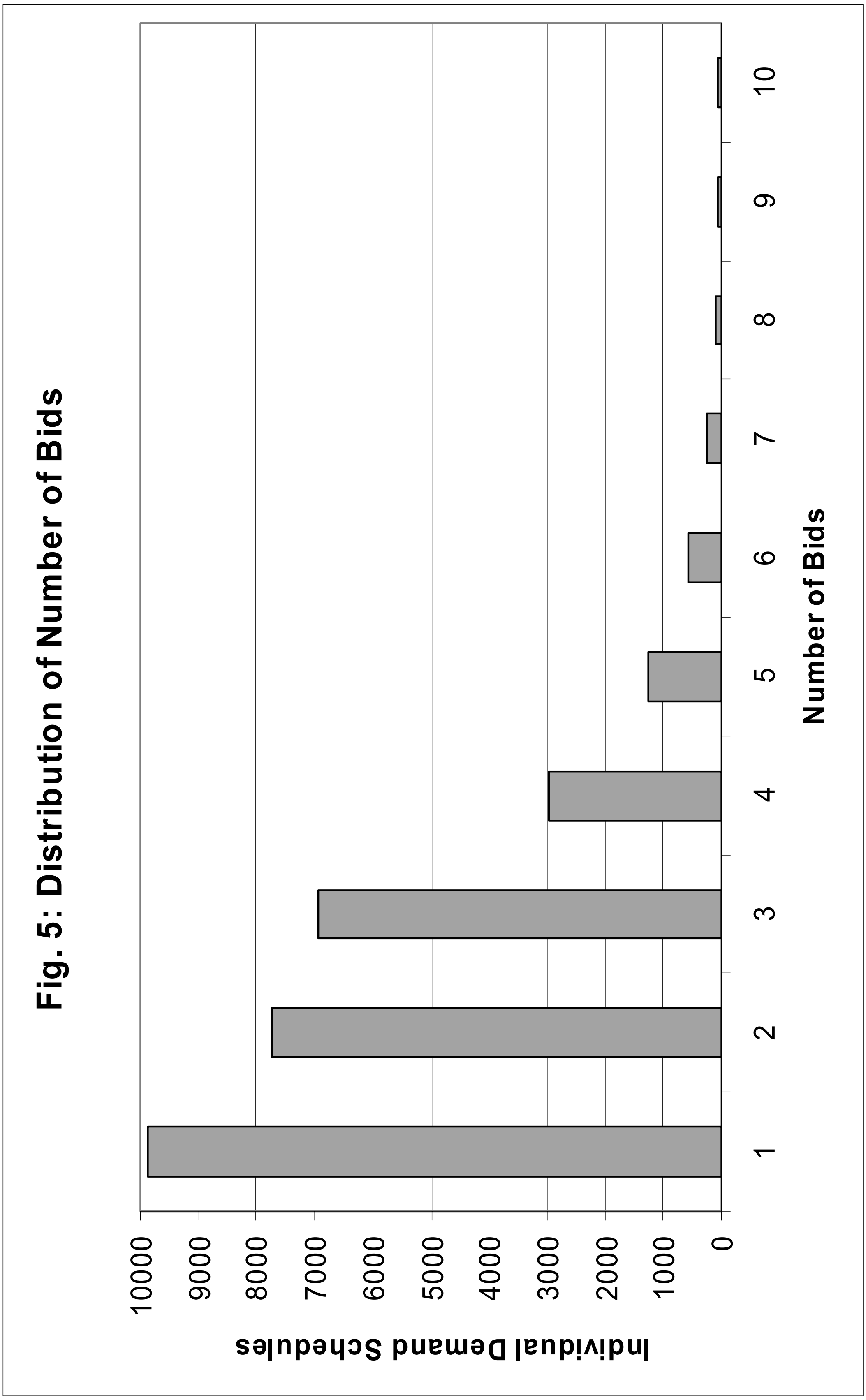


Fig. 5: Distribution of Number of Bids

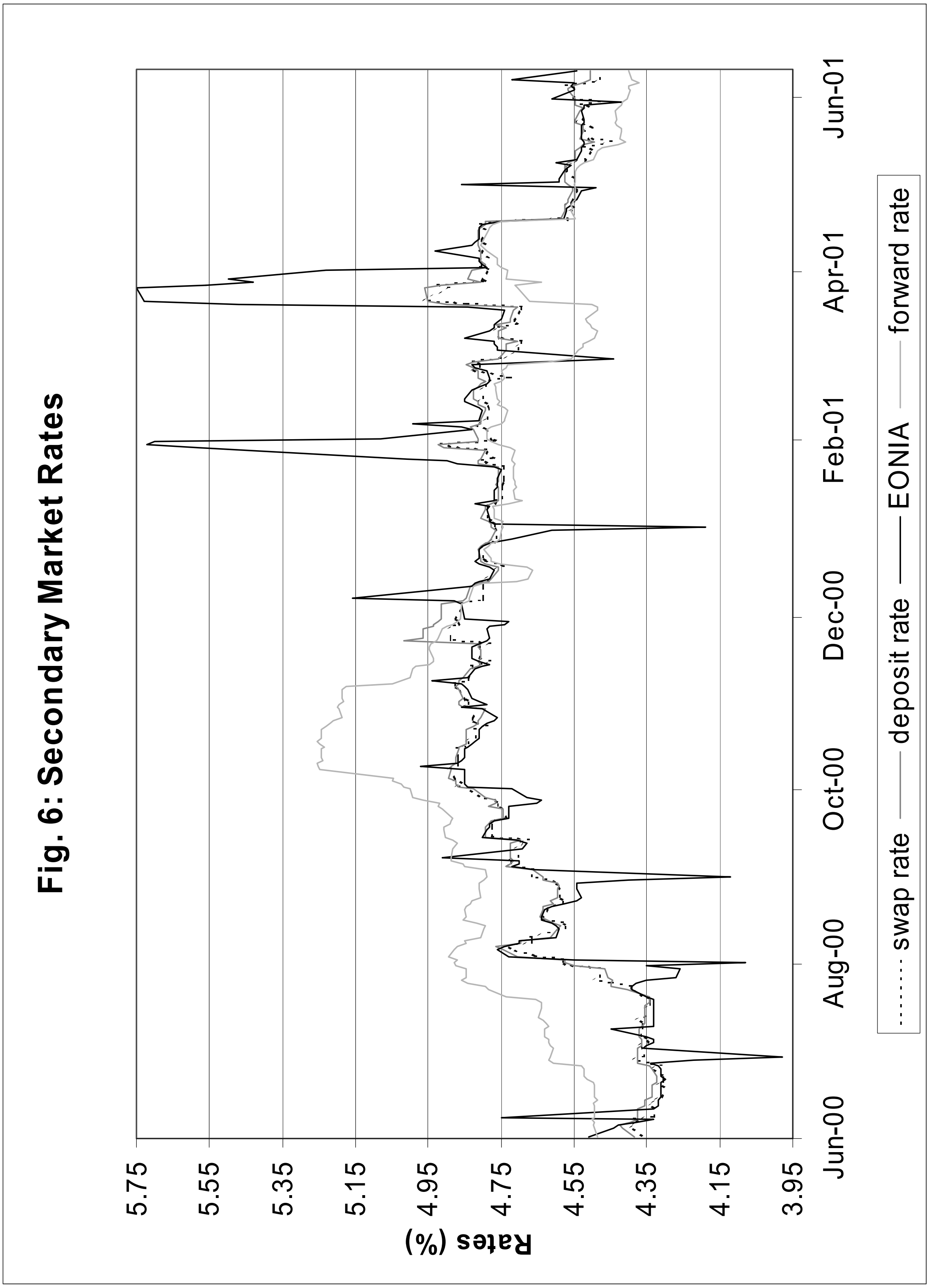


Fig. 6: Secondary Market Rates
Rates (%)
5.75
5.55
5.35
5.15
4.95
4.75
4.55
4.35
4.15
3.95
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
swap rate
deposit rate
EONIA
forward rate

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