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BANKS' PARTICIPATION IN THE EUROSYSTEM AUCTIONS AND MONEY MARKET INTEGRATION

by Giuseppe Bruno(*), Maurizio Ordine(**) and Antonio Scalia(**)

Abstract

This study performs a panel analysis of banks' participation and bidding in the Eurosystem weekly repo auctions during July 2000-August 2001, employing a data set of individual bids that includes the bidder code, size, nationality and membership in a banking group. We adopt the econometric approach of Wooldridge (1995) to obtain consistent estimates in the presence of endogenous sample selection. We find that an increase in interest rate volatility lowers the probability of bidding, but induces bidders to shade bid rates less relative to the interbank market rate. We document several country effects, related to differences in the structure of the domestic money market and the opportunity cost of collateral. Large bidders participate more regularly and shade their bids less. Group bidders demand larger amounts in the auction, thus showing an attitude to act as liquidity brokers towards the rest of the banking system. Large bidders and group bidders manage their collateral more efficiently, as revealed by their superior ability to "ride the yield curve" and submit multiple bids. Our findings support the transnational bank hypothesis, according to which banks with a multinational profile use their informational advantage to arbitrage out the differences in interest rates across countries, thus fostering money market integration.

JEL classification: D44, E43, E50, G21.

Keywords: Bidding behaviour, monetary policy operations, auctions, money market, reserve management

Contents

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1. Introduction[1]

Every week several hundreds of banks in the euro area participate in the Eurosystem repo auction, the so-called main refinancing operation (MRO), which injects reserve money in the banking system. With average weekly allotments that currently exceed 250 billion euro and several hundreds of bidders, MROs are the largest auctions ever held in the world. They take place in a decentralised fashion, whereby the collection of bids and the provision of funds are carried out at local level by the National Central Banks (NCBs), whereas the ECB compiles the aggregate bid schedule and decides on the allotment. Through the interbank market the successful bidders channel the allotted funds to 7,000 credit institutions in the area, for their day-to-day liquidity management and the fulfilment of the reserve requirement. Although not the exclusive vehicle of refinancing for the Eurosystem[2], the MROs are the primary instrument for the implementation of the single monetary policy. After an initial period in which the MROs were conducted through fixed rate tenders, in June 2000 the Eurosystem switched to a variable rate, discriminatory (pay your bid) auction. The present auction format retains some flavour of the old one because, in order to preserve the announcement effect, the ECB's Governing Council sets the minimum bid rate which acts as the indicator of the monetary policy stance, a role played in the US by the Federal funds target rate.

Who bids and why in the Eurosystem auctions? The objective of this paper is to perform a panel study of banks' participation and bidding in the MROs during June 2000-August 2001 with a new data set of individual bids that includes the bidder code, size, nationality and possible membership in a banking group.

Our motivation is twofold. Perhaps the most popular tenet of auction theory is the winner's curse hypothesis (Milgrom and Weber, 1982), according to which auction participants bid a price below their valuation of the good when uncertainty is high. Previous research on the Eurosystem auctions, adopting mainly auction theoretical models, has shown an apparently puzzling phenome-

[1] This paper draws from a contribution to the Study group on bidding behaviour set up by the Market Operations Committee of the ECB in 2001. We are grateful for helpful comments to Paolo Angelini, Fabio Panetta, Francesco Papadia, Margarida Catalao, Franco Peracchi, Stefano Siviero, Tuomas Välimäki, Sylvain Gouteron, Philipp Hartmann, Cyril Monnet, two anonymous referees and to seminar participants at the Banca d'Italia, the XI Tor Vergata Financial Conference, the 2003 European Finance Association Meeting and the ECB Workshop on Monetary Policy Implementation, January 2005. We are also very grateful to Ekaterini Kyriazidou and Maria Rochina-Barrachina for useful suggestions on econometric models for panel data with endogenous sample selection. The usual disclaimer applies.

[2] The so-called longer term refinancing operations (LTROs) are held by the Eurosystem once a month with a maturity of three months, through a variable-rate, discriminatory auction. LTROs, accounting on average for one quarter of the aggregate stock of refinancing, are not used for short term rate management. The third means of refinancng, denominated marginal lending facility, is an end-of-day standing facility at penalising rates and with overnight maturity. It should also be recalled that the Eurosystem remunerates required reserves at market rates.

non. Bindseil, Nyborg and Strebulaev (2004) measure the extent to which bid rates are below market rates in the MROs and find that this type of underpricing varies inversely with market rate volatility. This finding is at odds with the winner's curse hypothesis and most of the empirical evidence on treasury auctions[3]. On the other hand, examining the Eurosystem longer term refinancing operations, Linzert, Nautz and Bindseil (2004) show that banks behave accordingly to the winner's curse hypothesis[4].

Our first motivation is to shed light on bidders' behaviour in the MROs by exploiting primarily the implications of the models of banks' optimum reserve management. The Eurosystem auctions are different from treasury auctions for several reasons; among other things, bidders in the former face a quantity risk related to the minimum reserve requirement, and to the caps on and costs of alternative sources of funds, namely the interbank market and the end-of-day marginal lending facility of the Eurosystem. Our analytical framework also draws from money market microstructure considerations. The ensuing hypotheses form the basis for the empirical analysis. Our data enables us to perform panel regressions of each of four variables which completely characterise bidders' behaviour in the MROs. Through the individual bidder code we can track the decision to participate or not in the auctions, the first variable of interest, modelled as the sample *selection equation*. The knowledge of the individual bid schedules further allows us to model the three *regression equations*, respectively for the bid amount, the average bid rate and the dispersion of bid rates.

A methodological novelty of this paper, compared to the empirical studies of bidding behaviour in financial auctions, is that we properly account for the presence of two sources of bias in the estimates of the regression equations for the bid amount, rate and dispersion. The first source is related to unobservable heterogeneity in individual characteristics and preferences, which are potentially correlated with the observable variables. To control for this type of bias we adopt a fixed effects panel regression framework. The second potential distortion derives from endogenous sample selection, which arises because the sample employed in the analysis is selected non-randomly. To correct for sample selection bias we follow the Wooldridge (1995) two-step estimation approach, which yields consistent results for the vector of coefficients and the associated standard errors.

While the above considerations motivate the first part of this paper, where we formulate and estimate a general empirical model of participation and bidding in the auctions, a different aim in-

[3] See for example Nyborg, Rydqvist and Sundaresan (2002).

[4] The latter finding should be interpreted in light of the different nature and maturity of the LTROs compared to the MROs (see footnote 2). Among past studies, Breitung and Nautz (2001) perform a panel analysis of bidding by German banks under the Eurosystem fixed rate tenders.

spires the second part of the paper. Although from an econometric viewpoint we specialise the analysis, in the second part our interest is broader.

Achieving a high level of integration in the euro area money market has been among the priorities of the Eurosystem, in consideration of the anchoring role played by the short term rate for the whole yield curve (see for example ECB, 2004). This is reflected in the choice of an operational framework that supplies central bank refinancing to any bank in the area fulfilling some minimum standards, against a very wide pool of collateral. Yet, banks' activity in the money market may in principle be diversified in a number of fashions[5]. A remarkable feature of the European banking structure (Ehrmann et al., 2003) is the atomistic configuration of banks in some nations, notably Germany, Austria and Finland, characterised by a large number of credit cooperatives and savings banks in comparison to the other member countries. This in turn generates a network, or two-tier, banking structure, where large banks in the upper tier serve as head institutions for small, lower-tier banks[6]. The distinguishing feature of banks in other EMU countries, like France, Italy and Spain, is a larger availability of capital and liquid assets. The existence of a two-tier structure of the money market has been explicitly modelled by Freixas and Holthausen (2005), who show that big banks having access to information in several countries may achieve cross-border liquidity smoothing, thus overcoming the welfare-reducing effects of information asymmetries.

A few years after the inception of the single monetary policy, the quest of public authorities and market players for the integration of the euro area money market seems on the whole rewarded. The recent empirical studies have reached three broad conclusions. First, each of the unsecured and overnight swap segments have quickly merged into an area-wide market[7]. This ensures a smooth time-series path for the reference overnight rate, EONIA[8,9], as well as negligible interest rate differentials among member countries. Second, the development of the market for short term securities and repo contracts lags behind, owing mainly to legal and administrative segmentation, although cross-border repo turnover shows an increasing trend as traders make a growing use of links among Central

[5] The detection of frictions in the money market, and thus in the banks' access to liquidity, might have far reaching consequences for the monetary policy transmission mechanism. See for example Bean, Larsen and Nikolov (2003), Angeloni, Kashyap, Mojon and Terlizzese (2003).

[6] The role of bank size in the money market has been documented also in non-European countries. For the US see for example Allen, Peristiani and Saunders (1989).

[7] See ECB (2001a), Galati and Tsatsaronis (2003), Gaspar, Pérez Quirós and Sicilia (2001), Hartmann, Manna and Manzanares (2001).

[8] EONIA is the acronym of Euro Over-Night Index Average.

[9] See Pérez Quirós and Rodriguez Mendizábal (2004).

Securities Depositories[10]. Third, larger banks with a multinational dimension tend to centralise their liquidity management activities. What do we know about the "primary market" for liquidity, that is the Eurosystem repo auctions? Under the current auction format, the available evidence from analyses of aggregate data shows that bidding is competitive and most of the early problems encountered under the fixed-rate format have been overcome[11].

In the second part of this paper we look at the extent of integration in the repo auctions. These are by construction standardised and very open, yet participation may reflect peculiarities, related in particular to country effects, size effects and bank group effects. Each one of them in turn could tell us something on the issue of integration, which is essentially related to *institutional factors* and to *market factors*. The conjecture that country may matter is based on the available evidence, showing that the daily demand for reserves in member countries displays different degrees of interest–rate elasticity and that some regional effects are present in the interbank market's functioning (Angelini, 2002). The finding that country matters would thus suggest that, from the perspective of bidding behaviour, integration is not complete. One could then hypothesise that higher stages of integration might be achieved in the future, also in view of planned institutional innovations. We refer in particular to the enlargement of the pool of eligible collateral to include bank loans throughout the area, according to the ECB's Governing Council decision on the "single list" of 2004[12]. On the other hand, the finding that size and participation in a group systematically affect bidding behaviour across the geographical borders might have implications for the hypothesis that larger and/or multinational banks act as promoters of integration, which is typically a market factor. Therefore, using the information on the bidders' nationality, size and possible membership in a multi-country banking group, we specialise the panel analysis and test whether and how the behaviour of bidders is affected by each of these three variables in turn.

To put our effort in the right perspective, two remarks are in order. First, our investigation is largely exploratory. Unlike the studies on world market integration[13], we do not perform a test nor

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[10] See ECB (2001a), Galati and Tsatsaronis (2003), Giovannini Group (2002).

[11] The initial choice of the fixed-rate tender, aimed at conveying a strong signal on the stance of monetary policy, involved some distortions in bidding behaviour at times of interest rate change expectations; see for example Ayuso and Repullo (2001, 2003), Catalao (2001), Nautz and Oechssler (2003). Some distortions may appear also under the variable rate auction with minimum bid rate, if rate cut expectations prevail in the market. Välimäki (2002) and Ewerhart (2002) provide theoretical analyses of the auction under these circumstances.

[12] On 5 August 2004 the ECB announced the plan to replace the current two-tier collateral system, which allows some asset classes to be eligible in selected countries only, with a single collateral list throughout the euro area. Bank loans will be included in the single list. The single list will bring about a substantial increase in the eligible asset pool, particularly in eight countries where bank loans are currently ineligible.

[13] See for example Bekaert and Harvey (1995).

derive an index on the scale of integration in the repo auctions. This choice is related to the fact that our data sample spans a relatively short interval of time. Second, the notion of market integration is usually associated to the law of one price, and hence it might perhaps be viewed as an all-or-nothing issue. Our empirical results for the price equation, i.e. the bid rate, although revealing significant regularities, have an order of magnitude that does not seriously challenge the broad validity of the law of one price in the euro money market. Bearing in mind the above considerations, we see our contribution on the issue of market integration as an attempt to exploit the microeconomic evidence of bidding and pin down the factors, both institutional and market-driven, that are likely to hold back or foster integration in the euro money market in the future.

In Section 2 we describe the analytical framework and derive testable predictions for bidders' behaviour in the MROs. Section 3 presents the auction environment and gives summary statistics on the data sample. Section 4 describes our econometric approach. Section 5 shows the empirical results from the general model of participation and bidding. Section 6 presents the estimates on country effects. The evidence on size effects is given in Section 7. Section 8 contains the estimates on the effect of participation in a banking group. Section 9 summarises our findings and concludes. The Appendix provides details of the ARCH model for interest rate volatility.

2. Theoretical predictions

Banks' behaviour in the Eurosystem auctions should be viewed within the broader context of optimum reserve management models (see in particular Campbell, 1987; Hamilton, 1996; Furfine, 2000; Bartolini, Bertola and Prati, 2001; Taylor, 2001; Angelini, 2002). In a simple two-period setting characterised by a minimum reserve requirement with averaging, exogenous liquidity shocks and stochastic interbank interest rates, the bank's optimum demand for reserves in the first period is directly related to the forecast liquidity need and to the difference between the expected interest rate in the next period and the current interest rate (Taylor, 2001), i.e. to the forward rate spread. Under the hypothesis that banks are risk averse, it may further be shown (Angelini, 2002) that an increase in short term rate volatility will induce the representative bank to demand a larger amount of reserves in the first period. We note that bidding in the Eurosystem auctions is a key part of the bank's overall demand for reserves, the remainder being reflected in interbank market transactions, and we expect the former to be driven in the first place by the economic forces described by the theory. When we translate the theoretical hypotheses into our bidding environment, we note that each bank is no longer a rate-taker as in the stylised models, because it may bid a rate as well as a quantity of reserves. This implies that the three explanatory variables, namely liquidity need, forward rate spread and interest

rate volatility, should all have a positive effect on the decision to participate in the auction, the total bid amount and the average bid rate of each bank.

We list these qualitative hypotheses in Table 1, where the first column gives the candidate explanatory variables for each of the dependent variables, namely participation (column P), bid amount (column B), average interest rate (column R) and bid rate dispersion (column D). Each cell reports a +/- sign showing the effect of the explanatory variables onto each dependent variable and a symbol indicating the relevant theory.

When we move to a multi-period world with reserve averaging, it can be argued (Furfine, 2000) that the endowment of reserves inherited from the past enters into play, affecting inversely today's demand for balances. In our framework, the reserve endowment can be captured by the reserve fulfilment ratio of a bank, given by the average reserve holdings (until the day before the auction) divided by the bank's reserve requirement. The reserve fulfilment should thus have the opposite effect of liquidity need on the dependent variables P, B and R.

An additional feature of the reserve management model as it becomes increasingly realistic is that banks may have a target level of end-of-day reserves, related to the need for working balances and the desire to fulfil the requirement smoothly (Campbell, 1987; Hamilton, 1996; Bartolini. Bertola and Prati, 2001). We cast this hypothesis into our setting by postulating that the bidder seeks to some extent to roll over the amount of the MRO that expires on the auction's settlement day. Hence his decision to participate in the auction, bid amount and average bid rate should be positively affected by the explanatory variable Maturing MRO amount. Accordingly, these hypotheses are included in Table 1.

Participation and bidding in the MROs can also be viewed from the perspective of auction theory. A classical argument is that in a discriminatory auction with private information on the resale value of the good, bidders adjust their bids for the winner's curse. In our setting this would imply that bidders respond to an increase in interest rate volatility by reducing quantity demanded, reducing the average bid rate and increasing rate dispersion. It may also be argued that small, marginal bidders facing increased volatility could even decide to stay away from the auction, and make recourse instead to the interbank market. We note however that the "loser's nightmare" argument may be invoked against the prediction of the winner's curse on bid amount and rate. Namely, if the risk of losing, *not* winning, the auction is a concern for the participants, then it is possible that interest rate volatility may induce them to submit larger bids at higher rates (Simon, 1994). That the loser's nightmare may prevail over the winner's curse is suggested by the existence of caps on credit lines among banks, which constrain the recourse to the interbank market, and to the peculiar setting of the

MRO auction, where the auctioneer is in a special position, whereby he imposes an intertemporal constraint on the minimum amount of the good, i.e. reserves, that bidders have to hold. We note that the predictions of the loser's nightmare would be consistent with those of the reserve management model under risk aversion.

An important feature of our bidding environment is the possibility that some bidders are "squeezed" after the auction, thus being forced to borrow in the interbank market at very high interest rates in order to fulfil the reserve requirement. The squeeze may result from lower than expected supply in the auction, such as to make liquidity tight at the aggregate level. A model in which bidders face the risk of a squeeze subsequent to the auction is developed by Nyborg and Strebulaev (2001), who formulate in particular the hypothesis that a bidder entering the auction with a short liquidity position will increase the variance of bids. In the absence of data on the individual liquidity positions of bidders in our sample (see the next section), there is no direct translation of the above proposition in our setting on a cross-section basis. However, if we adopt extensively the above hypothesis over different auctions in time, it might be argued that an increase in the probability of a short squeeze is likely to make the short positions of bidders even worse. Thus we hypothesise that the likelihood of a short squeeze would increase the variance of bid rates, together with participation and bid amount.

Other strands of research and empirical considerations can be brought to bear on our empirical model. In particular, we believe that the Freixas-Holthausen hypothesis, that larger banks with a multinational role will arbitrage out the differences in interest rates across countries, has an important implication for bidding in the Eurosystem auctions. Ceteris paribus, we would expect larger banks to participate more actively in the auctions and submit larger bids compared to smaller banks with a local profile and limited information. This suggests that the bidder's size and participation in a multi-country banking group may be included among the set of explanatory variables.

The use of collateral to be pledged against the Eurosystem refinancing involves an opportunity cost for banks, related to the liquidity of the assets. As we have noted, there is a great variety in the list of eligible collateral. It may be argued that, as the auction size increases, corresponding to an increase in the aggregate liquidity need, the use of "dear" collateral is likely to increase as well. Other things being equal, the increase in the marginal cost of collateral would cause a downward pressure on the individual bid amount and rates, along with a tendency to disperse more. Furthermore, using a standard cost-of-carry argument, it may be argued that the cost of marketable collateral is inversely related to the spread between long term yields and the minimum rate set by the Eurosystem. An increase in the long term spread would indeed make it more profitable for banks to buy or repo-in collateral and fund it with short term money from the Eurosystem or, in the traders' parlance, "ride the curve". This is particularly true of assets with an active interbank repo market, like treasury securities

and asset-backed securities, which represent the bulk of eligible collateral in the euro area. Hence, we would expect the long term spread to have a positive impact on banks' participation and bid amount.

Lastly, we note that participation and bidding is also affected by the spread between the short term money market rate, represented by the 2-week EONIA swap rate[14], and the Eurosystem minimum bid rate, which incorporates the expectations on the stance of monetary policy. For instance, the expectation of an imminent rate cut by the ECB, pulling the value of the short term spread close to or even below zero, would involve a reduction in the number of bidders, bid amount, rates and dispersion. The opposite would hold under expectations of monetary policy tightening and a large value of the short rate spread. It might be argued that the short rate spread is correlated to some extent with another explanatory variable, namely the forward rate spread discussed earlier on. In practice, however, the two display a modest correlation[15].

We are aware that the analytical background presented in this section is eclectic in nature. Like all empirical studies of auctions, we cannot go beyond a list of qualitative hypotheses, and we clearly resolve the trade-off between theoretical elegance and heuristic power in favour of the latter. Nonetheless, we note that the ensuing predictions, with the significant exception of the effects of volatility, are unambiguous and coherent among themselves.

3. Market and data

3.1 The auction

The MROs are liquidity-providing operations with a maturity of two weeks[16] that enable the Eurosystem to resettle the desired amount of bank reserves once a week[17]. The minimum bid rate is established by the ECB's Governing Council in its monetary policy meetings. Each bidder can submit up to ten bids. The Council also sets the rates on the two end-of-day standing facilities, marginal lending and deposit, which delimit the "corridor" of short term interbank rates. In the sample period the minimum MRO rate was raised from 4.25 to 4.50 percent on 31 August 2000 and up again to

[14] Although general collateral repos on the interbank market are the closest financial substitute for the ECB repo, we take the 2-week overnight index swap rate as the key money market rate, like in other empirical studies, because the latter contract is by far the most liquid in the euro area.

[15] See footnote 22 for details.

[16] Since March 2004 the maturity of MROs has been shortened to 1 week. As a consequence, the average allotment amount has doubled compared to our sample period.

[17] The low frequency of central bank interventions compared to other countries is made possible by the large amount of the reserve requirement compared to the demand for settlement balances. The averaging provision on the former creates a liquidity buffer for banks' daily liquidity management.

4.75 percent on 5 October; it was then cut back to 4.50 percent on 10 May 2001 (see Figure 1). The reserve maintenance period starts on the 24th of each month and ends on the 23rd of the following month[18]. The requirement must be fulfilled on the average of the end-of-day reserve account balances of each bank and no carry-over is allowed from one period to the next[19].

The announcement of the auction takes place as a rule on Monday at 15:30, together with the publication of the autonomous liquidity factors of the euro area, i.e. the forecast stock of items in the Eurosystem balance sheet that cause a net absorption of bank reserves, like e.g. banknotes and government deposits. The published figure, covering a weekly horizon, enables the market to compute the "neutral" amount of the auction and thus formulate a forecast on the allotment, the actual amount of which is decided and announced by the ECB only ex post. The neutral amount is defined as the amount of reserves that, based on past fulfilment and on the projected autonomous factors, would bring the average reserve holdings one week ahead in line with the reserve requirement.

Bids may be submitted until 9:30 on Tuesday by any euro area bank presenting adequate operational and financial standards. Out of the 7,000 credit institutions operating in the area during our sample period, around 2,400 were eligible counterparties. In practice, in the 61 auctions covered by our data set the actual number of bidders was way below the potential and showed a diminishing trend, ranging between 798 and 240, as shown in Figure 2. In the sample period the total bid amount ranged between 25 and 258 billion euro, with an average of 145 billion euro (Figure 3). The allotment varied between 5 and 172 billion euro, with an average of 88 billion euro. The average bid-to-cover ratio is equal to 1.65.

After the collection of bids by the NCBs, the ECB ranks all bids in descending rate order and decides on the allotment. Bids below the marginal, or stop-out, rate are dropped; bids above the marginal rate win the auction, and bids at the stop-out rate are allotted pro-rata. The result of the auction is published by the ECB on wire services at 11:20 on the auction day. The announcement gives the total allotment, total bid amount, number of bidders, minimum and maximum bid rates, weighted average allotment rate, marginal rate and percentage of allotment at the margin. Settlement of the auction is on the day following the auction, i.e. normally on Wednesday.

The actual allotment tends to lie close to the neutral amount (ECB, 2002). The spread between the marginal rate and the minimum rate was between 0 and 43 basis points, the difference between

[18] In March 2004 the cycle of the reserve maintenance period has been changed, making it start soon after the monthly monetary policy meeting of the ECB's Governing Council.

[19] In order to make the requirement as neutral as possible to banks, minimum reserves are remunerated by the Eurosystem at the average marginal rate of the MROs conducted in the maintenance period. Excess reserves are not remunerated, whereas deficiencies incur a financial penalty.

the average allotment rate and the marginal rate was between 0 and 6 basis points (Figure 4). The standard deviation ranged between 4 and 19 basis points for the bid rates, and between 4 and 18 basis points for the allotment rates (Figure 5).

3.2 Data

In the empirical analysis we will consider the bidding behaviour of each bank, ignoring the amounts allotted ex post by the ECB and the resulting rates. We do that because, as we pointed out earlier, we are interested in the determinants of the demand for liquidity in the auctions, whereas the allotments would reflect the preferences of the Eurosystem as well as those of bidders.

Figures 6a-c give the breakdown of the number of bidders by country. All countries show a decreasing trend in the number of participants, although this phenomenon is more pronounced in Germany, France, Italy and Austria. The country with the largest number of participants is by far Germany, with 381 bidders per auction on average, followed by Italy (31), France (30), Luxembourg (26), Spain (21), Austria (16), Ireland (9), the Netherlands (9), Belgium (8), Greece (5)[20], Portugal (4) and Finland (2). The country shares of bidding are shown in Figures 7a-c.

We made some rearrangements on the raw data set of the individual bid schedules. First, we omitted the bidders from Greece, which took part in the auctions only from January 2001 onwards. Second, to avoid breaks in the time series of bid schedules, we aggregated the bid arrays of a small number of bidders which merged at some stage in the sample period, thus treating them as if they had been a single bidder from the start of the period. We thus ended up with 1032 bidders which took part in at least one auction in the period between the switch to the variable rate tender and the end of our sample. We note that in the following analysis we are forced to "sacrifice" the first two auctions of that period. In fact, we need to retrieve one important explanatory variable, namely the maturing amount for each bidder, which corresponds to the individual allotment amount of the MRO with two lags. We do not know this variable for the first two auctions under the new format. However, from the third auction onwards we are able to compute the maturing amount from the individual bidding schedules and the information on the auction results. Hence the dataset that will be used in the empirical analysis is made of 59 auctions.

The frequency of bidding is given in Table 2, which shows that 30 bidders, who bid at least once in the first two auctions under the new format, dropped out of the group of bidders in the following 59 auctions. 199 bidders placed bids between 1 and 10 times, 169 placed bids between 11 and

[20] The figure for Greece refers to January-.August 2001.

20 times, and so forth. The number of bidders which were present throughout the 59 auctions in the sample is 25. Table 3 gives the distribution of the average bid size across auctions by active bidder, i.e. including nonzero bids only. Bid size is expressed as a percentage of our scale variable, namely the area reserve requirement[21]. 260 bidders, the largest fraction, place bids which represent only one hundredth of a percentage point or less of the area reserve requirement. Bidders with average bids above 1 percent of the area requirement are 36.

Table 4 provides summary statistics on the variables that will be employed in the panel regressions. For the variables that vary over time and across bidders (see the upper part of the table), we give three rows of statistics. The first row refers to the overall sample, obtained by pooling all individuals and time periods. The "between" statistics (second row) are computed over the individual averages. The "within" statistics are computed on the deviation from each individual's average, where the global mean is added back in to make the results comparable.

After auction participation (see Table 2), the second dependent variable is the individual bid amount, as a percentage of the area requirement, with an overall mean value of 0.2249. The third dependent variable is the weighted average bid rate, taken as a spread over the minimum bid rate set by the ECB. Its overall mean value is 0.0547, i.e. over 5 basis points above the floor rate. The last dependent variable is the weighted dispersion of bid rates, given by their standard deviation. Its overall average is 0.0063, i.e. below 1 basis point, reflecting the fact that the majority of bidders does not avail itself of the possibility to submit multiple bids in the auction, and uses just one or very few bids. Indeed, we had a look at the overall frequency distribution of bid dispersion, and found that 35 percent of the bids are single bids (with a nil dispersion), and an additional 45 percent show a dispersion below 1 basis point.

Next we turn to the candidate explanatory variables. We do not have data on the individual reserve fulfilment of each bidder at the time of the auction, and our best proxy is the reserve fulfilment ratio of the bidder's country as of the day before the auction. The overall minimum and maximum are 59.22 and, respectively, 145.57.

The maturing amount of a bidder is equal on average to 0.0671 of the area requirement.

As concerns the bidder's size, we have accurate data on each bidder's reserve requirement during the thirteen monthly maintenance periods, which we use as the measure of bidder size. Again, we express this variable as a percentage of the area reserve requirement. The variable's overall mean

[21] In the sample period the area requirement, which represents a relatively stable component of the system's liquidity need, was equal on average to 118.6 billion euro, with a minimum of 111.8 billion euro and a maximum of 127.2 billion euro.

is equal to 0.0623 percent of the aggregate requirement. The individual bidder's size varies moderately over time, as shown by the low value of the within standard deviation, equal to 0.0174, as opposed to a between standard deviation of 0.2197.

The remaining explanatory variables are all bidder invariant, and their summary statistics are given in the bottom part of Table 4. The expected amount of the MRO has a mean value of 76.04 percent of the area reserve requirement.

The forward rate spread is given by the difference between the 2-week forward swap rate one week ahead and the current 2-week rate. This spread captures the difference between the expectation of the interest rate of the next MRO and that on the current MRO, and it measures the intertemporal trade-off between consecutive auctions. Its mean value is –2.36 basis points, with a range between –30 and +9 basis points.

The average short rate spread is defined as the difference between the 2-week EONIA swap rate on the day before the auction and the minimum auction rate. Its mean value is equal to 7.17 basis points, and it ranges between –6 and +45 basis points. The mean of the long rate spread, defined as the difference between the 10-year Bund yield on the day before the auction and the minimum bid rate, is equal to 41.07 basis points, and it ranges between –10 and +107 basis points[22].

We estimate short rate volatility using an ARCH(1) model on the daily series of the 2-week swap rate, where the short rate is a function of its own lag and the conditional variance is a function of the short rate spread plus dummy variables that capture calendar regularities and institutional features of the euro area money market (see the Appendix for details). The resulting conditional variance on the auction day is equal on average to 0.0014.

We construct an explanatory variable taking the value 1 if the bank belongs to a bank group. Among our bidders, we record 31 multinational banking groups with a minimum of 2 bidders and a maximum of 6 bidders each. The bidders belonging to a group are 79 in total. Finally, in the list of explanatory variables we include two other dummies. Both capture the increased likelihood that some bidders may end up squeezed after the auction. The first one, called "Post underbidding", is equal to 1 in the MRO that followed the underbidding episodes of 13 February and, respectively, 10 April 2001 (see ECB, 2001b). This dummy reflects the fact that, after those underbid auctions, bidders feared that the ECB might have squeezed liquidity by providing an amount of refinancing below the

[22] The three interest rate explanatory variables show some degree of correlation, which in principle might affect the precision of the regression estimates. It turns out that the correlation between the short spread and the forward spread is equal to 0.13; the correlation between the short spread and the long spread is 0.51; the correlation between the forward spread and the long spread is 0.37. In the presence of a degree of correlation that

neutral value, as it indeed happened. The second dummy is a period-end dummy variable taking the value 1 if the MRO is the last-to-be-settled in the maintenance period.

4. Estimation approach

From an econometric viewpoint, we are confronted with a problem of endogenous sample selection in a panel framework with unobserved individual components. Our first equation of interest concerns the decision to participate or not in the auction, which may be estimated using e.g. the probit or the logit model. This is usually called the *selection equation*, because it selects the sample in a nonrandom fashion across individuals and over time. The selection process generates an unbalanced panel data set: at any auction, we will observe the endogenous variables of interest (bid amount, rate and dispersion) only for those individuals who choose to participate in the auction. These endogenous variables are linked through the *regression equations* to (potentially) the same set of explanatory variables for the probability of bidding. We further assume that we are not able to track all individual specific characteristics, that the unobserved components are time invariant and that they are correlated with the explanatory variables. If the unobservable characteristics affecting the decision to participate in the auction are correlated with the unobservable characteristics that determine the three variables of interest, estimating the regression equations via standard fixed effects panel techniques would yield biased and inconsistent results (see Wooldridge, 2002, Ch. 17). We note that in a cross-section framework, estimation in the presence of endogenous sample selection can be performed relatively easily using the Heckman (1979) two-step approach. On the other hand, in a panel framework the problem is complicated by the time dimension. Wooldridge (1995) provides a two-step parametric approach for testing and correcting for selection bias in linear panel data models. The method requires a standard probit regression for each time period followed by a fixed effects linear regression. The errors in the selection equation are assumed to be normally distributed, but they are allowed to display arbitrary serial correlation and unconditional heteroskedasticity[23].

The model for each of the three regression equations is as follows:

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does not seem excessive among the three variables, and owing to the theoretical arguments in favour of their inclusion, we prefer to keep all of them in the regressions.

[23] Other approaches have also been proposed in the literature. In particular, Kyriazidou (1997) develops a semiparametric method based on "differencing out" over time both the unobserved components and the sample selection effect. Under alternative distributional assumptions, Rochina-Barrachina (1999) also develops a method that exploits estimation in differences. The latter two methods are devised essentially for panel data sets with a large number of individuals and a small number of observations. In our case, characterised by up to 59 observations for each individual, any estimation in differences would be extremely cumbersome, because it would involve a large number of pairwise combinations.

(1) $$y_{i,t} = \alpha_i + x_{i,t}\beta + u_{i,t} \qquad t = 1,\ldots T \quad i = 1,\ldots N$$

(2) $$h^*_{i,t} = f(\eta_i, x_{i,t}, \delta) + v_{i,t} \quad h_{i,t} = 1\left[h^*_{i,t} > 0\right].$$

In equation (1) we have omitted for simplicity the index that would distinguish the three variables of interest (equation 2 is valid for all of them). The symbol $x_{i,t}$ denotes the 1 x *K* vector of explanatory variables for each *i* and *t*; β is the *K* x 1 vector of interest; α_i is the unobservable fixed effect in the main equation; η_i is the unobservable fixed effect and δ is the *H x 1* vector of parameters of the selection equation. The generic endogenous variable $y_{i,t}$ is observed only when the selection variable $h_{i,t} = 1$. Selection bias arises because we allow the conditional mean of the residuals in the regression equation to be linearly correlated with the error in the selection equation. This is formally expressed by $E(u_{i,t} \mid \alpha_i, x_{i,t}, v_{i,t}) = E(u_{i,t} \mid v_{i,t}) = \rho v_{i,t}$.

For the variable describing the participation choice we have fitted a fixed effects panel probit model by "brute force" using Newton's method[24]. The program is able to estimate the vector of the structural parameters plus the *N* fixed effects because it takes advantage of the sparse structure with a large diagonal submatrix of the Hessian matrix (we refer the interested reader to Greene, 2003). In the regression equations for each of the three endogenous variables we have implemented the Woooldridge's two-step procedure as follows[25]. Starting from the assumption of a linear correlation between the errors of the selection equation and the errors of the regression equations, in the first step the inverse Mills ratios (henceforth IMRs) for the selection equation are estimated. The IMRs are achieved, for each time period $t = 1,\ldots T$, by running a standard cross-section probit regression on the following model:

(3) $$h^*_{i,t} = \delta_{t,0} + x_{i,1}\delta_{t,1} + \cdots + x_{i,T}\delta_{t,T} + v_{i,t},$$

where the IMR is defined as:

[24] We employed the algorithm available in LIMDEP, Version 8.

[25] We have not found any off-the-shelf implementation of the Wooldridge method in any of the econometric packages available to us. We have considered the following: LIMDEP, RATS, STATA, EViews, Pc-GIVE, and SAS. Professor Rochina-Barrachina kindly provided to us the GAUSS program that she had developed for her joint paper with C. Dustmann of 2000. Taking advantage of this program, we developed the code for the present paper as a do-file in STATA, Version 8.

$$\lambda_t = \frac{\phi\left(x_i \cdot \hat{\delta}\right)}{\Phi\left(x_i \cdot \hat{\delta}\right)},$$

$\phi(\cdot)$ is the standard normal probability density function and $\Phi(\cdot)$ is the standard cumulative distribution function. By stacking the T different IMRs resulting from each probit regression we generate the auxiliary regressor $\lambda = (\lambda_1', \lambda_2', \cdots, \lambda_T')'$ required to remove the sample selection bias[26]. The final step is a standard fixed effects regression on the set of all the variables x, λ, to obtain a consistent estimator of the vector of interest β. The model for this final step is as follows:

$$(4) \qquad y_{i,t} = \alpha_i + x_{i,t}\beta + \hat{\lambda}_{i,t}\rho + u_{i,t} \qquad t = 1,\ldots T \quad i = 1,\ldots N,$$

where $\hat{\lambda}_{i,t}$ is built by stacking the IMRs estimated for each cross-section.

This modelling framework yields both a variable addition test and a correcting device for selection bias. The hypothesis under test is $H_0 : \rho = 0$, by means of the *t*-statistic for $\hat{\rho}$; if the null hypothesis is rejected then we would have sample selection bias by omitting the variable $\hat{\lambda}_{i,t}$. As we will see later on, for all three behavioural variables the coefficient of λ displays a highly significant value.

A final issue is the computation of asymptotically consistent $(N \to \infty)$ standard errors for the coefficients. When a fixed effects regression equation includes predictor-generated regressors, such as our array of IMRs, the standard errors are generally inconsistent (see Pagan, 1984), because they do not take into account the sampling variability of the predictor generated regressor. In order to compute a consistent variance-covariance matrix we have implemented the sandwich estimator proposed by Wooldridge (1995). Considering the vector $\hat{\theta} = (\hat{\beta}, \hat{\rho})$ of the structural parameters in the main equation (4), we have $A\,\mathrm{var}(\hat{\theta}) = (X'X)^{-1} B (X'X)^{-1}$, where the matrix X collects all the data columns of the variables x, λ in the final fixed effects regression. Huber (1967) and White (1980) have originally proposed this approach to obtain a robust estimator in the presence of heteroskedasticity. In our case the outer matrix is simply the variance-covariance matrix provided by the fixed effects regression, while the inner matrix *B* accounts for the presence of errors in the series of the IMR variable estimated in the probit step. The matrix *B* is computed as the variance-covariance matrix of

[26] In our case, in the *T* auxiliary cross-section regressions required for the estimation of the IMRs we have been forced to discard the bidder-invariant variables from the selection equation.

the vector measuring the correlation with the residuals induced by the estimation of the IMRs (see the Appendix of Wooldridge, 1995 for further details).

5. Results of the general model

5.1 Participation

We estimate the probability of bidding with a panel probit regression of the type:

$$\Pr\left(h_{i,t}^{*} > 0 \,\middle|\, \mathrm{x}_{i,t} \right) = \Phi\left(\eta_{\mathrm{i}} + \mathrm{x}_{i,t}\, \delta \right), \tag{5}$$

where $h_{i,t}^{*}$ is the latent variable which underlies the decision to participate in the auction. We recall that we have 1,032 bidders in the data set and 59 auctions. $\mathrm{x}_{i,t}$ denotes the vector of explanatory variables for bidder *i* at time *t*, including for notational simplicity the time series variables that do not change across bidders and the dummy variables, and δ is the coefficients vector. Equation (5) says that the probability that a bidder participates in the auction is distributed as a standard normal and its argument is a linear function of our explanatory variables plus the individual specific fixed effect.

The regression results are given in Table 5, column P. All the explanatory variables are highly statistically significant. The country fulfilment ratio has a negative effect (-0.0077) on the probability of entering the auction, as predicted by reserve management theory. In words, the larger is the cumulative reserve position of banks in the bidder's country on auction day, the lower is the probability that each bidder will participate in the auction.

The forward rate spread has a positive effect on the likelihood of bidding, with a coefficient of 1.6285. This is again in line with the notion that bidders manage their reserves in an efficient manner. When the forward rate is larger than its spot value, reflecting for instance the expectation of a monetary policy hike in the following weeks, then more bidders enter the auction, and vice versa.

Short rate volatility has a negative and significant effect (-20.3052) on the probability of bidding. This finding goes against the hypothesis that banks are risk averse and, facing an intertemporal constraint on the minimum amount of reserves, they react to increased volatility on the cost of their funding by bidding more actively. On the other hand, the negative coefficient would seem consistent with the winner's curse hypothesis.

The coefficient estimate for the maturing MRO amount (1.1608) shows a direct effect on participation. This is consistent with the hypothesis that bidders have a target for the level of end-of-day reserves, related to the demand for settlement balances and the pursuit of a smooth fulfilment pattern.

The coefficients for the post underbidding dummy and the period end dummy are both positive (0.2597 and, respectively, 0.0981). The sign of the coefficients is as expected, based on the hypothesis that an increase in the likelihood of a short squeeze causes more bidders with a short position to bid in the auction.

The bidder size has a positive effect on the likelihood of bidding (1.0059). This seems consistent with the two-tier or transnational market hypothesis: other things equal, larger banks are more likely to participate in the auction owing to their role as liquidity dealers in the domestic and cross-border market.

The expected auction amount has a positive effect (0.0041) on the probability of bidding. We had no clear a priori. This result may perhaps be interpreted in light of optimum reserve management. The expected MRO amount is directly related to the perspective liquidity need of the banking system. We have already included an explanatory variable, the fulfilment ratio, that captures the liquidity need, although with a backward-looking orientation. The positive effect of the expected auction amount may therefore reflect the entry of marginal bidders in the auction as the forward-looking liquidity imbalance increases.

The long rate spread has a direct effect (0.4884) on the probability of participating in the auction. This is clearly consistent with efficient collateral management, and suggests that marginal bidders seek to ride the yield curve.

The short rate spread also has a direct effect (1.8815) on the probability of bidding, in line with the notion that rate hike expectations attract more bidders in the primary market for liquidity.

5.2 Bid amount

The regression for the (scaled) individual bid amount is performed according to equation (4), where $\mathrm{x}_{i,t}$ is the vector of explanatory variables for the scaled bid amount $y_{i,t}$ of bidder *i* in auction *t* and β is the coefficients vector. The regression results are given in Table 5, column B.

The country fulfilment ratio affects inversely the bid amount (-0.0006), as expected.

The forward rate spread displays a negative effect on the bid amount (-0.0715), contrary to our a priori. When the forward 2-week rate is larger than the spot rate, demand decreases. This seems at

odds with the idea that the forward rate spread reflects rate change expectations. However, we note that the spread is also mechanically linked to the very short term liquidity situation at the time of the auction, in addition to more fundamental factors. Let's take the example of a negative forward spread, which is true on average and by a small amount (see Table 4). This might be viewed as the result of a slightly tight liquidity situation today compared to what the market expects it to be in a week's time. If that is the case, then the coefficient estimate says that bidders demand more in the current auction, possibly owing to quantity constraints, and give up the rate decrease that is priced in the forward rate.

Interest rate volatility does not significantly contribute to explain demand in the auction.

The maturing auction amount has a positive and highly significant effect on bid amount. The size of the coefficient (0.5391) implies that bidders tend to renew on average over one half of the maturing auction amount. This finding lends further support to the hypothesis that bidders have a target level for end-of-day reserves.

The post underbidding dummy displays a positive effect on bid amount (0.0923), while the period end dummy is not significant.

The coefficient of the bidder size variable is equal to 0.8472 and highly significant. Bearing in mind that the size variable is given by the individual reserve requirement divided by the same scale variable as the bid amount, this implies that on average each bidder demands in the auction an amount corresponding to almost 85 per cent of his requirement.

The expected auction amount does not have a significant effect on the bid amount.

Consistently with the notion that bidders manage their collateral in an efficient manner, the long rate spread has a positive effect on the bid amount (0.0714). When the long rate increases relative to the monetary policy rate, it becomes more convenient to hold or acquire collateral and thus participate in the auction, compared to the alternative of borrowing in the unsecured market.

The short rate spread also significantly affects the bid amount, with the expected sign (0.1280). This finding lends support to the prediction that bidders demand is elastic to short term rate expectations.

Finally, the λ variable (0.0343) is highly significant, revealing the presence of a sample selection effect.

5.3 Average bid rate

The regression for the bid rate is carried out using equation (4), where $x_{i,t}$ is the vector of explanatory variables for the average bid rate $y_{i,t}$ of bidder *i* in auction *t* and β is the new coefficients vector. The regression results are given in Table 5, column R. With the exception of bidder size, all coefficient estimates are highly significant. As we would expect, the most significant variable is by far the short rate spread, which guides bidders' choices. Controlling for the other decision variables, the coefficient (0.7691) implies that on average bidders shade their bids below market rates, and "shift" on the bid rate slightly over three quarters of the 2-week money market rate spread over the minimum auction rate[27].

The fulfilment ratio has a negative effect (-0.0001), as predicted on the basis of optimising behaviour on the part of bidders. When the liquidity position is large, bidders shade their bids more, and vice versa.

The forward rate spread has a positive effect (0.0060), implying that bidders raise the bid rate when the spot market rate is low compared to its expected value at the next auction. This finding is also consistent with the notion that bidders behave efficiently.

Short rate volatility has a positive effect on the bid rate (2.7412). This finding would seem consistent with bidders' risk aversion and the loser's nightmare hypothesis.

The maturing MRO amount has a positive effect on the bid rate (0.0041). This lends additional support to the hypothesis that bidders have a target level of reserves in their decision process, and they are prepared to pay a price for it.

The two dummies for the likelihood of a liquidity squeeze provide apparently mixed signals. The post underbidding dummy shows a negative effect on bid rates (-0.0213), while the period end dummy has a positive effect (0.0060). Our interpretation is that, since after an underbidding episode the market rate rapidly rises, and the bid rate is linked to the market rate through the short rate spread, underbidding provides leeway for some degree of bid shading compared to the average behaviour.

The bidder size affects negatively the bid rate (-0.0035), although the effect is not statistically significant.

The expected MRO amount exerts a negative effect on the bid rate (-0.0002). This effect is consistent with the cost of collateral hypothesis.

[27] This is a downward biased estimate, which ignores the effect of the relatively few instances in which money market rates were below the policy rate.

The effect of the long rate spread on bid rates is negative (-0.0101). Our interpretation is that, as collateral becomes cheaper and more bidders enter into play (see section 5.1), the marginal bidders are less liquidity constrained than the "core" bidders, thus pushing bid rates down.

The λ variable (0.0078) is highly significant, implying again the presence of a sample selection effect.

5.4 Bid rate dispersion

The regression for bid rate dispersion is based on equation (4), where $x_{i,t}$ is the vector of explanatory variables for rate dispersion $y_{i,t}$ of bidder *i* in auction *t* and β is the new coefficients vector. The regression results are given in Table 5, column D. All coefficient estimates are highly significant. The extremely large values of the *t* statistics are related to the low degree of variation in bid rate dispersion, as we noted in section 3.2, and to the use of fixed effects. In other words, if a given bidder submits, say, 2 bids that differ by 2 basis points in one auction, it is likely that he will submit 2 bids differing by 2 basis points in any other auction.

The country fulfilment ratio has a positive effect on bid rate dispersion (2.E-5). This implies that as the liquidity position becomes more comfortable, each bidder tends to make a broader use of the possibility to submit multiple bids.

The forward rate spread also has a positive effect on dispersion (0.0012).

Based on auction theory, we predicted that short rate volatility will induce bidders to disperse more. This hypothesis is confirmed by the positive sign of the coefficient for market rate volatility (0.0158).

The maturing auction amount displays a positive effect on bid dispersion (0.0006). We record this finding, although we had no a priori on this relationship.

The likelihood of a short liquidity squeeze, captured by the two dummy variables, increases bid rate dispersion. We note that the effect of an underbidding episode on dispersion (0.0049) is around ten times as large as the "normal" effect at the end of each maintenance period (0.0005).

Large bidders disperse rates more, as shown by the positive coefficient for the bidder size (0.0025). This seems consistent with the notion that large bidders behave more efficiently.

The cost of collateral hypothesis implies a positive effect of the expected MRO amount on rate dispersion. This is confirmed by our regression coefficient (2.E-6).

The long rate spread has a positive effect on bid rate dispersion (0.0006).

Our last hypothesis was that an increase in the short rate spread should induce bidders to disperse more. This is confirmed by our coefficient estimate (0.0305).

The λ variable (-0.0004) is highly significant, showing the presence of a sample selection effect.

6. Country effects

We extend the basic model presented in section 4 by introducing the interaction of country dummies, denoted by d_c, with each explanatory variable. For simplicity we omit the analysis of bid rate dispersion, owing to its scarce variability, as well as the interactions of the two dummies that capture the likelihood of a short squeeze.

In the case of the selection equation we extend equation (5) as follows:

$$(6) \qquad \Pr\left(h_{i,t}^{*} > 0 \,\middle|\, \mathrm{x}_{i,t}\right) = \Phi\left(\eta_{\mathrm{i}} + \mathrm{x}_{i,t}\,\delta + \sum_{j}\sum_{c} \gamma_c^j \cdot x_{i,t}^j \cdot d_c\right).$$

The first part of the right-hand side of equation (6) is like that in equation (5), while the double summation term constructs the country interactions and the γ's are the country effects to be estimated. For the model's identification we take German bidders, representing the prevalent group, as our baseline (captured by the δ's) and omit the interaction of the variables with the country dummy for Germany. We thus have *j* running from 1 (country fulfilment ratio) to 8 (short rate spread), while the country index *c* runs from 1 to 10.

Analogously, we investigate the country effects on the bid amount and the average bid rate using the following extension of equation (4):

$$(7) \qquad y_{i,t} = \alpha_i + \mathrm{x}_{\mathrm{i,t}}\,\beta + \sum_{j}\sum_{c} \phi_c^j \cdot x_{i,t}^j \cdot d_c + \hat{\lambda}_{i,t}\rho + u_{i,t}.$$

Table 6 provides the regression results of equation (6), whereas Tables 7 and 8 give the results for the bid amount and, respectively, the average bid rate based on equation (7). We rank the country dummies in alphabetical order as follows: AT (Austria), BE (Belgium), ES (Spain), FI (Finland), FR

(France), IE (Ireland), IT (Italy), LU (Luxembourg), NL (the Netherlands), PT (Portugal). The average behaviour of German bidders is given by the non interacted terms. The behaviour of bidders from any other country can be computed as the sum of the baseline coefficient (δ or β, if significant) plus the coefficient of the relevant interaction (γ or ϕ, if significant). In very general terms, we observe a large number of significant coefficients: taking the 5 percent confidence level, the count of significant coefficients is 48 (out of 88) in Table 6, 52 in Table 7, 55 in Table 8. We again find extremely significant values of λ.

To improve the readability of our results, in Table 9 we report the significant effects only for the three equations, providing for each country different from DE the total effect of each variable. Therefore, rather than looking in detail at Tables 6-8, we move to the comparative table and examine the main effects of each explanatory variable across the three equations of interest.

Starting with the effect of volatility, we note that bidders from FR, IT, LU, NL and PT share with bidders from DE a "moderate" negative impact on participation, equal to –15.6062. On the other hand, the impact is from 3 to 5 times larger for bidders from AT, BE, ES, FI and IE. This points to a larger fear of the winner's curse in the latter group of countries.

The explanatory variable which reveals the largest number of country variations is the maturing amount of refinancing. In terms of the participation decision, taking as a benchmark the coefficient for DE, equal to around 1, we observe that almost all countries display a larger effect. This reaches a maximum in the case of FR, with a coefficient roughly equal to 7. However, in terms of bid amount we note that the country which demands the largest fraction of the amount on expiry is DE (0.5669), followed by ES, IE and IT, all of which have a coefficient above 0.5. The countries which are prepared to pay the highest price in terms of bid rate to renew their amount of refinancing are BE, ES and FI, with coefficients in the range 0.0046-0.0055. At the other extreme , the countries with the lowest values are AT, IE and IT, with coefficients in the range 0.0003-0.0005.

The effect of bidder size is mostly diversified when looking at the equation for the bid amount. The largest coefficients are obtained in the case of DE (3.6253) and ES (8.0132). This is suggestive of the idea that in these countries, more than elsewhere, a two-tier structure is present in the domestic money market.

An increase in the long rate spread has the largest impact on auction participation in the case of BE (1.0050) and LU (0.8678). This is not surprising, since in those countries a large amount of relatively cheap collateral is available, and marginal bidders may find it convenient to enter the auction with the main aim of riding the yield curve. In terms of bid amount, the biggest impact is observed for ES (0.2014) and FI (0.2675). Furthermore, in those two countries the degree of bid shading re-

sulting from the bid rate equation, and associated with an increase in the long rate spread, is on the low side in absolute value (-0.0041 for ES and –0.0065 for FI, compared to –0.0113 for DE). If we take the view that the long rate spread is an inverse measure of collateral cost, then the above findings suggest that ES and FI are the countries where such cost may be more binding.

Finally, we turn to the effects of the short rate spread. In terms of the probability of bidding, three countries distinguish themselves from the rest. ES displays the largest coefficient (3.9343) while, at the other extreme, FR and LU have the lowest coefficients (0.3567 and, respectively, 0.2874). Interestingly, we note that each country has specific preferences in terms of bid shading compared to money market rates. The ones which pursue bid shading to the largest extent are ES (with a coefficient of 0.7053) and FI (with a coefficient of 0.6444). Then come AT (with a coefficient of 0.7470) and IT (0.7464). At the other end BE, LU and NL apply bid shading to the lowest degree, with coefficients in the range 0.8403-0.8684).

7. Size effects

In this section we restrict our data sample to two groups of bidders. The first group includes all bidders in the lowest two deciles ranked by size, the second group includes all bidders in the highest two deciles by size. We thus specialise the basic regressions (5) and (4) taking the "small" as the baseline case and interacting a Large bidder dummy (LBD), equal to 1 if the bidder belongs to the second group, with each of the explanatory variables (except the liquidity squeeze dummies). In the case of bidders' participation the equation is as follows:

$$\Pr\left(h_{i,t}^{*} > 0 \,\middle|\, \mathrm{x}_{i,t}\right) = \Phi\left(\eta_{\mathrm{i}} + \mathrm{x}_{\mathrm{i,t}}\,\delta + \mathrm{x}_{\mathrm{i,t}} \cdot \mathrm{LBD} \cdot \varphi\right). \tag{8}$$

We estimate equation (8) by means of a fixed effects panel probit regression. Analogously, we modify equation (4) to obtain:

$$y_{i,t} = \alpha_i + \mathrm{x}_{i,t}\,\beta + \mathrm{x}_{i,t} \cdot \mathrm{LBD} \cdot \chi + e_{i,t}\,. \tag{9}$$

We estimate equation (9) for each of the three endogenous variables bid amount, rate and dispersion by means of the Wooldridge two-step procedure.

The results of equations (8) and (9) are given in Table 10. The large bidders display a number of significant differences compared to the small ones. While the effect of country reserve fulfilment

on dispersion is positive for the small (0.0001), it becomes nil for the large. Interestingly, when volatility is high the small bidders withdraw from the auction (with a coefficient of –4.9417 in the P column) at a relatively low rate compared to the large bidders (with a differential coefficient of –33.4189).

The maturing amount of refinancing is not an important factor in the participation decision for the big bidders as opposed to the small ones, since we note that the differential effect for the former (-3.4338) almost cancels out the baseline effect for the latter (4.0431). However the same variable induces large bidders to demand slightly more in the auction (0.0379 in addition to a baseline coefficient of 0.5173, from column B), at lower average rates (-0.0022 plus 0.0057, from column R), and with a larger dispersion of bids (0.0001 plus 0.0003, from column D).

The individual size affects directly the decision to participate for small bidders (205.7991), while it is unimportant for the large ones (with an offset of -205.2501). Compared to the small bidders, the large ones respond to, e.g., an increase in the long rate spread by increasing their demand more (0.1627 in addition to 0.0540), by shading their bids more (-0.0017 in addition to –0.0073) and by dispersing more (0.0007 plus 0.0003). Finally, the large bidders shade their bids less relative to the short term spread (with a differential effect of 0.0625 on top of 0.7215 for the small bidders).

These findings point to the following conclusions. First, while large bidders are more reactive to an increase in volatility, their participation is otherwise more stable than that of small bidders, and the latter are thus more likely to have withdrawn from the MROs over our sample period. Second, large bidders seem less risk averse than small bidders, probably on account of their better access to the money market. Third, it appears that collateral is managed more efficiently by large bidders, also because they make a better use of the possibility to submit multiple bids. Fourth, large bidders set the average bid rate closer to the money market rate.

8. Bank group effects

In order to investigate the effects of participation in a banking group, we extract in the first place the sample of the 79 bidders that belong to a group (we will refer to them as the group bidders). Second, to construct a control sample, for each group bidder we extract another bidder not belonging to a group, from the same country and with similar size (we will call those in the second sample the single bidders). Next we construct a Bank group dummy (BGD), equal to 1 in the case of group bidders and to 0 for single bidders. We then run the participation probit using equation (8) above, where we replace the variable LBD with the BGD dummy. Similarly, we examine bid amount, rate and dispersion by means of equation (9) with the same replacement.

Table 11 gives the empirical estimates. Interestingly, we note that volatility shows an effect not revealed by the previous estimates. Namely, volatility has a negative impact on the bid amount, equal to –10.8940 in the case of single bidders and augmented in absolute value by –20.9629 for group bidders. This seems to indicate that group bidders are responsive to the winner's curse, a phenomenon that was not statistically significant in the regression of the previous section. However, group bidders also increase the bid rate when volatility is high (with a differential effect of 0.4925 compared to the baseline of 2.8029, from column R).

Group bidders demand in the auction a larger proportion of the amount on expiry (with a coefficient of 0.1381 in addition to a baseline of 0.4196, from column B) and are less keen on paying a price for the renewal of the operation (with a differential coefficient of –0.0019 compared to a baseline effect of 0.0041, from column R).

The positive effect of size on bid amount, which we found in the estimate of the general model, is particularly strong for group bidders (2.0590, to be added to –0.5393 of the baseline).

Group bidders significantly increase demand in the auction when the expected MRO amount increases (with a differential effect of 0.0006), while single bidders show a negative effect. Finally, in analogy with the evidence for large bidders of the previous section, we find that group bidders significantly increase their demand in the auction when the long rate spread increases (with a differential effect equal to 0.1004 on top of the baseline coefficient equal to 0.1720).

In the case of the participation decision, the main effect is the lower responsiveness of group bidders to the expected size of the auction (-0.0035 in addition to 0.0050, from column P). At the same time, when the latter increases group bidders disperse more than single bidders (with a differential coefficient equal to 2.2E-5 compared to a baseline value hardly distinguishable from 0).

Two findings provide an argument in favour of the transnational bank hypothesis. First, group bidders demand in the auction an amount of reserves that is equal to roughly 1.5 times their reserve requirement (i.e. the size variable) against an average for the entire population of 0.8 (from Table 5). Second, unlike single bidders, group bidders increase their demand when the expected auction amount increases. This clearly indicates that they are set to act as brokers of the Eurosystem liquidity provision towards the rest of the banking system. However, when volatility increases group bidders are ready to lower the bid amount and, at the same time, they bid the rate up. Finally, we note that group bidders pursue efficiency in the management of collateral, through their responsiveness to changes in the slope of the yield curve and, hence, in collateral cost.

9. Conclusion

We formulated an analytical framework for the decision to participate in the Eurosystem refinancing auctions and the three variables that characterise individual bidding behaviour. Our findings generally support the hypotheses derived from reserve management theory. In particular, the reserve fulfilment ratio has an inverse impact on participation, amount and bid rate. The forward rate spread affects positively the decision to participate and the bid rate. Interest rate volatility shows mixed effects. An increase in volatility reduces auction participation but, at the same time, pushes bid rates up. Hence, marginal bidders are sensitive to the winner's curse and display a low risk aversion, as revealed by their exit from the auction when volatility increases; at the same time, "core" bidders seem to have a larger degree of risk aversion, shown by their willingness to bid rates up when volatility is high. The individual amount on expiry exerts a positive effect on all variables, supporting the hypothesis that banks have a target level of end-of-day reserves for settlement purposes or due to the preference for a smooth fulfilment pattern.

Based on auction theory, we included two indicator variables reflecting the increased likelihood of a liquidity squeeze in the interbank market. These variables generally display the predicted effects on participation, bid amount and dispersion. An additional underpinning of the model was provided by the transnational bank hypothesis of Freixas-Holthausen, according to which larger banks with a multinational profile use their informational advantage to arbitrage out the differences in interest rates across countries. This feature would induce transnational banks to participate and bid in the auction above the rest of banks. Indeed, the results of the general model show that the bidder size has a positive effect on both the likelihood of bidding and the amount. The finding that the expected auction amount has a negative effect on bid rates, and that the long rate spread displays a positive effect on participation and bid amount, both support the view that bidders seek to make an efficient use of collateral.

Our results show the presence of national patterns in auction participation and bidding, which may to a large extent be attributed to differences in the structure of domestic money markets. The cost and availability of collateral also play an important role. Our analytical framework helped us interpret these patterns. Broadly speaking, we can safely dismiss the idea that bidders' behaviour is homogeneous across the euro area in favour of a more diversified view.

We sought to test whether two important bidder attributes, size and participation in a banking group, are powerful enough to characterise auction participation and bidding across the national borders. The answer from our evidence is affirmative. Auction participation by large bidders and group bidders is more stable over time compared to small bidders and, respectively, single bidders. How-

ever, when volatility increases the former two groups withdraw more swiftly from the auctions, on account of their better access to the money market. Group bidders demand larger amounts in the auction, thus showing their attitude to act as liquidity brokers towards the rest of the banking system. Large bidders and group bidders manage their collateral more efficiently, as revealed by their superior ability to ride the yield curve and submit multiple bids. The latter findings provide additional support for the view that group bidders are able to play a multinational role.

Our findings have important implications on the issue of integration in the money market of the euro area. In the first place, the documented relevance of microeconomic collateral management suggests that the future introduction of the single list, by creating a level playing field in terms of collateral availability and cost, will foster the integration of bidders' behaviour in the repo auctions. Second, we showed the peculiar role of large banks and group banks and provided clear arguments in favour of the transnational bank hypothesis. The existence of efficient, multinational liquidity brokers, in addition to a larger mass of medium and small players, is an extra market factor that will promote integration in the euro money market.

Along with the empirical results, the analytical framework and the methodology adopted in this paper lend themselves as a reference for future analyses of bidding in the Eurosystem repo auctions, when new developments will suggest the opportunity to re-examine the performance of the primary segment of the euro money market. We refer in particular to changes in the composition of the collateral pool, further advances in the concentration of the banking industry and the enlargement of the monetary union.

Appendix - The ARCH model for interest rate volatility

The empirical literature abounds in the choice of alternative specifications for the volatility of interest rates. E.g., in the case of the US federal funds rate, Bartolini, Bertola and Prati (2000) adopt an EGARCH(1,1) model. Our problem is to estimate the daily conditional variance of the 2-week EONIA swap rate.

We considered the ARCH(1) as the obvious candidate model, and started with a specification search on the explanatory variables for the conditional mean and variance of the 2-week rate. This led to the estimates presented in Table 12. As concerns the conditional mean equation, the lagged rate enters with coefficient 1 and we could not find any other significant and plausible explanatory variable, consistently with the hypothesis that the rate follows a martingale process. Conditional variance is positively affected in the first place by the short rate spread, with a coefficient of 3.503, which we took with one lag to avoid simultaneous endogeneity problems. Then we included dummy variables that capture calendar regularities and institutional features of the euro area money market. The first such dummy takes the value 1 on the days of the monetary meetings of the ECB's Governing Council and 0 otherwise, and it affects positively (with a coefficient of +3.142) the interest rate variance, as expected. The dummy Negative MRO is equal to 1 on auction day if the lagged short spread is negative, i.e. when the probability of underbidding is positive. The risk of underbidding has a positive effect on variance (3.962), as expected. The Post underbidding dummy takes the value 1 after the occurrence of an underbidding episode. This dummy has a positive effect (1.606), although lower than that of the ex ante dummy. The Last-in-month and Second-last-in-month dummies take value 1 on the last and, respectively, the second last working day of the month. They have a technical nature, related to month-end increases in the demand for short term funds for regulatory purposes. Their coefficients present mixed signs, showing that uncertainty on the interest rate is overall relieved on the last day of the month. The Second-last in period dummy is equal to 1 on the second last day of the maintenance period. This dummy has a positive effect (0.936) on variance. The dummy for the last day of the period turned out to be insignificant. Finally, the ARCH coefficient is equal to 0.290. All estimates are highly significant.

In the specification search for conditional variance we tried the inclusion of additional explanatory variables and calendar dummies, which turned out insignificant. We also tried variations of the ARCH model, like an ARCH(2) specification, the inclusion of an AR(1) term, a GARCH(1,1) model, an EGARCH(1,1) model, and so on. In most cases the alternative specifications did not converge. In the remaining cases the estimates led to rejection of the alternative specifications.

Tables and Figures

Table 1

THEORETICAL PREDICTIONS

This table summarises the predicted effects on bank's participation and bidding in the Eurosystem auctions discussed in section 2.2. The hypotheses are derived from the reserve management models, unless otherwise specified. The symbol (a) stands for auction theory, (b) stands for the transnational bank hypothesis, (c) is the cost of collateral hypothesis, (d) stands for monetary policy expectations.

Explanatory variables	*Dependent variables and hypotheses*			
	Participation P	Bid amount B	Average bid rate R	Bid rate dispersion D
Liquidity need	+	+	+	
Forward rate spread	+	+	+	
Short rate volatility	+ -/+ (a)	+ -/+ (a)	+ -/+ (a)	+ (a)
Reserve fulfilment	-	-	-	
Maturing MRO amount	+	+	+	
Short squeeze likelihood	+ (a)	+(a)		+(a)
Size	+(b)	+(b)		
Participation in bank group	+ (b)	+ (b)		
Expected MRO amount		- (c)	- (c)	+ (c)
Long rate spread	+ (c)	+ (c)		
Short rate spread	+ (d)	+ (d)	+ (d)	+ (d)

Table 2

FREQUENCY OF BIDDING

No. of auctions	No. of bidders	Percent	Cum.
0	30	2.91	2.91
1-10	199	19.28	22.19
11-20	169	16.38	38.57
21-30	153	14.83	53.39
31-40	138	13.37	66.76
41-50	155	15.02	81.78
51-58	163	15.79	97.58
59	25	2.42	100
Total	1032	100	

Table 3

DISTRIBUTION OF AVERAGE BID SIZE BY ACTIVE BIDDER

Range	No. of bidders	Percent	Cum
< 0.01	260	25.95	25.95
0.01-0.025	179	17.86	43.81
0.025-0.05	162	16.17	59.98
0.05-0.075	91	9.08	69.06
0.075-0.1	50	4.99	74.05
0.1-0.25	130	12.97	87.03
0.25-0.5	64	6.39	93.41
0.5-0.75	23	2.30	95.71
0.75-1	7	0.70	96.41
> 1	36	3.59	100.0
Total	1002	100.0	

Table 4

SUMMARY STATISTICS

The variables Bid amount, Expected MRO amount, Bidder size and Maturing amount are all expressed as a percentage of the area reserve requirement. Volatility is given by the conditional variance of the 2-week swap rate estimated with the ARCH model. The Average bid rate, Short rate spread and Long rate spread are differences with respect to the minimum auction rate set by the ECB. The Country fulfilment ratio is in percentage of the country reserve requirement.

Variable		Mean	Std. dev.	Min	Max	Observations
Bid amount	overall	0.2249	0.6373	0.0008	18.19	N = 29820
	between		0.4223	0.0008	5.76	n = 1002
	within		0.3390	-4.8483	12.66	T-bar = 29.7605
Average bid rate	overall	0.0547	0.0708	0	0.65	N = 29820
	between		0.0283	0	0.38	n = 1002
	within		0.0688	-0.1203	0.65	T-bar = 29.7605
Bid rate dispersion	overall	0.0063	0.0082	0	0.28	N = 29820
	between		0.0051	0	0.05	n = 1002
	within		0.0072	-0.0261	0.27	T-bar = 29.7605
Ctry fulfilment ratio	overall	98.9932	5.7360	59.2200	145.57	N = 60888
	between		2.2174	92.9534	108.73	n = 1032
	within		5.2905	57.9944	141.55	T = 59
Maturing amount	overall	0.0671	0.3212	0	17.88	N = 60888
	between		0.2296	0	3.51	n = 1032
	within		0.2246	-3.4387	14.44	T = 59
Bidder size	overall	0.0623	0.2203	0	3.29	N = 60888
	between		0.2197	0	2.92	n = 1032
	within		0.0174	-0.4841	0.63	T = 59
Exp MRO amount		76.04	27.01	-3.59	152.04	59
Forward rate spread		-0.0236	0.0626	-0.30	0.09	59
Volatility		0.0014	0.0027	4.E-05	0.0115	59
Long rate spread		0.4107	0.3346	-0.1	1.07	59
Short rate spread		0.0717	0.0847	-0.06	0.45	59

Table 5

GENERAL MODEL: PROBABILITY OF BIDDING, BID AMOUNT, AVERAGE BID RATE AND BID RATE DISPERSION

	Probability of bidding		Bid amount		Average bid rate		Bid rate dispersion	
	P		B		R		D	
	Coef	*t stat*	*Coef*	*t stat*	*Coef*	*t stat*	*Coef*	*t stat*
Ctry fulfilment ratio	-0.0077	*-6.16*	-0.0006	*-2.91*	-0.0001	*-24.29*	2.E-05	*454.5*
Forward rate spread	1.6285	*12.81*	-0.0715	*-25.06*	0.0060	*89.90*	0.0012	*1528.9*
Short rate volatility	-20.3052	*-7.51*	-5.2195	*-0.82*	2.7412	*18.01*	0.0158	*9.2*
Maturing MRO amt	1.1608	*19.67*	0.5391	*560.60*	0.0041	*219.65*	0.0006	*2606.8*
Post underb dummy	0.2597	*4.96*	0.0923	*3.46*	-0.0213	*-33.45*	0.0049	*676.2*
Period end dummy	0.0981	*5.74*	0.0001	*0.01*	0.0060	*44.37*	0.0005	*353.4*
Bidder size	1.0059	*2.38*	0.8472	*4.66*	-0.0035	*-0.81*	0.0025	*51.5*
Expected MRO amt	0.0041	*13.38*	0.0000	*-0.11*	-0.0002	*-115.54*	2.E-06	*98.1*
Long rate spread	0.4884	*19.44*	0.0714	*35.66*	-0.0101	*-211.53*	0.0006	*1076.8*
Short rate spread	1.8815	*19.08*	0.1280	*4.68*	0.7691	*1177.87*	0.0305	*4120.2*
Lambda			0.0343	*16.57*	0.0078	*158.55*	-0.0004	*-750.7*
No of obs	60888		29820		29820		29820	
No of groups	1032		1002		1002		1002	
Obs per group: min			1		1		1	
avg			29.8		29.8		29.8	
max			59		59		59	
R squared: within			0.2468		0.8007		0.1808	
between			0.7471		0.5161		0.0332	
overall			0.6097		0.7781		0.1365	
F(11,28807)			858.23		10518.80		577.88	
Prob>F			0.0000		0.0000		0.0000	

Table 6

COUNTRY EFFECTS
PROBABILITY OF BIDDING

	Coeff.	*t stat.*		*Coeff.*	*t stat.*
Ctry fulfilment ratio	-0.0128	*-6.183*	Bidder size	-0.0441	*-0.04*
AT	0.0215	*2.216*	AT	-23.4937	*-2.375*
BE	0.0185	*2.146*	BE	-2.4719	*-0.572*
ES	0.0160	*2.814*	ES	-2.3369	*-0.749*
FI	-0.0096	*-1.675*	FI	1.4176	*0.708*
FR	0.0138	*2.503*	FR	-6.4112	*-0.986*
IE	0.0076	*1.732*	IE	5.3478	*1.64*
IT	0.0116	*2.637*	IT	-5.8323	*-1.743*
LU	0.0075	*1.549*	LU	0.8734	*0.71*
NL	0.0094	*1.375*	NL	4.5873	*2.046*
PT	0.0073	*0.68*	PT	11.4254	*3.165*
Forward rate spread	2.0070	*13.724*	Exp MRO amount	0.0039	*11.209*
AT	-2.3586	*-3.078*	AT	-0.0031	*-1.739*
BE	-1.8131	*-1.577*	BE	0.0003	*0.118*
ES	-1.7353	*-2.888*	ES	0.0028	*1.975*
FI	-0.6711	*-1.178*	FI	0.0038	*2.861*
FR	-2.8472	*-3.523*	FR	-0.0027	*-1.492*
IE	-1.1405	*-2.217*	IE	0.0013	*1.106*
IT	-1.6378	*-2.672*	IT	-0.0028	*-2.04*
LU	-2.1336	*-2.637*	LU	0.0022	*1.193*
NL	0.2601	*0.233*	NL	0.0002	*0.067*
PT	-0.1025	*-0.072*	PT	-0.0029	*-0.917*
Volatility	-15.6062	*-4.962*	Long rate spread	0.4791	*16.165*
AT	-38.2051	*-2.271*	AT	0.0165	*0.093*
BE	-59.6205	*-2.163*	BE	0.5260	*2.033*
ES	-31.5907	*-2.156*	ES	0.1677	*1.272*
FI	-31.3766	*-2.383*	FI	0.2077	*1.682*
FR	-15.9462	*-0.866*	FR	-0.5755	*-3.251*
IE	-25.9069	*-2.211*	IE	0.0066	*0.057*
IT	-0.2477	*-0.019*	IT	0.1165	*0.862*
LU	31.2321	*1.763*	LU	0.3887	*2.164*
NL	1.7301	*0.062*	NL	-0.0857	*-0.355*
PT	0.9886	*0.028*	PT	-0.1034	*-0.321*
Maturing amount	0.9950	*12.97*	Short rate spread	1.8913	*16.291*
AT	1.3251	*2.46*	AT	-0.3213	*-0.476*
BE	-0.6296	*-2.768*	BE	0.7694	*0.752*
ES	0.2898	*1.132*	ES	2.0430	*3.751*
FI	0.0395	*0.156*	FI	-0.4822	*-0.999*
FR	5.8772	*9.24*	FR	-1.5346	*-2.326*
IE	1.1930	*4.404*	IE	-0.1318	*-0.299*
IT	1.2956	*4.457*	IT	-0.6931	*-1.339*
LU	-0.8054	*-4.553*	LU	-1.6039	*-2.532*
NL	1.8383	*2.213*	NL	1.4840	*1.625*
PT	2.3538	*2.189*	PT	0.0274	*0.022*
Post underb dummy	0.2490	*4.682*			
Period end dummy	0.1096	*6.314*			
.			No of obs	60888	

Table 7

COUNTRY EFFECTS
BID AMOUNT

	Coeff.	*t stat.*		*Coeff.*	*t stat.*		
Ctry fulfilment ratio	0.0004	*1.11*	Bidder size	3.6253	*10.18*	No of obs	29820
AT	-0.0027	*-2.25*	AT	-2.6967	*-3.20*	No of groups	1002
BE	-0.0054	*-2.42*	BE	-2.0626	*-2.38*	Obs per group:	
ES	-0.0031	*-3.20*	ES	4.3879	*6.47*	Min	1
FI	-0.0020	*-1.86*	FI	-4.7940	*-11.73*	Avg	29.8
FR	-0.0003	*-0.17*	FR	-4.2420	*-0.94*	Max	59
IE	0.0002	*0.43*	IE	-2.4140	*-4.48*	R squared:	
IT	-0.0005	*-0.72*	IT	-4.9843	*-6.89*	Within	0.2767
LU	-0.0009	*-2.55*	LU	-3.9455	*-9.86*	Between	0.3913
NL	-0.0013	*-0.26*	NL	-3.7133	*-22.57*	Overall	0.3467
PT	-0.0009	*-0.36*	PT	-2.9098	*-1.88*		
Forward rate spread	-0.0899	*-2.81*	Exp MRO amount	-0.0002	*-23.80*	F(91,28727)	120.79
AT	0.0752	*1.04*	AT	0.0002	*14.01*	Prob > F	0.0000
BE	-0.8910	*-6.79*	BE	0.0041	*18.85*		
ES	-0.2801	*-2.99*	ES	0.0004	*11.61*		
FI	-0.0219	*-0.34*	FI	0.0014	*31.93*		
FR	0.0962	*0.47*	FR	0.0001	*4.25*		
IE	0.0059	*0.10*	IE	0.0004	*9.10*		
IT	-0.1041	*-2.01*	IT	0.0004	*12.86*		
LU	0.1972	*0.92*	LU	0.0008	*5.87*		
NL	0.1961	*0.33*	NL	0.0002	*5.04*		
PT	0.3656	*0.43*	PT	0.0008	*75.46*		
Volatility	-3.6711	*-0.83*	Long rate spread	0.0373	*20.03*		
AT	-2.0010	*-0.13*	AT	0.0193	*4.05*		
BE	-54.3155	*-1.25*	BE	0.0088	*1.84*		
ES	-5.6094	*-0.34*	ES	0.1641	*21.88*		
FI	-13.5325	*-1.04*	FI	0.2303	*31.68*		
FR	2.3021	*0.09*	FR	-0.0368	*-48.35*		
IE	0.1691	*0.02*	IE	0.0835	*19.31*		
IT	-0.0894	*-0.01*	IT	0.0613	*7.60*		
LU	-11.7828	*-0.46*	LU	0.0903	*13.39*		
NL	1.8825	*0.02*	NL	-0.0592	*-1.40*		
PT	-4.0887	*-0.03*	PT	-0.0626	*-0.69*		
Maturing amount	0.5669	*382.27*	Short rate spread	0.0781	*6.81*		
AT	-0.3002	*-43.38*	AT	-0.0790	*-1.73*		
BE	-0.3073	*-68.87*	BE	0.2264	*5.20*		
ES	-0.0425	*-28.74*	ES	0.1660	*0.00*		
FI	-0.1846	*-224.04*	FI	0.4614	*13.47*		
FR	-0.1819	*-2.59*	FR	0.0247	*0.00*		
IE	-0.0140	*-7.47*	IE	0.2283	*9.92*		
IT	-0.0348	*-51.34*	IT	0.0209	*0.62*		
LU	-0.3691	*-86.27*	LU	-0.2076	*-2.19*		
NL	-0.3409	*-4.56*	NL	-0.0178	*-0.07*		
PT	-0.7623	*-5.84*	PT	-0.1238	*-0.85*		
Post underb dummy	0.0850	*18.85*	Lambda	-0.0145	*-187.13*		
Period end dummy	-0.0017	*-1.99*					

Table 8

COUNTRY EFFECTS
AVERAGE BID RATE

	Coeff.	*t stat.*		*Coeff.*	*t stat.*		
Ctry fulfilment ratio	-0.0001	*-5.73*	Bidder size	-0.0491	*-1.91*	No of obs	29820
AT	-0.0002	*-2.63*	AT	0.1330	*2.18*	No of groups	1002
BE	0.0002	*1.37*	BE	0.1488	*2.37*	Obs per group:	
ES	0.0009	*13.43*	ES	0.0514	*1.05*	Min	1
FI	0.0004	*5.49*	FI	0.0307	*1.04*	Avg	29.8
FR	-0.0006	*-4.33*	FR	0.0288	*0.09*	Max	59
IE	-0.0007	*-18.56*	IE	-0.0497	*-1.27*	R squared:	
IT	0.0003	*5.70*	IT	0.0643	*1.23*	Within	0.8036
LU	0.0001	*2.37*	LU	0.0718	*2.48*	Between	0.2636
NL	0.0005	*1.34*	NL	-0.0482	*-4.10*	Overall	0.6143
PT	0.0003	*1.60*	PT	0.1951	*1.74*		
Forward rate spread	-0.0027	*-1.19*	Exp MRO amount	-0.0002	*-391.08*	F(91,28727)	1291.29
AT	-0.0082	*-1.57*	AT	-8.E-6	*-7.05*	Prob > F	0.0000
BE	-0.0679	*-7.14*	BE	-0.0001	*-3.51*		
ES	-0.0518	*-7.63*	ES	-0.0001	*-24.45*		
FI	-0.0491	*-10.65*	FI	-0.0001	*-18.81*		
FR	0.0176	*1.18*	FR	0.0001	*72.20*		
IE	-0.0257	*-5.87*	IE	2.E-5	*5.56*		
IT	0.0040	*1.08*	IT	3.E-6	*1.26*		
LU	-0.0964	*-6.19*	LU	-0.0001	*-11.94*		
NL	-0.0744	*-1.73*	NL	-0.0002	*-79.60*		
PT	-0.0376	*-0.61*	PT	-1.E-5	*-12.88*		
Volatility	2.9410	*9.22*	Long rate spread	-0.0113	*-82.37*		
AT	-0.6305	*-0.58*	AT	0.0029	*8.29*		
BE	-0.1194	*-0.04*	BE	-0.0004	*-1.25*		
ES	-1.1308	*-0.95*	ES	0.0072	*13.34*		
FI	-0.8030	*-0.85*	FI	0.0048	*9.26*		
FR	-0.0891	*-0.05*	FR	0.0050	*91.41*		
IE	-0.3772	*-0.49*	IE	-0.0010	*-3.18*		
IT	-0.0260	*-0.03*	IT	0.0017	*2.98*		
LU	0.7712	*0.42*	LU	-0.0045	*-9.32*		
NL	-2.1108	*-0.30*	NL	-0.0129	*-4.22*		
PT	-0.4090	*-0.04*	PT	0.0044	*0.66*		
Maturing amount	0.0021	*21.28*	Short rate spread	0.7696	*927.66*		
AT	-0.0019	*-3.77*	AT	-0.0226	*-6.82*		
BE	0.0026	*8.12*	BE	0.0989	*31.33*		
ES	0.0034	*39.74*	ES	-0.0642	*-71.89*		
FI	0.0025	*409.91*	FI	-0.1251	*-50.48*		
FR	0.0082	*1.61*	FR	0.0365	*4.26*		
IE	-0.0016	*-12.90*	IE	0.0114	*6.85*		
IT	-0.0016	*-192.90*	IT	-0.0231	*-9.40*		
LU	0.0001	*0.47*	LU	0.0707	*10.30*		
NL	-0.0080	*-1.48*	NL	0.0915	*5.28*		
PT	0.0104	*1.10*	PT	0.0248	*2.35*		
Post underb dummy	-0.0226	*-69.25*	Lambda	-0.0096	*-509.23*		
Period end dummy	0.0064	*100.77*					

Table 9

COUNTRY EFFECTS
COMPARATIVE TABLE

		Probability of bidding	Bid amount	Average bid rate			Probability of bidding	Bid amount	Average bid rate
		P	B	R			P	B	R
Ctry fulfilment	DE	-0.0128		-0.0001	Bidder size	DE		3.6253	
	AT	0.0087	-0.0027	-0.0004		AT	-23.2447	0.9286	0.1330
	BE	0.0057	-0.0054			BE		1.5628	0.1488
	ES	0.0031	-0.0031	0.0008		ES		8.0132	
	FI			0.0003		FI		-1.1687	
	FR	0.0009		-0.0007		FR			
	IE			-0.0008		IE		1.2113	
	IT	-0.0012		0.0001		IT		-1.3590	
	LU		-0.0009	-0.0001		LU		-0.3201	0.0718
	NL					NL	4.5873	-0.0880	-0.0482
	PT					PT	11.4254		
Forward rate sprd	DE	2.0070	-0.0899		Exp MRO amt	DE	0.0039	-0.0002	-0.0002
	AT	-0.3516				AT		0.0001	-0.0002
	BE		-0.9809	-0.0679		BE		0.0040	-0.0003
	ES	0.2717	-0.3700	-0.0518		ES	0.0028	0.0003	-0.0003
	FI			-0.0491		FI	0.0038	0.0013	-0.0003
	FR	-0.8402				FR		-0.0001	-0.0001
	IE	0.8665		-0.0257		IE		0.0002	-0.0002
	IT	0.3692	-0.1940			IT	-0.0028	0.0002	
	LU	-0.1265		-0.0964		LU		0.0006	-0.0003
	NL					NL		0.0000	-0.0004
	PT					PT		0.0007	-0.0002
Volatility	DE	-15.6062		2.9410	Long rate spread	DE	0.4791	0.0373	-0.0113
	AT	-53.8113				AT		0.0566	-0.0084
	BE	-75.2266				BE	1.0050		
	ES	-47.1968				ES		0.2014	-0.0041
	FI	-46.9828				FI		0.2675	-0.0065
	FR					FR	-0.0965	0.0005	-0.0062
	IE	-41.5131				IE		0.1208	-0.0123
	IT					IT		0.0986	-0.0095
	LU					LU	0.8678	0.1275	-0.0158
	NL					NL			-0.0242
	PT					PT			
Maturing amount	DE	0.9950	0.5669	0.0021	Short rate pread	DE	1.8913	0.0781	0.7696
	AT	2.3201	0.2668	0.0003		AT			0.7470
	BE	0.3654	0.2596	0.0047		BE		0.3045	0.8684
	ES		0.5245	0.0055		ES	3.9343		0.7053
	FI		0.3823	0.0046		FI		0.5396	0.6444
	FR	6.8722	0.3850			FR	0.3567		0.8060
	IE	2.1880	0.5530	0.0005		IE		0.3065	0.7810
	IT	2.2905	0.5321	0.0005		IT			0.7464
	LU	0.1896	0.1978			LU	0.2874	-0.1295	0.8403
	NL	2.8332	0.2261			NL			0.8610
	PT	3.3488	-0.1953			PT			0.7944
Post underb dummy		0.2490	0.0850	-0.0226					
Period end dummy		0.3586	-0.0017	0.0064					

Table 10

BIDDER SIZE EFFECTS: PROBABILITY OF BIDDING, BID AMOUNT, AVERAGE BID RATE AND BID RATE DISPERSION

	Probability of bidding		Bid amount		Average bid rate		Bid rate dispersion	
	P		B		R		D	
	Coef	*t stat*	*Coef*	*t stat*	*Coef*	*t stat*	*Coef*	*t stat*
Ctry fulfilment ratio	-0.0041	*-1.19*	0.0000	*-0.02*	-0.0002	*-11.82*	0.0001	*202.7*
LBD * x	0.0026	*0.63*	-0.0008	*-0.08*	0.0001	*1.90*	-0.0001	*-70.6*
Forward rate spread	1.8472	*6.79*	0.2210	*0.26*	-0.0053	*-1.01*	0.0030	*41.8*
LBD * x	-0.7305	*-1.96*	-0.7473	*-0.54*	-0.0056	*-0.66*	-0.0061	*-51.9*
Volatility	-4.9417	*-0.82*	-6.2660	*-0.20*	2.4423	*12.89*	0.0209	*8.0*
LBD * x	-33.4189	*-3.98*	-10.9712	*-0.05*	0.6502	*0.51*	-0.0056	*-0.3*
Maturing amount	4.0431	*10.55*	0.5173	*18.33*	0.0057	*33.12*	0.0003	*116.5*
LBD * x	-3.4338	*-8.85*	0.0379	*2.02*	-0.0022	*-18.94*	0.0001	*71.3*
Postt underb dummy	0.3221	*3.74*	0.2045	*0.50*	-0.0238	*-9.40*	0.0054	*156.3*
Period end dummy	0.0652	*2.32*	-0.0088	*-0.11*	0.0053	*10.66*	0.0005	*74.5*
Bidder size	205.7991	*7.78*	0.5556	*0.00*	-0.1998	*-0.10*	-0.0856	*-3.0*
LBD * x	-205.2501	*-7.76*	0.3263	*0.00*	0.1986	*0.10*	0.0879	*3.1*
Exp MRO amount	0.0017	*2.65*	-0.0004	*-0.74*	-0.0002	*-66.32*	-8.E-06	*-206.3*
LBD * x	0.0025	*2.92*	0.0006	*0.58*	0.0000	*-0.27*	2.E-05	*251.3*
Long rate spread	0.4077	*7.28*	0.0540	*0.74*	-0.0073	*-16.31*	0.0003	*44.6*
LBD * x	0.0410	*0.50*	0.1627	*62.41*	-0.0017	*-108.41*	0.0007	*3281.0*
Short rate spread	1.8356	*8.54*	0.0675	*1.05*	0.7215	*1827.27*	0.0287	*5272.0*
LBD * x	0.0792	*0.25*	0.2255	*0.34*	0.0625	*15.55*	0.0037	*66.2*
Lambda			0.0735	*1.18*	0.0065	*16.93*	-0.0004	*-78.4*
No of obs	23178		11641		11641		11641	
No of groups	402		387		387		387	
Obs per group: min			1		1		1	
avg			30.1		30.1		30.1	
max			59		59		59	
R squared: within			0.2666		0.7961		0.1868	
between			0.7521		0.4782		0.0166	
overall			0.5968		0.7551		0.1315	
F(19,11235)			214.96		2309.05		135.87	
Prob>F			0.0000		0.0000		0.0000	

Table 11

BANK GROUP EFFECTS: PROBABILITY OF BIDDING, BID AMOUNT, AVERAGE BID RATE AND BID RATE DISPERSION

	Probability of bidding		Bid amount		Average bid rate		Bid rate dispersion	
	P		B		R		D	
	Coef	*t stat*	*Coef*	*t stat*	*Coef*	*t stat*	*Coef*	*t stat*
Ctry fulfilment ratio	-0.0018	*-0.61*	-0.0004	*-15.05*	-0.0001	*-463.8*	0.0001	*9428.2*
BGD * x	-0.0092	*-2.15*	0.0008	*8.71*	-0.0001	*-173.5*	-4.9E-05	*-6555.9*
Forward rate spread	1.0723	*2.44*	0.0787	*8.82*	-0.0016	*-58.6*	0.0010	*883.7*
BGD * x	-0.1265	*-0.22*	-1.2372	*-33.14*	-0.0129	*-220.5*	-0.0061	*-3984.3*
Volatility	-35.6375	*-3.81*	-10.8940	*-55.08*	2.8029	*2630.8*	0.0451	*2738.3*
BGD * x	-14.0389	*-1.09*	-20.9629	*-17.68*	0.4925	*59.6*	-0.0335	*-1456.6*
Maturing amount	0.7711	*6.84*	0.4196	*69.86*	0.0041	*1505.7*	0.0011	*4669.3*
BGD * x	-0.1232	*-0.91*	0.1381	*19.73*	-0.0019	*-634.0*	-0.0008	*-3263.4*
Postt underb dummy	0.8011	*5.81*	0.3439	*75.14*	-0.0215	*-1486.3*	0.0058	*17727.4*
Period end dummy	0.0106	*0.24*	-0.0171	*-16.18*	0.0047	*1564.6*	0.0004	*8034.0*
Bidder size	-1.6458	*-1.71*	-0.5393	*-19.20*	0.0019	*54.1*	-0.0008	*-394.7*
BGD * x	2.6118	*2.40*	2.0590	*24.56*	0.0049	*89.1*	0.0037	*1730.5*
Exp MRO amount	0.0050	*4.82*	-0.0003	*-15.71*	-0.0002	*-4617.8*	-2.2E-06	*-1102.8*
BGD * x	-0.0035	*-2.61*	0.0006	*15.45*	7.2E-06	*125.5*	2.2E-05	*7061.1*
Long rate spread	0.6067	*6.70*	0.1720	*79.71*	-0.0117	*-4351.9*	0.0014	*8482.2*
BGD * x	-0.0778	*-0.60*	0.1004	*24.64*	0.0037	*672.1*	-0.0007	*-2984.4*
Short rate spread	0.9161	*2.66*	0.2452	*28.69*	0.7651	*26835.8*	0.0360	*14984.5*
BGD * x	-0.0448	*-0.09*	0.1092	*8.30*	0.0173	*389.4*	-0.0030	*-1064.6*
Lambda			-0.0464	*-30.38*	-0.0093	*-2127.9*	0.0001	*438.1*
No of obs	9322		5354		5354		5354	
No of groups	158		155		155		155	
Obs per group: min			2		2		2	
avg			34.5		34.5		34.5	
max			59		59		59	
R squared: within			0.2670		0.8374		0.2687	
between			0.4550		0.5148		0.0350	
overall			0.4002		0.8122		0.1976	
F(19,5180)			99.32		1404.58		100.17	
Prob>F			0.0000		0.0000		0.0000	

Table 12

ARCH ESTIMATION FOR 2-WEEK INTEREST RATE VOLATILITY

We report our specification for the conditional variance of the daily 2-week EONIA swap rate (see Appendix 1). The Governing council dummy takes the value 1 on the day of the ECB Governing Council meeting and 0 otherwise. The Negative MRO dummy is equal to 1 on auction day if the lagged short spread is negative, i.e. when the probability of underbidding is positive. The post underbidding dummy takes the value 1 after the occurrence of an underbidding episode. The Last-in-month and Second-last-in-month dummies take value 1 on the last and, respectively, the second last working day of the month. The Second-last in period dummy is equal to 1 on the second last day of the maintenance period. The symbol *** indicates a significance level of 1 percent or less.

	ARCH(1) model		
	Coeff.	*Std. err.*	*Sign.*
Conditional mean			
Lagged rate	1.000	0.000	***
Conditional variance			
Lagged short rate spread	3.503	1.057	***
Governing council dummy	3.142	0.315	***
Negative MRO dummy	3.962	0.546	***
Post underbidding dummy	1.606	0.589	***
Last-in-month dummy	-2.274	0.820	***
Second-last-in-month d.	1.370	0.418	***
Second-last-in-period d.	0.956	0.338	***
Constant	-8.360	0.140	***
ARCH(1)	0.290	0.069	***

Fig. 1

ECB interest rates and money market rates

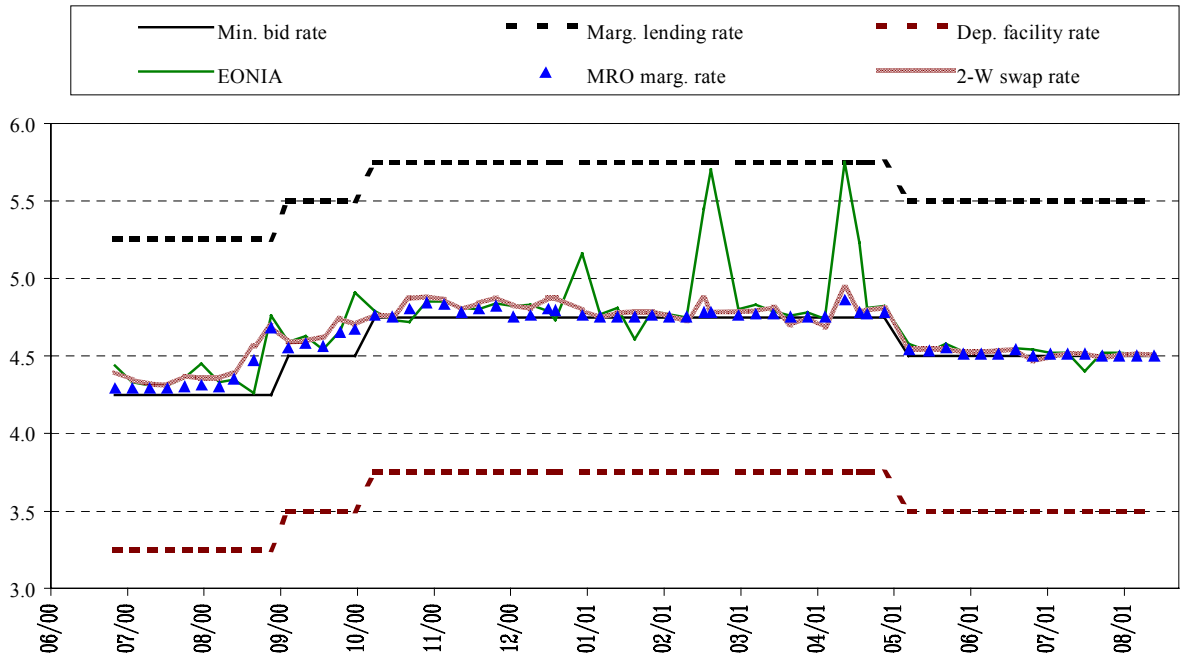


Fig. 2

Total number of bidders

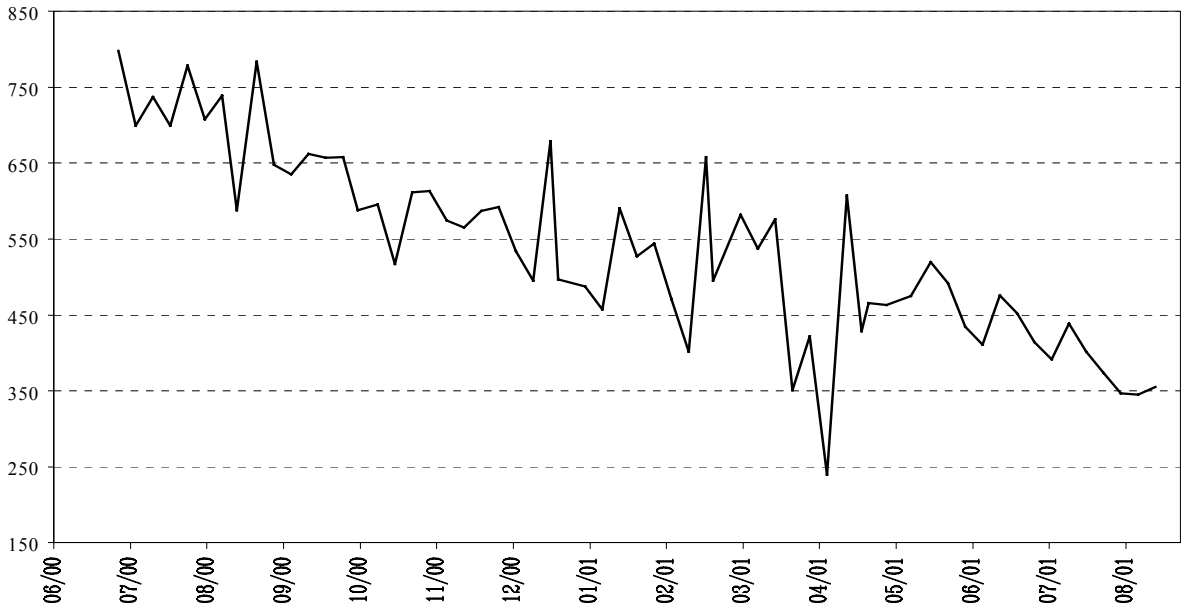


Fig. 3

Aggregate bid amount and allotment

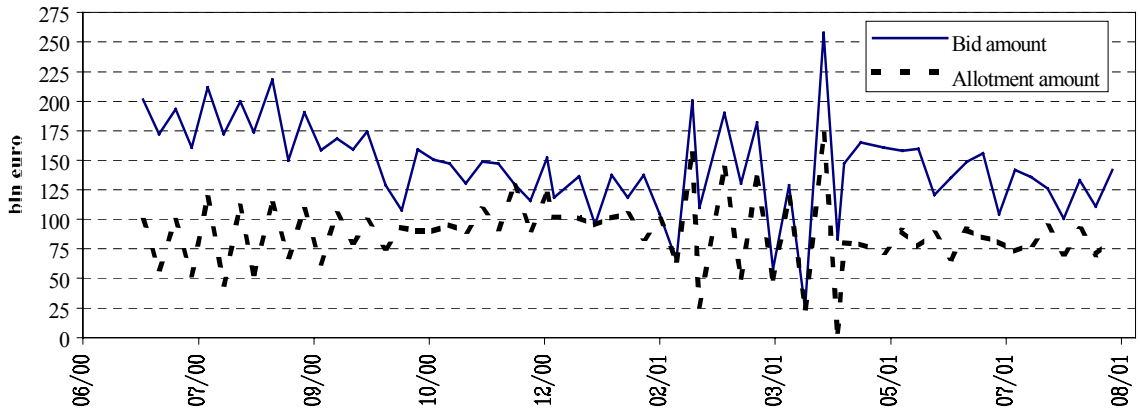


Fig. 4

Minimum rate, avg bid rate, avg allotment rate, marginal allotment rate

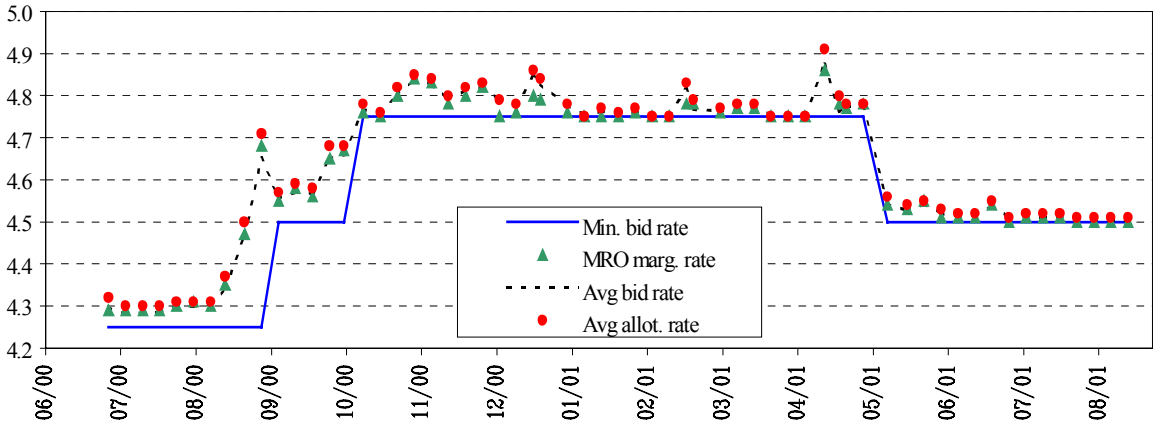


Fig. 5

Standard deviation of bid rates and allotment rates

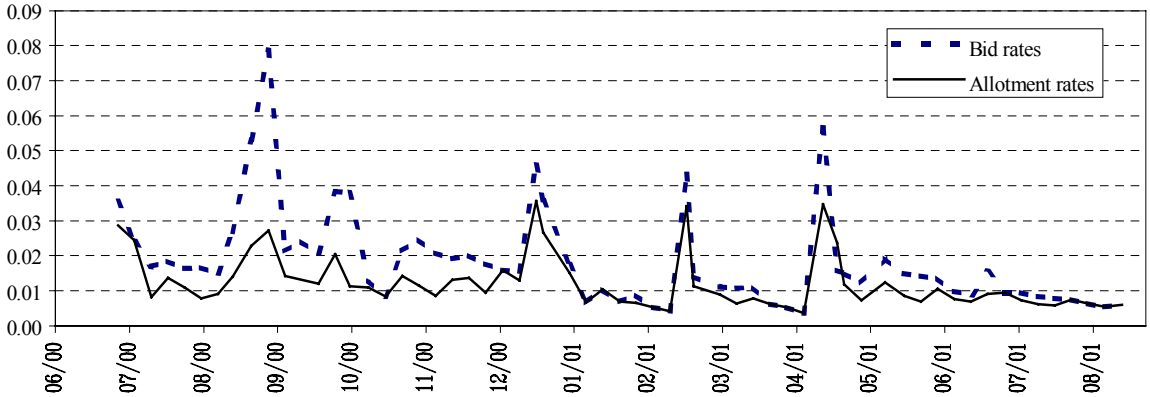


Fig. 6a

Number of bidders from DE

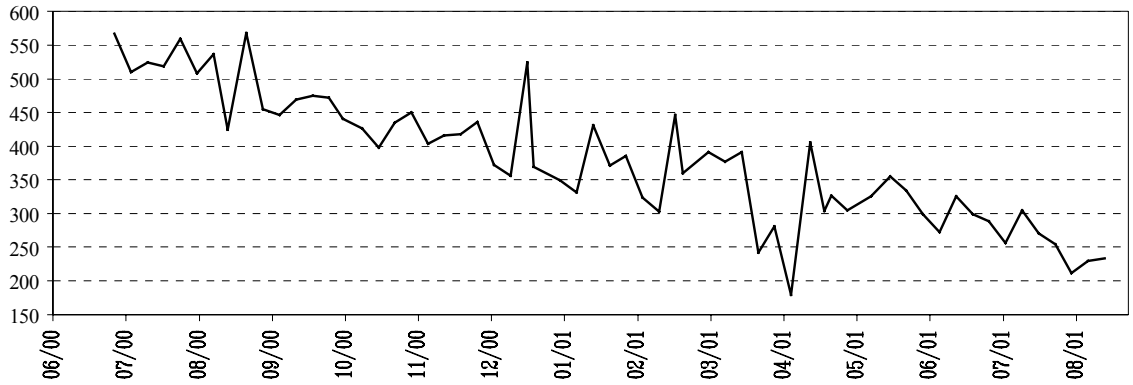


Fig. 6b

Number of bidders from AT, ES, LU, FR, IT

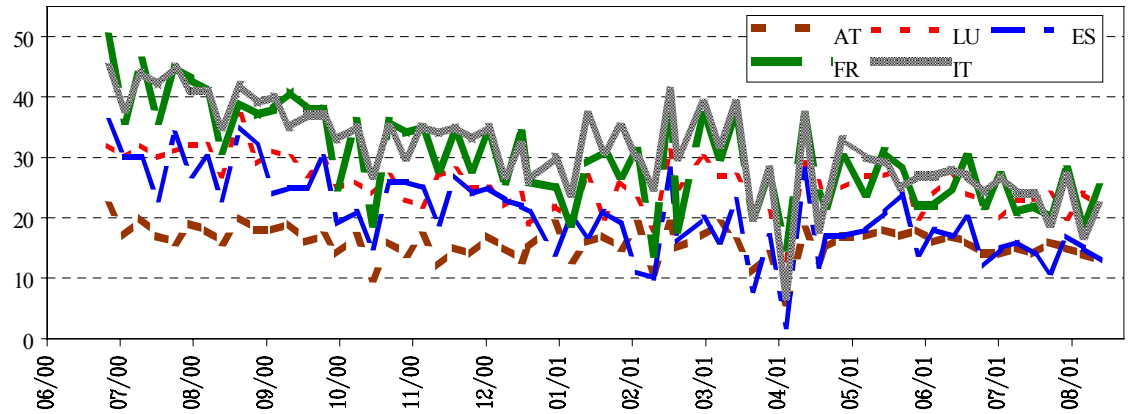


Fig. 6c

Number of bidders from FI, PT, GR, BE, NL, IE

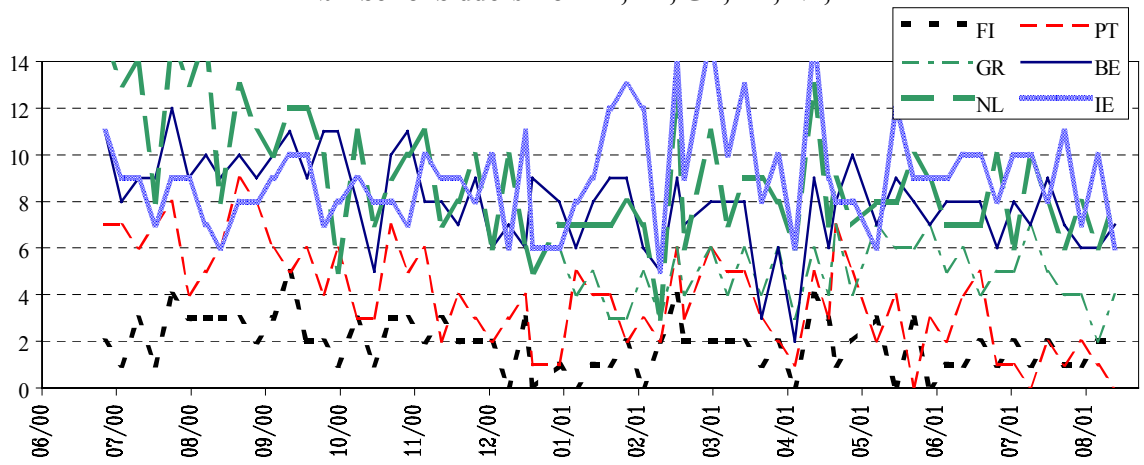


Fig. 7a

Country shares of demand from DE, FR, IT, LU

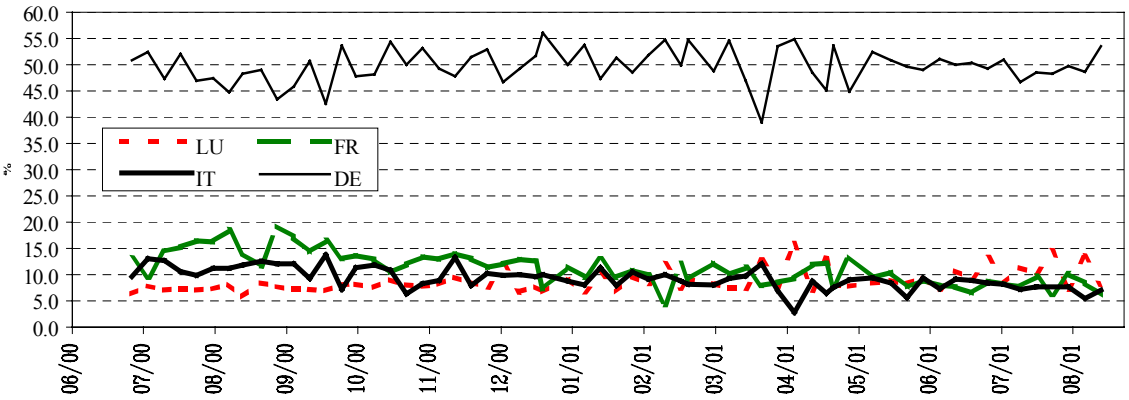


Fig. 7b

Country shares of demand from AT, BE, NL, ES

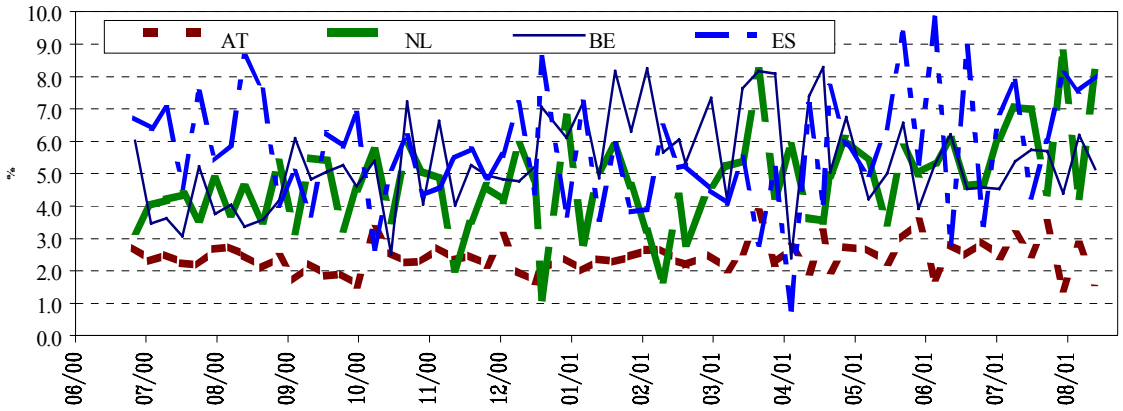
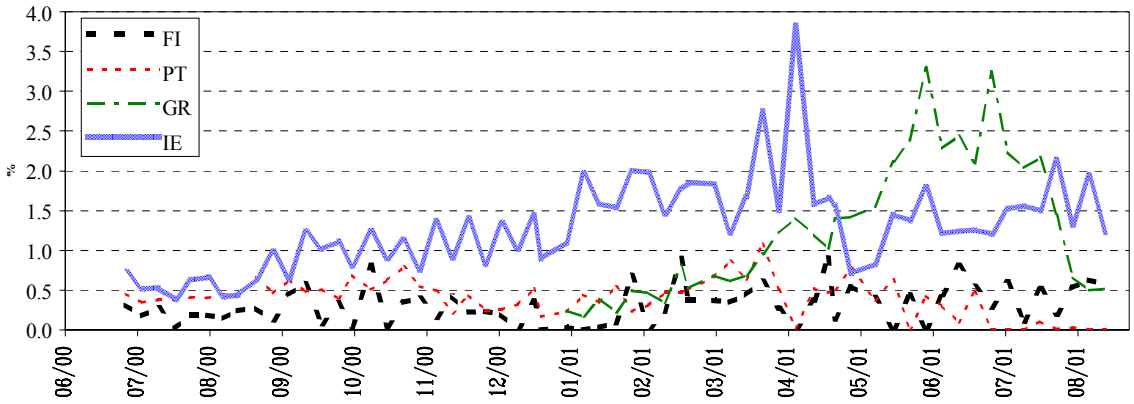


Fig. 7c

Country shares of demand from FI, PT, GR, IE



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