Tuomas Välimäki

Why the marginal MRO rate exceeds the ECB policy rate?

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Why the marginal MRO rate exceeds the ECB policy rate?

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Abstract

In the Eurosystem, banks' interest rate expectations should no longer have resulted in a non-zero tender spread, the difference between marginal and minimum price for liquidity, when the ECB reformed its operational framework for monetary policy implementation in March 2004 so that the policy rates remain constant within reserves maintenance periods. Yet, the tender spread was wider in 2005 than in any single year after 2000, when the ECB switched from fixed to variable rate tenders. Parts of the relevant literature have argued that because of the ECB's asymmetric preferences over deviations of the market rates up and down from the policy rate, the shortest euro interest rates persistently exceed the policy rate This paper argues, however, that when the central bank applies a quantity oriented liquidity policy, a positive tender spread may result from money market inefficiencies and banks' risk aversion even if the central bank preferences are symmetric and the markets do not anticipate any changes in the policy rates. In such a case, the driving force behind the tender spread is banks' uncertainty about their individual allotments at the marginal rate for the Eurosystem main refinancing operations (MROs).

Furthermore, the allotment uncertainty is shown to be significantly related to the amount of liquidity supplied in each operation. Hence, the expansion in the MRO volumes experienced since 2002 may have had a major contribution to the emergence and observed growth of the tender spread.

Key words: main refinancing operations, liquidity, tender spread, allotments

JEL classification numbers: D44, E58

Miksi likviditeetin todellinen korko EKP:n perusrahoitusoperaatioissa on korkeampi kuin politiikkakorko?

Suomen Pankin tutkimus
Keskustelualoitteita 20/2006

Tuomas Välimäki
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

EKP muutti maaliskuussa 2004 rahapolitiikan toimeenpanossa käytettävää toimintakehikkoa siten, että keskuspankin ohjauskorkoja ei nykyisin muuteta vähimmäisvarantojen pitoperiodien sisällä. Näin ollen eurojärjestelmän pankkien korko-odotusten ei pitäisi enää vaikuttaa operaatiokorkojen muodostukseen eikä siis erityisesti huutokauppakorkojen eroon, jolla tarkoitetaan perusrahoitusoperaatioiden marginaalikoron ja niissä sovellettavan politiikkakoron eli efektiivisen huutokauppakoron ja minimitarjouskoron välistä eroa. Huutokauppakorkojen ero oli muutoksesta huolimatta vuonna 2005 suurempi kuin yhtenäkään aiempana kalenterivuonna sen jälkeen, kun EKP alkoi kesäkuussa 2000 toteuttaa huutokaupat vaihtuvakorkoisina huutokauppoina. Aiemmissa tutkimuksissa on esitetty, että euron lyhyimmät korot ylittävät politiikkakoron, koska EKP:llä on epäsymmetriset preferenssit korkopoikkeamien suhteen, mistä syystä se suhtautuu suopeammin tilanteeseen, jossa markkinakorot ylittävät politiikkakoron, kuin tilanteeseen, jossa politiikkakorko alittuu. Tässä työssä osoitetaan kuitenkin, että huutokauppakorkojen ero voi syntyä markkinoiden epätäydellisyyksistä ja pankkien riskin kaihtamisesta silloinkin, kun keskuspankin preferenssit ovat symmetriset eivätkä pankit odota politiikkakorkojen muuttuvan. Korkoero määräytyy tässä tapauksessa siitä epävarmuudesta, jota yksittäinen pankki kokee sille huutokaupassa kohdennetusta likviditeetin määrästä. Likviditeettiepävarmuuden osoitetaan lisäksi riippuvan ratkaisevasti kussakin operaatiossa jaettavasta likviditeetin kokonaismäärästä. Korkoero saattaakin näin ollen johtua operaatioiden keskikoon erittäin voimakkaasta kasvusta viime vuosina.

Avainsanat: perusrahoitusoperaatiot, likviditeetti, huutokauppakorkojen ero, jako-osuudet

JEL-luokittelu: D44, E58

Contents

1 Introduction

Although the ECB has not explicitly announced an operational target for its monetary policy (like the Fed funds target rate), it is clear that the monetary policy implementation in the euro area aims at stabilizing the short-term interest rates to a level close to the ECB policy rate.[1] Moreover, the ECB has been quite successful in pursuing this goal; during 1999–2005 the spread between the euro overnight rate and the ECB key policy rate (*EONIA spread*)[2] showed an average of 6.7 bps with a standard deviation of 15 bps. Yet, the behaviour of this spread has varied quite a lot from one year to another. However, the stability of the spread seems to have steadily improved.

The volatility of the shortest euro interest rate was significantly lower in 2005 than during any other year since the beginning of the Eurosystem. This indicates that the latest changes to the Eurosystem operational framework (March 2004) have helped the ECB in achieving its goal. On that occasion, the timing of the *reserve maintenance periods*[3] was adjusted so that now the changes of the periods coincide with the ECB's Governing Council interest rate meetings. Also, the maturity of the main refinancing operations (*MROs*) was halved in March 2004.[4] The increased stability of the EONIA spread improves the clarity of the monetary policy signals provided by the policy rate, and it also reduces the probability of the interest rate volatility being transmitted further along the yield curve.

The spread between the shortest market rate of interest and the rate at which liquidity is provided to the market should be lower when interest rate expectations (within a given reserves maintenance period) are static (ie no rate change expected) than in a situation where expectations affect banks' demand for liquidity. Yet, whereas the effect of the March 2004 reforms (after which the ECB rates are constant within any given reserve maintenance period) on the volatility of the EONIA spread seems to have been significant, the average spread does not seem to have reduced significantly. Without questioning the success of the reforms, the main focus of this paper will be in the factors behind the level of the spread; ie we want to understand why (contrary to the theoretical expectations) the average EONIA spread has not diminished after the adjustments. Special attention is paid to the analysis of the difference between the effective price of liquidity in the central bank operations and

[1] This view can be deducted eg from the first ECB annual report, which tells that the ECB oriented its allotment decisions towards ensuring an average interbank overnight rate close to the tender rate (ECB, 1999). Similar message is restated in several publications since then.

[2] EONIA (Euro Overnight Index Average) is an index that represents the weighted average of overnight borrowing in euros. Henceforth, the difference between EONIA and the main refinancing rate that is used to signal the ECB monetary policy stance (either the fixed tender rate or the minimum bid rate) will be called EONIA spread.

[3] Banks in euro area are required to hold compulsory deposits with the Eurosystem (minimum reserve requirement). The holding of the required reserves is based on averaging. That is, compliance with the requirement is determined on the basis of the average of the daily balances on a bank's account over a reserve maintenance period.

[4] The first major reform to the ECB operational framework took place in June 2000, when the ECB switched from conducting the MROs as fixed rate tenders to applying a variable rate tender procedure.

the policy rate. That is, why banks bid at rates above the policy rate (the minimum bid rate) in the MROs?[5]

According to the ECB benchmark liquidity policy rule[6], the liquidity provision in the MROs is not rationed below the level of liquidity banks need to comply with their reserve requirements. Hence, in the absence of interest rate expectations, there is no obvious reason for a risk neutral bank to bid the price of liquidity in the MROs up from the minimum bid rate. Yet, in 2005 the average marginal MRO rate[7] was 5 basis points above the minimum bid rate, and the average rate of successful bids was 1 basis point further above the marginal MRO rate. That is, the spread between the marginal MRO rate and the minimum bid rate was higher than on any other single year between 2001–2004. The annual cost to the banking sector from the higher bid rates amounted to some EUR 100 million in 2005. Moreover, the tender spread seems not to be shrinking, as the average spread stood at 6.7 basis points during the first 5 months of 2006.

This study falls into the rapidly growing literature on the ECB monetary policy implementation, as it touches the neutrality of the ECB liquidity policy, and the bid behaviour of the banks. The ECB liquidity policy is also analyzed eg in Ayuso and Repullo (2003), Bindseil (2002), and Välimäki (2001, 2002a and 2002b).[8] Ayuso and Repullo argue that the ECB liquidity policy is asymmetric so that the ECB prefers to see market rates deviating upwards from the policy rate rather than downwards. Due to this asymmetry, there is a positive spread between the market rate of interest and the policy rate. However, besides central bank's potential appetite for high interest rates, tight liquidity conditions can result also from a combination of quantity oriented liquidity policy and banks interest rate expectations, as shown in Bindseil (2002) and Välimäki (2001 and 2002a). This paper will go one step further by showing that the liquidity conditions may appear tight even under static interest rate expectations, if the benchmark policy is quantity oriented and the money market is not fully efficient.

The basic logic behind our argument is the following. In ECB tenders, the bids are pro rata rationed at the marginal rate (as long as the total

[5] Minimum bid rate is the reserve price for liquidity in the ECB MROs. When the ECB switched from fixed rate tenders into variable rate tender procedure in June 2000, the minimum bid rate replaced the fixed rate as the key policy rate used by the ECB to signall the monetary policy stance (ECB, 2000b). In each of the interest rate setting meetings, the Governing Council sets the minimum bid rate which will be subsequently applied in the MROs until the next interest rate meeting.

[6] See ECB (2002) for a detailed description on the derivation of the benchmark allotment volume.

[7] Marginal MRO rate is the lowest rate at which bids are accepted in the ECB variable rate tender operations. Whereas all bids at rates above the marginal rate are accepted in full, the bids at marginal rate are normally pro-rata rationed according to the ECB target liquidity provision.

[8] In addition to these papers, questions related to the monetary policy framework of the Eurosystem, and the ECB's liquidity management style are analyzed eg in Ejerskov, Moss & Stracca (2003), Ewerhart (2003), Ewerhart et al (2004) and Moschitz (2004). Furthermore, Würtz (2003) presents a comprehensive EONIA model. Banks bidding in the ECB operation has been studied empirically eg in Scalia and Ordine (2005), Nyborg et al (2002) and Linzert et al (2004).

bid volume exceeds the central bank's intended allotment volume). The forthcoming percentage of allotment at the marginal rate is stochastic to the banks, as a bank does not know the bid volume from the rest of the banks when placing its own bid. Hence, the bank may be willing to secure its share of the MRO allotment by bidding at a rate higher than the expected marginal rate. If most banks want to pay this kind of an 'insurance fee' to secure their allotments, the weighted average rate of the accepted bids as well as the marginal MRO rate may turn out to be higher than the minimum bid rate. Furthermore, in the absence of a natural focal point for expectations over the forthcoming percentage of allotment at the marginal rate, banks may have adaptive expectations. Consequently, the allotment uncertainty may result in a dynamic path, where the marginal rate keeps drifting up from one operation to another. Moreover, it will be shown that the incentives to bid at rates above the expected marginal MRO rate depend on the allotment volumes; banks will bid the more at high rates, the larger the MRO volumes. So, the evidenced growth in the average tender spread in the Eurosystem MROs may be related to the rapid expansion in the average size of the individual operations experienced since 2002.

The rest of this paper is structured as follows. First, we briefly review the link between the ECB policy rate and the shortest euro market rates. Section 2 starts by presenting some stylized facts on the EONIA spread, after which the focus is geared to the differences between the effective price for liquidity in the MROs and the policy rate. In section 3, a simple model on the banks bidding behaviour in the ECB variable rate tenders will be developed, and the evolution of the shortest euro interest rates will be assessed against it in section 4. Finally, conclusions are presented in section 5.

1.1 Link between policy rate and the overnight rate

In the ECB monetary policy operational framework, the link between the policy rate (currently *the minimum bid rate*) and the overnight interbank rate can be presented as follows. Banks operate in a liquidity deficit vis-a-vis the Eurosystem (ECB and the national central banks of euro area). Basically this means that the sum of the outstanding volume of banknotes and the minimum reserve requirements is larger than the investment assets (including foreign reserves) held by the Eurosystem. Thus, the banking sector needs to get refinancing from the ECB, that fulfils this need by providing liquidity through MROs according to its *estimate* on the liquidity shortage. If the supply falls below banks' actual liquidity need, they need to obtain the missing liquidity from the marginal lending facility. On the other hand, when the liquidity supply is abundant (relative to the actual need), banks need to use the deposit facility to collect income for their central bank balances exceeding the reserve requirements. Therefore, the two standing facility rates (*marginal lending rate* and *deposit rate*) provide the interbank market with a corridor, in which the overnight interest rate may fluctuate.[9] Moreover, the expected value of the shortest market interest rate can be derived as a probability weighted average of the standing facility rates, and hence, it is decreasing in liquidity.

In this paper, we define *neutral liquidity* as the amount of liquidity at which the market rate[10] equals the policy rate. Similarly, the volume of the central bank liquidity provision at which the expected market rate equals the policy rate will be called *neutral allotment*.

A single bank may obtain liquidity from the central bank tender operation or the interbank market. It's not feasible to participate in the tender, if the expected market rate is below the policy rate. Hence, the liquidity supply cannot (continuously) exceed the neutral allotments, and the expected market rate cannot fall below the policy rate. If this kind of a 'loose liquidity policy' was pursued, banks' expected aggregate bid volume would equal the neutral allotment volume, and the central bank would not be able to allot liquidity according to its preferences. In the ECB context, this phenomenon has been labelled *underbidding*. On the contrary, the central bank can restrict the liquidity supply below the neutral allotment. If 'tight liquidity policy' was followed, the expected market rate would be higher than the policy rate. This spread would give incentives for the banks to compete over the central bank liquidity provision, and the marginal MRO rate would increase accordingly, if the MRO's were conducted as variable rate tenders. Between Jan 1999 and Jun 2000 the ECB applied fixed rate tender procedure in the main refinancing operations. Tight liquidity provisions together with fixed rate tenders would result in banks bidding extensively for more liquidity than they need to comply with the minimum reserve requirements. In the literature on the ECB monetary policy implementation, bid volumes exceeding the neutral allotments has been called *overbidding*.

The ECB's benchmark allotment in the last MRO of each reserve maintenance period aims at providing the market with liquidity that minimizes the expected use of the standing facilities (ECB, 2002). This allotment should result in the expected market rate equalling the policy rate (ie benchmark allotment should be neutral), as long as the interest rate corridor is symmetric about the policy rate, the liquidity shock distribution is symmetric[11], and the money market is efficient. In the earlier operations, the ECB aims at a stable path for banks' liquidity holdings within the maintenance period. That is, it adjusts the supply to forecasted liquidity changes until the following

[9] Marginal lending facility is one of the two standing facilities provided to the banks by the ECB. Banks can borrow overnight liquidity from the marginal lending facility against adequate collateral at a predefined rate. In addition to the marginal lending facility, eurosystem provides the banks with a deposit facility. That is, banks may place overnight deposits with the eurosystem at a predefined rate. Thus, the two standing facility rates (marginal lending rate which is set above the policy rate and deposit rate which is set below it) create a corridor for the overnight market rate. Furthermore, the standing facility rates are typically set symmetrically around the ECB policy rate (see Figure 1).

[10] The market rate needs to have similar characteristics to the policy rate. E.g. they must have equal maturities and be based on similar collateralization. In practise, this kind of a market rate may not exist, so one may need to derive it by adjusting an excisting rate with the effects of the differencies in the characteristics of the actual rates.

[11] On the asymmetric liquidity shock distributions and the symmetry of the interest rate corridor about the policy rate, see Välimäki (2000).

operation and to the effect of past liquidity shocks (ie liquidity forecast errors). Therefore, although the determination of the benchmark allotment volume is quantity oriented, it is likely to produce neutral allotments, if banks' interest rate expectations (over the ECB rates) are static (ie no change expected) within the reserves maintenance period and the secondary market for reserves is efficient. However, with the benchmark allotment rule, the expected market rate on any day of the maintenance period will equal the mid-point of the interest rate corridor expected to prevail at the end of the reserve maintenance period (ie the martingale hypothesis holds[12]). Hence, if a rate cut (hike) is expected within the same reserves maintenance period, the banks prefer to backload (frontload) their reserve holdings until the policy rate is changed. In such occasions, the ECB benchmark allotment volumes are not neutral, and underbidding will occur, when banks are expecting a rate cut, while rate hike expectations result in overbidding.

2 Stylized facts from ECB operations

In this section we recall some stylized facts from the shortest interest rates and the main refinancing operations in the euro area. The EONIA, the standing facility rates and the MRO policy rate are shown in Figure 1. The figure indicates that there are regular spikes in EONIA. Yet, these end of reserve maintenance period (off-the-target) deviations are common to all operational frameworks with reserves averaging provision.[13] Secondly, the market rate seems to have followed the policy rate rather closely. On average the difference between EONIA and the policy rate (EONIA spread) has been 6.7 bps (1.1.1999–31.12.2005).

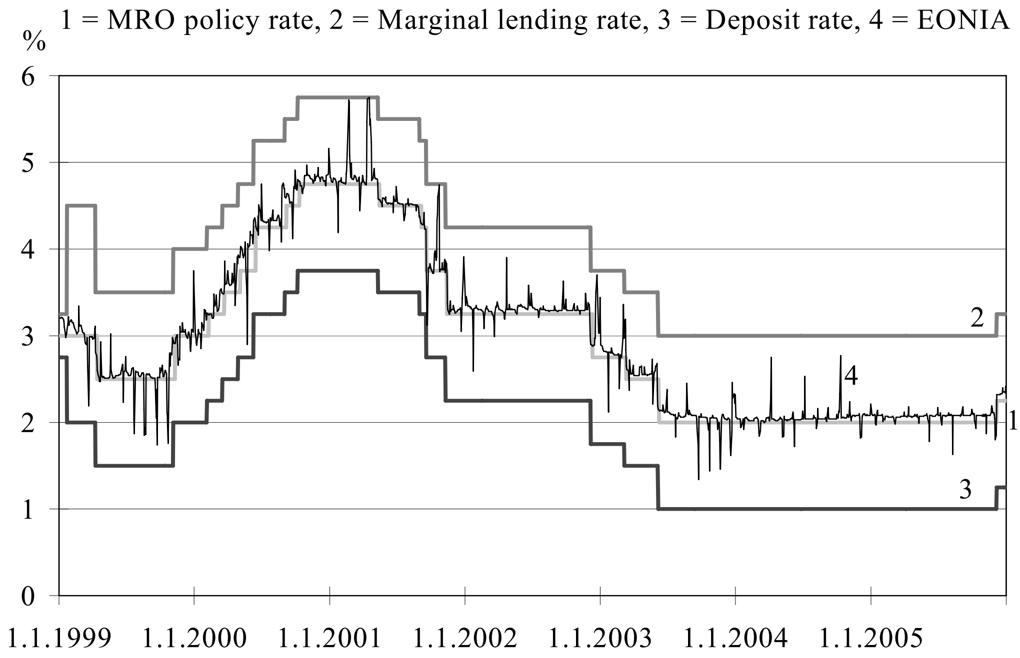
There are several factors for which the average EONIA differs from the policy rate. Some of these factors are closely related to market features. For example, whereas EONIA is based on unsecured lending, the ECB liquidity provision is based on full collateralization. Hence, when comparing these rates, one needs to adjust the EONIA by a relevant risk premium. Furthermore, whereas the maturity of EONIA is overnight, the maturity of the MROs has been one or two weeks.[14] Thus, EONIA should be slightly lower than the MRO rate, for their effective rates to equal. Yet, with the current (low) level of interest rates, the magnitude of this effect is well below one basis point. Besides these market related features, a positive average EONIA spread can

[12] According to the martingale hypothesis, any differences in the expected overnight rate during a given reserve maintenance period should be arbitraged away from the market (see eg Hamilton, 1996).

[13] This results from the fact that, on the last day of a maintenance period the reserve need is fixed (ie averaging provision does not reduce the interest rate elasticity on the final day). In the Eurosystem case, the end-of-period interest rate volatility usually picks up already a couple of days before the final day, which mainly reflects the fact that until the end of 2004 the ECB normally provided the market with liquidity only from its regular (weekly and monthly) open market operations. Nowadays, the ECB tends to neutralise signifficant liquidity shocks with final day fine-tuning operations (see ECB, 2005).

[14] The maturity usually applied in the main refinancing operations was cut from two weeks down to a week in March 2004.

Figure 1: ECB rates and EONIA between 1.1.1999 and 31.12.2005



Source: Bank of Finland

result from issues that are more related to monetary policy. For example, banks' expectation over a rate change within the on going reserve maintenance period results in a positive spread between the market rate and the policy rate (as long as the benchmark allotment policy is followed).[15] Moreover, the benchmark allotment volumes might be below the neutral liquidity supply for other (than interest rate expectations) reasons. The list of such factors includes market imperfections and asymmetries in the liquidity shock distributions (see Section 1.1).

To analyze the factors affecting the EONIA spread, we divide the total period (presented in Figure 1) in three sub-periods, reflecting the two major adjustments in the ECB operational framework. The ECB liquidity policy applied during the first period (Jan 1999-Jun 2000), was characterized by

[15] When banks' are expecting the central bank rates to be cut during the reminder of a reserve maintenance period, they want to backload their reserve holding within the period. Hence, the central bank would not be able to allot according to its benchmark rule prior to the rate change. In such a case, underbidding would prevent the market rates from falling below the current (ie pre cut) policy rate. Furthermore, it can be shown that with overlapping operations, the equilibrium expected market rate would be above the current policy rate, if a rate cut were expected (see Välimäki, 2002b). On the contrary, if the banks were expecting the central bank to rise its rates before the end of the period, they would want to frontload their liquidity holdings. However, the benchmark liquidity policy would not allow the banking sector as a whole to frontload their liquidity holdings, and hence, the market rate would reflect the end-of-period interest rate expectations already as soon as the expectations pick up.

three key features: i) MROs were conducted as fixed rate tenders[16], ii) the benchmark allotment rule aimed at stable liquidity holdings within the maintenance periods and minimizing the use of the standing facilities,[17] and iii) the policy rates could be (and were) changed within the maintenance periods.

After a period of severe overbidding, the ECB switched from fixed rate tender procedure into variable rate MROs (ECB, 2000b). In the variable rate MROs, ECB applies a reserve price for liquidity (the minimum bid rate), which is currently also the key policy rate. The second period starts from the first MRO in which the new procedure was applied (23 June 2000).

The third sub-period begins from the latest changes into the ECB operational framework in March 2004. On that occasion, the timing of the reserve maintenance periods was adjusted so that, now the change of the periods always takes place on the settlement day of the first MRO after the ECB Governing Council's meeting where the interest rate decision is taken. *This means that, as a rule, the policy rates are kept unchanged within the reserve maintenance periods.* Yet, this change also prolonged the lag between the last MRO allotment and the end of a reserve maintenance period from an average of 5 days into 8 days. Hence, the accuracy of the liquidity supply diminished with the changes. However, to counter the growth in the liquidity uncertainty, the ECB has started to fine-tune regularly the end-of-period liquidity imbalances.[18] Furthermore, the maturity of the MROs was cut from fortnight into one week. Therefore, the consecutive (weekly) operations are not overlapping any more. Finally, the benchmark rule for liquidity supply has survived through all the changes in the operational framework.

Whereas the June 2000 changes were aimed at affecting the banks' bid behaviour, the March 2004 modification was expected also to affect the evolution of the spread between the market rate and the policy rate. Before March 2004, banks' liquidity demand was heavily affected by their interest rate expectations. Hence, both the average EONIA spread and its standard deviation should have reduced after the Eurosystem moved into a framework with constant interest rates (within RMPs). The volatility of the EONIA spread seems to have declined quite remarkably since the latest changes (standard deviation of the spread during the three sub-periods was 20.2, 16.2 and 7.5), but the average spread does not seem to differ significantly between the three sub-periods (7.2, 6.7 and 6.4 bps). Moreover, one should bear in mind that especially during the first period, the ECB changed the rates very frequently, while the policy rate was kept unchanged between June 2002 – December 2005.

To get a better idea about the relative contributions of different sources to the EONIA spread, we divide the spread in two parts for the 2nd and 3rd sub-periods. The first part, the *tender spread,* is the difference between the

[16] In a fixed rate tender, each bank tells the central bank how much liquidity it is willing to borrow at the pre defined tender rate. When the cumulative bid amount exceeds the allotment volume, the central bank allots each bank only a proportion of its bid (ie pro-rata rationing is applied).

[17] The ECB benchmark allotment rule is explained in detail in ECB (2002).

[18] See ECB (2005b) for reference.

marginal MRO rate and the minimum bid rate.[19] A positive tender spread means that the effective price of central bank liquidity provision differs from the policy rate. This indicates that there are policy related factors behind the EONIA spread, as with static interest rate expectations, neutral liquidity policy, efficient markets and risk neutral banks the tender spread should be zero. So, a non-zero tender spread hints that the benchmark allotment are below the neutral amount either due to banks interest rate expectations, central bank's deliberate policy decision to leave the market tight, or as a result of some kind of market imperfections[20].

The second part of the EONIA spread, the *market spread*, is the difference between EONIA and the marginal MRO rate. It is related to the above mentioned 'natural' differences between the interest rates (differences in maturities and collateralization, day of the week/month/year effects etc.), or to stochastic changes in liquidity conditions after the final allotment decision is taken. Some factors behind the market spread are rather stable (eg maturity and collateral related differences), while other factors are extremely volatile (eg end-of-period spikes). Yet, the volatile ones affect the rates only for a few days. Hence, they are not expected to spill over to the longer interest rate periods. Therefore, the rest of the paper is mainly concerned about the factors behind the tender spread.

2.1 Tender spread

The tender spread from the ECB MROs is illustrated in Figure 2. Although the average tender spread has been only slightly lower after the changes in the operational framework in march 2004 (3.7 bps vs. 4.2 bps), it is obvious that the behaviour of the spread within these two sub-periods is very dissimilar. This can be confirmed by looking at the annual averages of the spread and its annual standard deviations (Figure 3). Whereas the average spread in 2005 was wider than on any single year between 2001–2004, its standard deviation has diminished from one year to another, reaching only 1bps in 2005. Moreover, the high average tender spread recorded in 2005 does not seem to be an exception, as during the first 5 months of 2006 the spread has averaged at 6.7 basis points.

It seems that the changes in the ECB operational framework have been able to produce stability into the difference between the effective price for ECB reserves and the policy steering rate, even if it has not significantly reduced the spread. Considering the central bank's ability to signal its monetary policy stance, the stability of this spread is probably more important than its width. If the spread was constant, it would be easy to take it into account when deciding on the appropriate level of the policy rate. Yet, it is important to understand the factors behind the level of the tender spread, as it is a key for understanding the evolution of the spread. For example, the tender spread stood unchanged at 0 bps for almost 5 consecutive months in the first half of

[19] We leave the 1st sub-period out of the analysis, as the tender spread is not a meaningful concept under the fixed rate tender procedure.

[20] For example, banks' risk aversion can lead to a positive tender spread, if they are linked with market frictions.

Figure 2: Tender spread (ie the spread between the marginal MRO rate and the minimum bid rate) 2000–2005

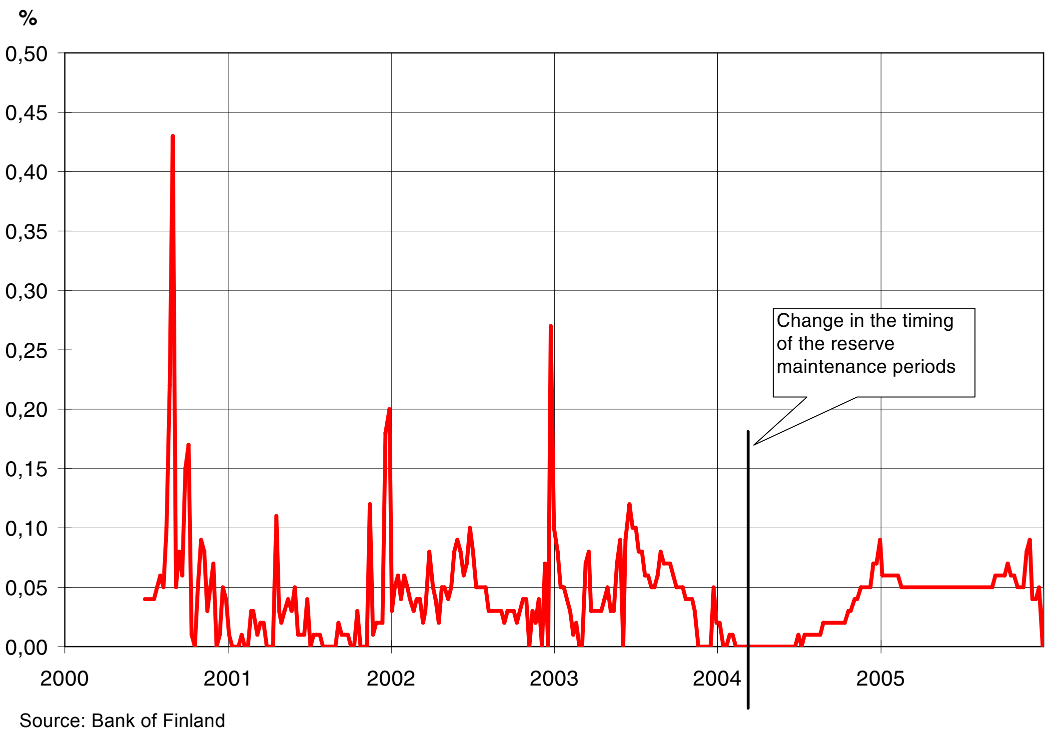
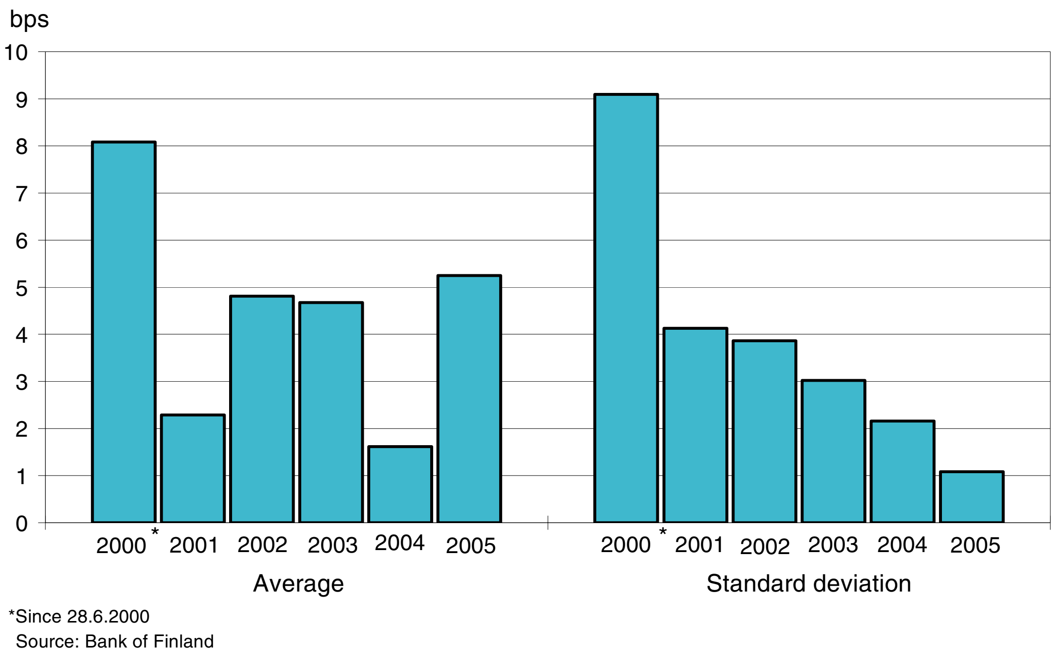


Figure 3: Average annual tender spread and its volatility



2004, and at 5 bps for another seven months in early 2005. However, in the 6 months in between these two periods, the tender spread rose rather steadily by 9 basis points (from 0 to 9 bps).

The next section analyses the determinants of the spread, by building a stylized model of the ECB operational framework, and the banks' bid behaviour in the MROs.

3 Model of bidding in the MROs

Like in the case of the Eurosystem, the model banking sector (that consists of n banks) operates in a liquidity deficit vis-a-vis the central bank (CB). Banks are also subject to a reserve requirement, and the reserve holding is based on an averaging provision. The banking sector can obtain liquidity (ie CB reserves) via two channels; either from a tender operation or from the marginal lending facility. The price for reserves in a tender is determined by the banks' bid rates. Yet, the CB applies a reserve price (minimum bid rate, r^{MBR}) in these operations. This rate functions as the main tool for signalling the monetary policy stance. The ex ante defined *marginal lending rate* is the cost of obtaining reserves from the marginal lending facility. In addition to these two liquidity providing mechanism, banks have an access to a deposit facility, in which they can place overnight funds at a predetermined rate (*deposit rate*). All the CB rates are kept constant within a reserve maintenance period (RMP).

The CB is assumed to apply a quantity oriented liquidity policy, that aims at minimizing the use of the standing facilities. That is, in the last tender operation (MRO) of a given RMP, the CB aims at providing the banks with precisely the liquidity it forecasts they need to comply with the reserve requirements. In the earlier operations, the CB aims at stable liquidity conditions within the RMP. The CB's target liquidity provision is denoted by (d).

The exact evolution of some autonomous liquidity factors between the last MRO allotment and the end of the RMP, is uncertain when the allotment decision is taken. The liquidity forecast errors (*liquidity shocks*) result in end-of-period liquidity imbalances, which banks will counter by using one of the two standing facilities. Moreover, we assume the level of required reserves to be high enough that, with the CB's target liquidity, the banking sector (as a whole) does not need to rely on the standing facilities before the last day of a RMP. That is, the reserve requirements are calibrated so that they exceed the cumulative effect of the liquidity shocks between two MROs.

The (interbank) overnight rate (r) is given as a probability weighted average of the standing facility rates, and thus, it is a decreasing function of liquidity after the final tender operation for a given RMP.[21] Prior to the last liquidity

[21] After liquidity providing shocks, the banks will use the deposit facility to collect income for the otherwise unremunerated excess reserves. Accordingly, the overnight market rate will drop down to the level of the deposit rate. On the other hand, after liquidity draining shocks, banks need to fill the negative liquidity imbalance by borrowing from the marginal lending facility, and the overnight market rate will rise up to the marginal lending rate.

allotment, the expected net imbalance on the final day of the RMP is zero, as the CB liquidity provision is unbiased. Hence, on any day before the final MRO (which takes place a week before the end of the RMP), the expected final day overnight rate should equal the mid-point of the interest rate corridor (as long as the interbank market is efficient and the liquidity shocks are symmetrically distributed). According to the martingale hypothesis, this expectation should hold also for the expected market rate on the earlier days ($\mathrm{E}_1[r_1] = \mathrm{E}_1[r_2] = \ldots = \mathrm{E}_1[r_T] = \mathrm{E}_1\left[r_T^{MBR}\right] = r_t^{MBR} \equiv$ policy rate).

3.1 Bidding in the tenders

A single bank can acquire reserves either directly from the CB, or it can borrow liquidity from the other banks through the interbank market. Yet, only liquidity that originates from the CB increases the aggregate money market liquidity. Let l_i denote the amount of reserves bank i aims at holding at the end of the day. This target amount is a decreasing function of the market rate of interest ($\partial l_i(r)/\partial(r) < 0$).[22] As the interbank market must clear, the banks need to be willing to hold the total money market liquidity at the equilibrium market rate.

The CB operations are conducted before the interbank market closes. Hence, the amount bank i borrows from or lends to the interbank market, is given by $l_i - q_i$, where q_i is the bank's allotment from the tender. That is, if the allotment for the bank is smaller (larger) than its target liquidity need, it will borrow the missing liquidity from (lend the excess liquidity to) the market.[23]

There are several elements a bank needs to take into account when preparing its bids for a CB operation. The main objective for the bank is to minimize the cost of holding liquidity throughout the RMP. To do this, the bank is allowed to leave in each operation a bid array that may consist of up to three price-quantity pairs.

The lowest rate at which bids are accepted is called the *marginal MRO rate* (r^m). Bank i's bid volume at this rate is denoted by b_i^m, while b_i^+ (b_i^-) denotes its bid volume at rates above (below) the marginal rate. Similarly, the banking sector wide aggregate bids are denoted by b^m, b^+, and b^-. The cumulative bid at a given rate or at rates above it is denoted by $B_i^{\text{interest rate}}$ (eg $B_i^m = b_i^+ + b_i^m$) and its banking sector wide counterpart is again given by $B^{\text{interest rate}}$ (eg $B^m = b^+ + b^m$). So, B^{MBR} (where MBR stands for minimum

[22] The private value of l_i to bank i is given as the probability weighted average of the standing facility rates and the market rate. When l_i increases, it's less probable that the bank needs to use the marginal lending facility, while the probability of using the deposit facility increases. Hence, the marginal value of l_i is decreasing with the liquidity. As bank i can lend and borrow liquidity at the interbank market, the marginal value of l_i needs to equal the market rate.

[23] To ease the notation, we have implicitly assumed (without any losses to the generality of the results) the banks' initial liquidity positions (before the CB allotments) to equal zero. That is, on average the aggregate target refinancing needs equal the reserve requirements.

bid rate) gives the total bids in an operation, as r^{MBR} is the lowest rate at which any bank is allowed to bid.

The market liquidity is given by min $\left[d, B^{MBR}\right]$. That is, the CB can meet its target liquidity provision as long as the total bid volume is sufficient to cover it. Therefore, either the bid volume at the marginal MRO rate satisfies $b^{+} < d \leq B^{m} \leq B^{MBR}$, or the CB cannot allot according to its preferences (ie *underbidding* occurs, when $d > B^{MBR}$). That is, when the market rate with the CB's target liquidity would be below the minimum bid rate ($r^{MBR} > r(d)$), banks underbid the MRO, as it would not pay for them to participate in an operation, if the expected price for liquidity was lower at the secondary market. With unbiased quantity oriented liquidity policy, underbidding occurs when the banks want to backload their reserve holdings. The incentives for backloading are obvious when the CB is expected to cut the rates within the ongoing RMP, but with static expectations the reasons for underbidding as an equilibrium outcome are not obvious.

Let q_i^m, q_i^+ and q_i^- denote for bank i's allotment for a bid at the marginal MRO rate, at rates above it (r^+), or below it (r^-). If the operation was underbid ($B^{MBR} < d$), all bids would be accepted in full ($q_i = b_i$). When $B^{MBR} \geq d$, bids at r^+ are fully successful ($q_i^+ = b_i^+$), bids at r^- are ineffective ($q_i^- = 0$), and bids at r^m are pro rata rationed ($q_i^m = \left(d - b^+\right)/b^m b_i^m$).

Bank i's cost minimizing problem is given by equation (3.1)

$$
\begin{aligned}
\min_{\overline{b_i}} \Pi_i &= \left(q_i^+ r_i^+ + q_i^m r_i^{r^m}\right) + \left(l_i - q_i\right) r + c_i \left(l_i - q_i\right)^2 \qquad (3.1)\\
\text{s.t. } q_i^+ &= b_i^+,\ q_i^m = \min\left[1, \left(d - b^+\right)/b^m\right] b_i^m, q_i^- = 0 \text{ and } b_i^+, b_i^m, b_i^- \geq 0.
\end{aligned}
$$

The first term in the minimization problem is the direct cost bank i faces for participating in an MRO. The second term represents the (common) cost/revenue from interbank trading, while the final term is the bank's private cost of deviating from the target liquidity. This component reflects the fact that having to rely on the interbank market may be costly to (some) banks. The private costs may (in ECB MROs) originate eg from risk aversion, market frictions or capital adequacy requirements. First, risk averse banks could prefer low exposure to the interbank markets, even if the expected market rate equalled the policy rate, as the market rate varies around the policy rate. This holds specially for the last operation of a RMP. Second, credit lines may limit some banks' capability to trade extensively at the interbank market. Third, the range of eligible collateral in the ECB operation is wider than that of general collateral repo market. So, banks that are constrained by their collateral possessions, may prefer receiving liquidity directly from the CB to using the collateralized interbank markets. Fourth, some banks may want to try to limit their need for interbank trading due to capital adequacy reasons. The individual weighting parameter for the private costs is assumed to be positive, and will be denoted by c_i. A quadratic form is chosen for the private cost component to reflect the idea that the banks have a target for CB allotments. By this construction, banks suffer not only from receiving too little CB liquidity, but they can also be allotted with too much. The symmetric treatment of liquidity deviations (off the target) can be justified especially, when the main factor behind the private value for allotments is risk aversion. Alternatively, one could have formulated the private cost component so that it would punish the banks only for being allotted less than their target liquidity. We opted for modelling the banks with target allotments instead of having merely minimum levels for their allotments, as we believe that the risk aversion is the main factor for the private cost component, as well as we want to find out whether a symmetric target for allotment volumes would be a sufficient condition for a tender spread to emerge.[24] Finally, the bank optimizes over its bid array ($\overline{b_i} = \left[b_i^+, b_i^m, b_i^-\right]$), and the optimization problem is subjected to the allotment rules followed in the MRO.

Inserting the allotment rules directly to minimization problem yields

$$\begin{aligned}\min_{\overline{b_i}} \Pi_i &= \left(Ab_i^m + b_i^+\right)(r^m - r) + b_i^+(r_i^+ - r^m) + l_i r \\ &\quad + c_i \left(l_i - b_i^+ - Ab_i^m\right)^2 \\ &\quad \text{s.t. } b_i^+, b_i^m \geq 0,\end{aligned} \tag{3.2}$$

where A stands for the allotment ratio at the marginal MRO rate ($A = \min\left[1, (d - b^+)/b^m\right]$). This ratio is 1, if the operation is underbid, and $(d - b^+)/b^m$ otherwise. Bank i's total allotment q_i is given by $Ab_i^m + b_i^+$.

Bids at rates below the marginal rate are ineffective. Hence, any bid at these rates can be regarded as optimal, as long as bidding is costless. However, if there were even an arbitrarily small cost of bidding, the bid volume at rates below marginal rate would be zero.

Let us next analyze the banks' optimal bid volumes and rates. We start the analysis from the simplest case, where we assume that banks have full information on the central bank preferences and the bid behaviour of each other.

3.2 Full information: bidding under certainty

Proposition 3.1 *Under full information, it is optimal for banks to place bids only at the marginal rate.*

Proof. An extra unit allotted to bank i yields the market rate of interest r, but the marginal cost from it depends both on the bid rate(s) and the distance from the target liquidity. The (net) marginal cost of one additional unit of bid at r_i^+ is $(r_i^+ - r) - 2c(l_i - q_i)$, while it's $[(r^m - r) - 2c(l_i - q_i)](A + b_i^m \partial A/\partial b_i^m)$ for one additional unit of bid at r^m. By substituting a bid of $1/(A + b_i^m \partial A/\partial b_i^m)$ units at r^m for a bid for one unit at r_i^+, bank i substitutes a unit of q_i^m for a unit of q_i^+. Such a substitution would decrease the net cost the bank faces by $r_i^+ - r^m$, and as $r_{i,j}^+ > r^m$, it's optimal for the bank to continue the substitution until $b_i^+ = 0$. ■

[24] Note that, a tender spread is more likely to emerge, if the banks have only minimum allotment volumes instead of target levels, as the optimal bid in the first case needs to be at least as large as with symmetric targets. This will be obvious based on the analysis in the next section.

Proposition 3.2 *Under full information, the equilibrium bid volume for bank i equals its target liquidity times the allotment ratio. Furthermore, the marginal MRO rate equals the expected market rate.*

Proof. The analysis on bank i's optimal bid is divided in three possibilities: i) the bid volume from the other (than bank i) banks is larger than the central bank's target provision ($d \leq B^m_{-i}$)[25], ii) bank i's bid prevents the operation from being underbid ($d \leq B^m_{-i}+b^{m*}_i$), and iii) the operation is underbid ($d \leq B^{MBR}$).

1) Assume first that the CB can allot according to its preferences even without bank i participating in the operation. In this case, bank i's bid would not affect the market rate ($\partial r(d)/\partial b^m_i = 0$ if $d \leq B^m_{-i}$). The optimal bid for bank i is given as the FOC of equation (3.2) w.r.t. b^m_i. Remembering, that it's not optimal to bid at r^+, and that the bids at rates below the marginal rate are ineffective, we get the following optimal condition

$$b^*_i = \begin{cases} b^{+\,*}_i = 0, \text{ for all } r^T_{i,j} \in 1, ..., r^{m+1} \\ b^m_i = \frac{l_i}{A} + \frac{r-r^m}{2c_iA} \\ b^{-\,*}_i \in [0, \infty[\text{ for } r^-_i \end{cases}. \tag{3.3}$$

Based on equation (3.3), bank i's desired allotment ($q^*_i = Ab^{m\,*}_i$) is $l_i + (r - r^m)/2c_i$. If the expected market rate is higher than the marginal rate ($r > r^m$), then $q^*_i > l_i$, ie the bank is aiming to be a net lender (borrower) of liquidity at the interbank market in order to profit from the expected positive (negative) spread between the market rate and the marginal MRO rate. However, as this optimality condition holds for all banks (independent of c_i or l_i), this cannot constitute a sustainable equilibrium. In equilibrium, the banks as an aggregate must be willing to hold the total money market liquidity. So, without underbidding there is a unique equilibrium in which the banks bid for their target liquidity at the marginal rate ($r = r^m$ and $b^{m\,*}_i = l_i/A$).

2) Assume next that the operation is not underbid as a result of bank i's bid ($d \leq B^m_{-i} + b^{m*}_i$). Also in this case, r^m is not affected by a marginal change in bank i's bid, and the equilibrium conditions for this case would be similar that of $d \leq B^m_{-i}$.

3) The third possibility is that the operation is underbid. Here, we have $\partial r/\partial b^m_i < 0$, as $q_i = b^m_i$ (ie $\partial q_i/\partial b^m_i = 1$) and $\partial r/\partial l < 0$. Furthermore, any feasible bid would be accepted in full in an underbid operation, and hence the equation (3.1) can be written as

$$\begin{aligned} \min_{b_{i,r^{MBR}}} \Pi_i &= b^{r^{MBR}}_i r^{MBR} + \left(l_i - b^{r^{MBR}}_i\right) r + c_i \left(l_i - b^{r^{MBR}}_i\right)^2 \\ \text{s.t. } b^{r^{MBR}}_i &\geq 0, \end{aligned} \tag{3.4}$$

and the FOC becomes

$$\left(r^{MBR} + r\right) + \left[2c_i \left(\frac{\partial l_i}{\partial b_i} - 1\right) + \frac{\partial r}{\partial b^*_i}\right] (l_i - b^*_i) = 0. \tag{3.5}$$

[25] B^m_{-i} is the cumulative aggregate bid volume at rates above or equal to the marginal rate from all banks but bank i, ie $B^m - b^+_i - b^m_i$.

As $2c_i \left(\partial l_i / \partial b_i - 1\right) + \partial r / \partial b_i^* < 0$, this holds only, if $sign\left(r^{MBR} + r\right) = sign\left(l_i - b_i^*\right)$. That is, the optimal bid for bank i equals its liquidity target, if the expected market rate (with the bid) equals the minimum bid rate. The bank would aim at being a lender (borrower) of liquidity at the interbank market, if the market rate is above (below) the tender rate. Yet again, it's not feasible for the rest of the banks to be net borrowers (lenders) at the interbank market, if the expected market rate is above the minimum bid rate and all bids are accepted in full. Hence, the only sustainable equilibrium with underbidding is such that all banks bid for their liquidity needs, and the expected market rate equals the minimum bid rate. ∎

Furthermore, if the CB targets neutral allotments, we have $r = r(d) = r^m = r^{MBR}$; ie the marginal rate equals the expected market rate, which also equals the policy rate. So, $b_i^{m*} = l_i / A$ and $r = r(d) = r^m = r^{MBR}$ hold under irrespective of whether the operation is underbid.

3.3 Allotment uncertainty

It was shown in Section 2 that, banks bid in the ECB main refinancing operations at rates above the monetary policy signalling rate, ie a non-zero tender spread has existed since mid 2004 even in the absence of expectations on interest rate changes within the reserve maintenance periods. Furthermore, the bids seem to concentrate at rates close to the marginal MRO rate, but yet, the weighted average rate of the accepted bids has always exceeded it.[26] This means that, although the benchmark allotment policy aims at neutral liquidity conditions, the effective price for liquidity is normally higher than the policy rate, and the banks do bid at different or multiple rates.

The positive tender spread could result from the benchmark allotment rule providing the markets with less than neutral allotment volumes. That is, the effective price for liquidity would (by definition) be above the policy rate, if the CB liquidity policy was intentionally tighter than neutral. Yet, the benchmark allotment rule used by the ECB aims at providing the market with more liquidity than what is strictly needed for the fulfilment of the reserve requirements.[27] Hence, the liquidity policy applied by the ECB does not seem to be intentionally tight. Furthermore, the average actual liquidity provisions have not been tight, when compared to the benchmark policy. The average net use of the standing facilities on the last days of the RMPs is on the deposit facility.[28] That is, banks have deposited more liquidity to the deposit facility than acquired liquidity from the marginal lending facility. Finally, whereas

[26] The average spread between the weighted average of the accepted bids and the marginal MRO rate was some 0.9 basis points (March 2004 and December 2005). However, this spread was quite often recorded below 0.5 bps, and it exceeded 2 bps only in the last operations of 2004 and 2005.

[27] A small portion of the banks' liquidity holdings with the Eurosystem reserve accounts does not contribute to the actual reserve holdings (see eg Bindseil et al, 2003). This effect is taken into account in the determination of the benchmark allotment volume (ie the liquidity provision is increased accordingly).

[28] This will be shown below in section 4.1.

the tender spread could be explained by a tight liquidity policy, it would not explain the multiple bids from the banks or different banks bidding at different rates. For this end, we need to relax the assumption according to which the banks have full information set while they prepare their bids. This section tries to find out whether the observed tender spread could be explained by the uncertainty that result from this kind of incompleteness in the banks' information.

There are several potential sources for uncertainty when the banks prepare their bids. The most obvious one is that a single bank does not know the bids of the other banks while placing its own bids. Hence, the forthcoming allotment ratio (A) is a stochastic variable to the bank. This uncertainty could be resolved only by having a clear focal point to be used as a valid reference about the forthcoming A. So far, the allotment ratio at the marginal rate in the ECB main refinancing operations has fluctuated between 0.003 and 1, with an average of 0.56 and standard deviation of 0.30 (June 2000 December 2005).[29] This indicates that its hard for banks to find a good reference to be used in the bidding process. The only exceptions are the operations that were expected to be underbid.

With stochastic A, the cost minimization (or profit maximization) problem for bank i is no longer trivial. Bidding at the marginal rate is associated with allotment uncertainty, while bidding at one basis point above it (r^+) gives certainty over allotment. Hence, equation (3.2) becomes

$$\begin{aligned} \min_{\overline{b_i}} \mathrm{E}_i\left[\Pi_i\right] &= \left(\mathrm{E}_i\left[A\right] b_i^m + b_i^+\right)\left(r^m - r\right) + b_i^+(r^+ - r^m) + l_i r \qquad (3.6) \\ &\quad + c_i \mathrm{E}_i\left[\left(l_i - b_i^+ - A b_i^m\right)^2\right] \\ &\quad \text{s.t. } b_i^m \geq 0, \text{ and } b_i^+ \geq 0 \end{aligned}$$

Due to this uncertainty, either the private cost component will be positive ($\mathrm{E}_i\left[\left(l_i - b_i^+ - A b_i^{r^m}\right)^2\right] > 0$, if $b_i^m > 0$) or bank i pays a premium over r^m for its whole allotment. Hence, for a given q_i, the bank needs to trade-off the cost of bidding at r^+ with the benefits stemming from the certainty of allotment volumes for bids at higher rates. As $r^+ - r^m$ is (at least) one basis point, bank i increases its bid volume at r^+ from zero up to the amount at which the marginal benefit from the reduction (stemming from smaller b_i^m) in the allotment uncertainty no longer exceeds 0.0001.

Assume first that (as in case of complete information) the marginal rate equals the market rate with the allotment desired by the CB ($r^m = r(d)$). In this case, the cost minimization problem would reduce to

$$\begin{aligned} &\min_{\overline{b_i}} \left(0.0001 b_i^+ + c_i \mathrm{E}_i\left[\left(l_i - b_i^+ - A b_i^{r^m}\right)^2\right]\right), \qquad (3.7) \\ &\text{s.t. } b_i^m \geq 0, \text{ and } b_i^+ \geq 0 \end{aligned}$$

It's easy to see from equation (3.7) that, bank i's incentives to bid at rates above the marginal rate increase with the individual weighting parameter,

[29] During the fixed rate tenders this ratio varied between 0,008 and 1 (with average value at 0.08 and standard deviation of 0.12).

uncertainty related to the allotment volume at the marginal rate (denote this uncertainty by $\sigma_{A,i}$), and also with the bank's target liquidity ($\partial b_i^+/\partial c_i \geq 0, \partial b_i^+/\partial l_i \geq 0, \partial b_i^+/\partial \sigma_{A,i} \geq 0$).

The biggest difficulty in deriving banks optimal bid volumes in explicit from is that, it is far from trivial to model how banks form their expectations over the forthcoming A. Note that, $\partial q^m/\partial b^+ \leq 0$ and $\partial A/\partial b^m = -\left(d - b^+\right)/2(b^m)^2$. That is, an increase in the bid volume at rates above the marginal rate or at the marginal rate, will both result in a lower allotment ratio. Now, whereas b^+ must be related to the c_i:s, and l, the equilibrium bid volume at the marginal rate can be rather arbitrary. That is, let $k = 1/A$, based on proposition 2, the ex post optimal bid for a bank would be $b_i^m = k * l_i$ for any value of k. So, the more accurately bank i can anticipate the bid volumes from the rest of the banks, the narrower is the distribution of the forecasted values over the forthcoming allotment ratio, and hence, the less it will bid at the rates above the marginal rate (*ceteris paribus*).

To illustrate this, consider the following simple example with a mean preserving spread on a bank's subjective probability distribution on A. First, bank i assumes A to take either the value of 0.4 or 0.6 with equal probabilities. The optimal b_i^+ would be given by $\max\left[0, l_i - 0.0013/c_i\right]$, and $b_i^{m*} = 0.0025/c_i$. Then, if the bank's expectation over A was less accurate (larger $\sigma_{A,i}$), say $A = 0.25$ or 0.75 with equal probabilities, the optimal bid volumes would be $b_i^+ = \max\left[0, l_i - 0.00025/c_i\right]$, and $b_i^{m*} = 0.0004/c_i$. That is, bank i does not dare to rely so heavily on the bid at the marginal rate, when the (subjective) standard deviation of the expected allotments increases. Note also that, the probability of bank i bidding at b_i^+, as well as its bid volume at that rate increases with l_i.[30] Thus, *with the quantity oriented liquidity policy, the larger the banking sector's liquidity deficit vis-a-vis the CB, the more likely it is that the banks bid at rates above the marginal rate.*

MROs as repeated games: on the dynamics of the bidding behaviour

If the private cost component is of relevant magnitude to only a few credit institutions or the liquidity deficit is very low (ie $c_i \simeq 0$ or l_i is very low compared to $1/c_i$ for most i's), the equilibrium outcome does not change much from the complete information case. Most bids would still be placed at the marginal rate, although a few bids could pay an extra basis point. However, the more there are banks that want to secure their allotment quotas by paying higher rates at the tender operations, the less liquidity would be supplied at the marginal rate. Furthermore, an increase in the volume of 'safe bids' would result in a wider spread between the weighted average rate of the successful bids and the marginal MRO rate.

As long as $\sigma_{A,i}, c_i$ and l_i are constant, the magnitude of placing safe bids should be rather stable. In case of the Eurosystem, we know that the liquidity deficit has been growing very rapidly since 2002. In terms of our model this would be reflected as increasing l_i for an average bank. So basically, the fact that the Eurosystem has let the liquidity deficit to grow (with the volume of

[30] With the parameters of the example $b_i^+ > 0$, iff $l_i > 0.00025/c_i$ (or $l_i > 0.0013/c_i$ with the second set of expectations over A).

the banknotes in circulation), may have increased banks' incentives for bidding at rates above the marginal rate.[31]

As noted above, the average $\sigma_{A,i}$ depends on banks' capability to anticipate the forthcoming allotment ratio. The Eurosystem monetary policy implementation framework itself does not contain a focal point for determining a unique optimal bid volume at the marginal rate. However, as the tender operations are conducted regularly, one could use the outcome of previous operations as a benchmark when forming the expectations over the allotment ratio A (or the bid ratio k, where $k = 1/A$). If most banks were using such adaptive expectations, one could possibly observe a stable bid volumes from one operation to another for a period of time.

However, such a stable equilibrium could be disturbed by an unexpected change in the allotment ratio between two operations.[32] Consider, as an example, a case where the allotment ratio decreased between the two latest operations. As a response to the reduction in A, banks' (that have adaptive expectations) would increase (in the following operation) their bid volumes at r^m. A single bank would also anticipate the rest of the banks similarly to raise their bid volumes. This would result in a further reduction in the expected A, which subsequently needs to be compensated by a further increase b_i^m. As the exact response from the other banks would be hard to estimate, an increase in $\sigma_{A,i}$ would follow an expectation of a change in A. This increase in the allotment uncertainty, would subsequently result in a larger b^+. As $\partial A/\partial b^+ = -1/b^m < 0$, one should expect the allotment ratio to decrease as a result of the increased bidding at r^+. Moreover, if an unexpected reduction in the allotment ratio is followed by expectation of a further decrease in it, an equilibrium (with adaptive expectations) may be such that the bid volumes at rates above the marginal rate increase from operation to another.

In sum, *the fact that the operations are repeated regularly, may result in a dynamic behaviour, where the bidding can be stable for a period of time, but following an increase in the allotment uncertainty, the steady equilibrium breaks down resulting in a vicious circle, in which the bid volumes at rates above the marginal rate increase and the percentage of allotment at the marginal rate decreases between operations.*

Emergence of a tender spread

The allotment uncertainty the banks face is likely to depend also on the expected level of the allotment ratio itself. To illustrate this, consider an example where bank i expects the allotment ratio either to be high ($A = 0.7$ or 0.8 with equal probabilities) or low ($A = 0.2$ or 0.3). Assume the bank to bid so that the expected allotment for it equals the target liquidity ($b_i^m = l_i/\mathrm{E}[A]$). In the former case ($\mathrm{E}[A] = 0.75$), the bank would receive the target amount +/-7%, whereas in the second case ($\mathrm{E}[A] = 0.25$), the actual allotment would

[31] Remember also that, the average size of a single MRO doubled as a result of the March 2004 adjustments (see Section 4.1).

[32] Note that, A could vary slightly around its expected value even if all banks were bidding according to $b_i^m = \mathrm{E}[k]\, l_i$. This results from the fact that the ex post values for d and l may differ from each other although we have $\mathrm{E}[d] = \mathrm{E}[l]$. This difference results from d being derived by the CB, whereas l aggregates the banks' estimates on their neutral liquidity volumes.

be the expected volume +/- 20%, although the standard deviation of A is similar in both cases. That is, the lower the expected allotment ratio, the higher the allotment uncertainty, unless the bank's forecast accuracy on A is inversely related to E[A].[33]

If c_i was significant enough for most banks, it could be the case that almost all bidders in an operation would aim at securing their allotment volumes. Based on the analysis above, this would be most likely after an operation with low and/or decreasing A. In such a case, $b^+ < d$ would no more hold with certainty.[34] Thus, the marginal rate itself could become a stochastic variable, and bank i could not be certain that a bid at one basis point above the *expected* marginal rate will be fully successful. Consequently, banks with the largest c_i:s may start avoiding the possibility of being rationed by bidding at two bps above the expected marginal rate. So, high allotment uncertainty could result in a non-zero tender spread and a more downward sloping aggregate bid schedule.

Moreover, for banks with adaptive expectations, it could be possible that, an initial increase in the marginal rate were followed by further increases in the uncertainty over the allotment volumes at the marginal rate as well as on the forthcoming marginal rate. This could subsequently increase the bid volumes and/or rates at which banks bid in the following tenders; ie the lack of a focal point for banks' expectations over the allotment ratio could result in an adaptive behaviour, which may result in the effective tender rates (marginal rate and the weighted average rate of the accepted bids) drifting slowly upwards from the policy rate.

As the CB allotment policy is assumed to be immune to the bid rates and volumes ($r(d) = r^{MBR}$ regardless of b), a non-zero tender spread would be accompanied with a positive spread between the marginal rate and the (expected) market rate ($r^m > r$, if $r^m > r^{MBR}$).[35] In terms of the model, this means that the first term on the right hand side of equation (3.6) becomes positive. That is, when a tender spread emerges, the direct cost of borrowing liquidity from the CB becomes higher than the (expected) cost of borrowing from the interbank market. In such a case, banks face extra incentives to decrease their bid volumes compared to the case where $r^m = r$. This effect can be illustrated with an example using the same expectations over A that were applied in the example with the mean preserving spread. With lower allotment uncertainty (A either 0.4 or 0.6), the optimal bid from bank i would be $b_i^+ = \max[0, l_i - 0.00135/c_i]; b_i^{m*} = 0.0025/c_i$, while under a less accurate

[33] This results from the fact that although the standard deviation of A is the same (0.071) in both of the example cases, the standard deviation of the bid ratio ($1/A$) is the larger, the lower the expected A. However, the standard deviation of the expectations over A would be inversely related to the expected value, if the banks capability to forecast the total bid volume at r^m and r^+ were independent of the bid volumes. Yet, it seems that in practise, commercial banks' liquidity managers do anticipate directly the forthcoming A, and hence the allotment uncertainty they face is the greater the lower the expected A.

[34] See footnote 32 for a discussion on the relation between d and l.

[35] The expected market rate on the last day of a RMP equals the probability weighted average of the standing facility rates. So, as long as the liquidity policy is neutral, the rate expected (before the last allotment) for the final day equals the mid-point of the interest rate corridor. Due to the averaging provision, banks should arbitrage away any intra-maintenance period differences in the expected rates. Hence, the expected market rate for any day within a given RMP should, equal the policy rate valid for the same period.

estimate over the allotment ratio (ie A is either 0.25 or 0.75) it would be $b_i^+ = \max[0, l_i - 0.0003/c_i]$, and $b_i^{m*} = 0.0004/c_i$. That is, the *bid volumes at rates above the marginal rate decrease when the marginal rate itself increases.* Hence, the higher the expected marginal rate, the less there is upward pressure on the tender rates. So, the higher the liquidity deficit and banks' risk aversion are, the higher the allotment uncertainty is, and consequently the higher the tender spread can grow.

In the next section, we will have a brief glance at the Eurosystem experience of the tender spread.

4 Evidence from bidding in the MROs

The previous section argued that a tender spread may result from banks' incomplete information over the bid behaviour of the other banks. That is, a non-zero tender spread does not necessarily indicate that the central bank is intentionally aiming at tight liquidity conditions. In this section we will try to asses whether the tender spread evidenced in the Eurosystem main refinancing operations could be a result of the banks' trying to avoid the allotment uncertainty. Before going into the analysis of the bid behaviour of the ECB monetary policy counterparties, we briefly review the ex post allotment volumes of the ECB main refinancing operations.

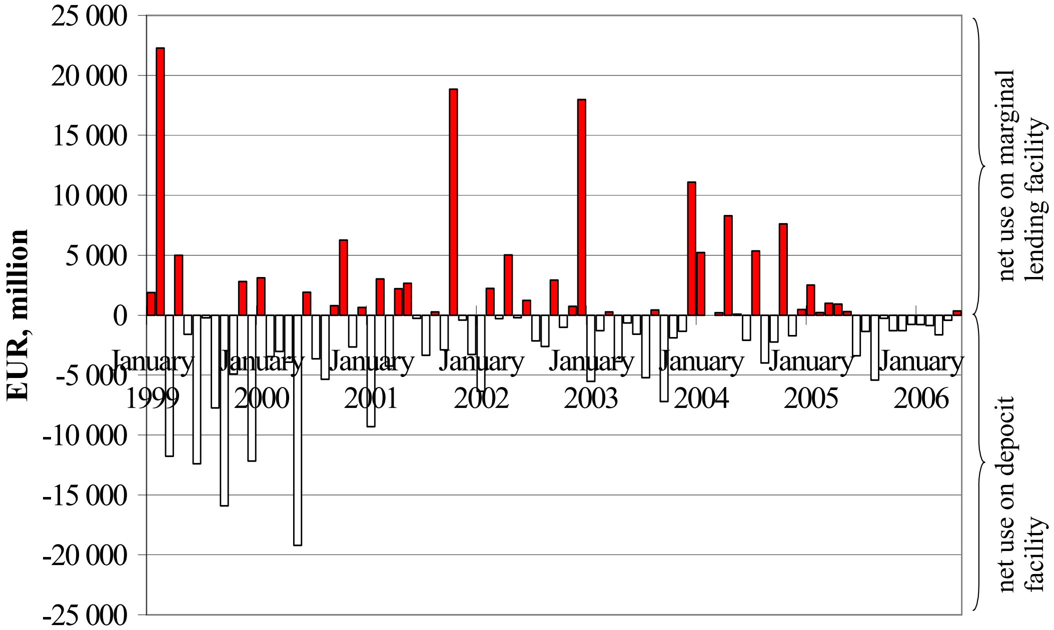
4.1 Allotment volumes

Figure 4 illustrates the banking sector's net use of the standing facilities on the final day of each reserve maintenance period between Jan 1999 and May 2006. The average net use (marginal lending volume - use of the deposit facility) amounts to EUR -620 million. That is, on average banks have placed more liquidity to the deposit facility than obtained reserves from the marginal lending facility. As some of the periods in which the net use is heavily on the marginal lending side were stemming from underbidding episodes,[36] it seems that under normal circumstances the ECB has provided the banks with more liquidity than the benchmark allotment rule suggests. That is, the actual liquidity policy of the ECB can be regarded as tight only, if the quantity oriented benchmark policy produces allotment volumes below the neutral allotments.

Mainly thanks to the increased frequency of end-of-period fine tuning operations, the average final day net standing facility use has been very close to zero (EUR -10 million) since the latest changes to the operational framework . Although the average liquidity supply seems to have diminished slightly since March 2004, one should notice that during the latest 12 months (Jun 2005 – May 2006) only one reserve maintenance period has ended with a net recourse to the marginal lending facility. So, it seems that the evidenced positive tender

[36] See ECB (2002) for a discussion on the approach taken by the ECB, when the operations were underbid.

Figure 4: Net use of standing facilities (marginal lending volume – us of the deposit facility) on the final day of each reserve maintenance period



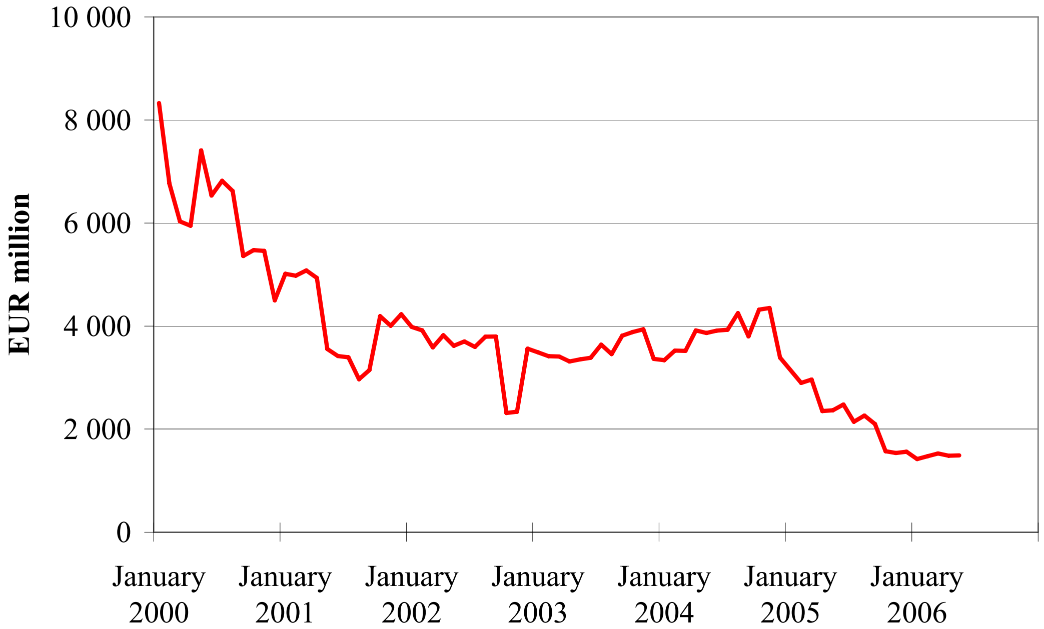
spread under the framework with static interest rate expectations, is not a result of the ECB restricting the liquidity supply below the level needed for compliance with the reserve requirements.

The target volume of liquidity supply is naturally the most important element when the banks assess the neutrality of the liquidity policy. However, even if the allotments are not biased, volatility of liquidity may affect the banks' bidding, especially if banks are risk averse. As the average lag between the last MRO allotment and the end of each RMP increased after the March 2004 changes to the operational framework, the accuracy of the benchmark allotments could have reduced, and the last day liquidity imbalances[37] might have increased accordingly. Indeed, an increase in the imbalances was observed after the changes, and as a response to the decline in the accuracy of the liquidity supply, the ECB increased the frequency at which fine tuning operations are conducted (ECB, 2005). Since November 2004, the ECB has conducted 16 final day fine-tuning operations during the 19 RMPs. The increase in the fine-tuning frequency reduced the end-of-period liquidity imbalances considerably. This effect is visible in Figure 5, which shows the absolute net use of the standing facilities as a 12 months moving average.[38] During 2005 the average net use of (either of) the standing facilities declined below EUR 2 billion from EUR 4 billion, the level close to which it had remained between 2001 and 2004. However, based on the actual liquidity

[37]Liquidity imbalance refers to the net use of the standing facilities (ie the absolute value of the marginal lending volume – use of the deposit facility).

[38]Here the average is taken over the absolute value of the difference between the marginal lending and deposit volumes.

Figure 5: 12 months moving average of the (absolute value of the) net use of the standing facilities

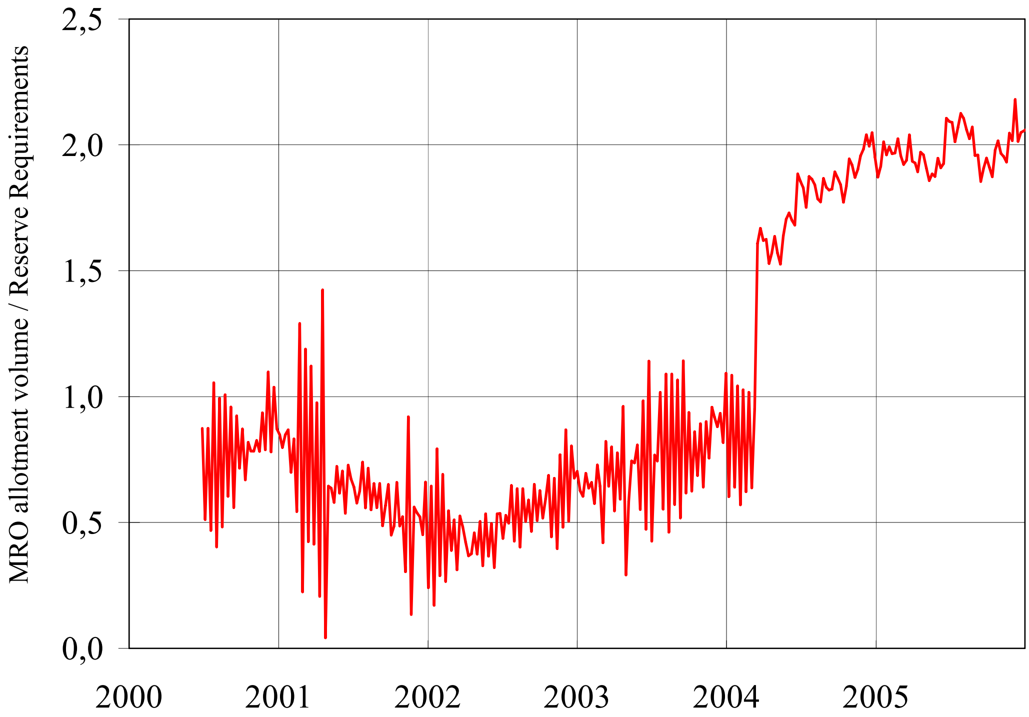


imbalances one cannot totally rule out the possibility that an initial increase in the lag between the last ECB operation and the end of the RMP was one of the key contributors to the increase of the tender spread during the 2nd half of 2004. Yet, the spread seems not to have declined after the major reduction in the accuracy of the liquidity supply related to the fine tuning operations.

In March 2004, the maturity of the MROs was halved from 2 weeks into one week. If not accompanied by other changes, the reduction in the main refinancing maturity would have doubled the refinancing volumes rolled over in each operation.[39] According to the argument laid down in the previous section, an increase in the MRO volumes raises the banks' cost related to the uncertainty of the allotment at the marginal rate (ceteris paribus). Figure 6 shows the allotment volumes of the variable rate MROs in relation to the reserve requirements (which approximates the average liquidity holdings). The size of the operations seems to have increased gradually since the cash-change-over, but the largest jump results from the cut of the MRO maturity. Whereas before the changes to the operational framework the MROs amounted (on average) to 50–100% of the money market liquidity, in 2005 the average MRO volume was twice the size of the total euro liquidity. Therefore, it cannot be ruled out that the emergence and growth of the tender spread during the second half of 2004, was linked to the allotment uncertainty at the marginal MRO rate as described in section 3.2.

[39] However, the ECB increased the volume of each of its three outstanding longer term refinancing operations from EUR 45 billon in 2003 to current EUR 120 billion.

Figure 6: Size of the operations compared to the average market liquidity



4.2 On single bank's incentives

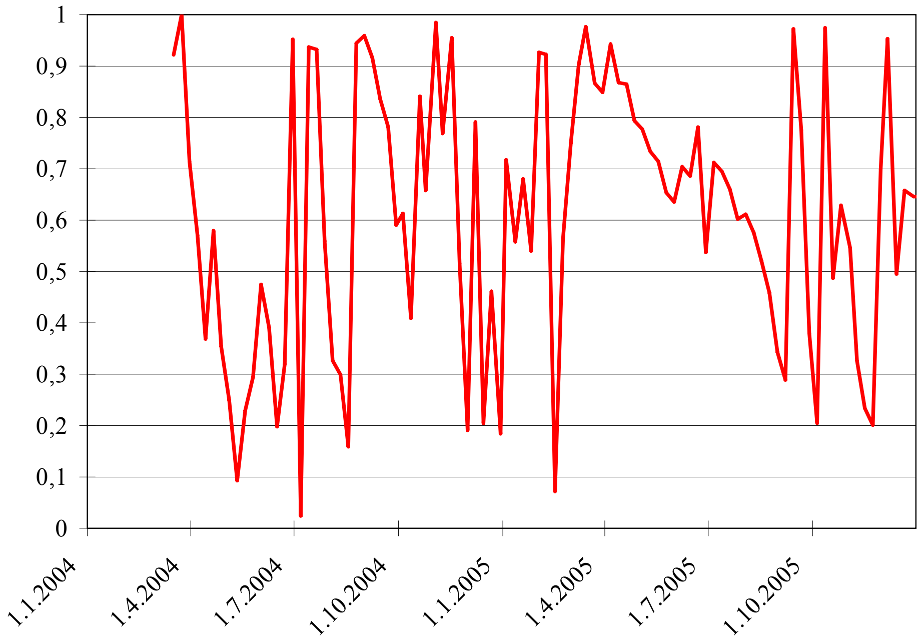
When calculating the cost of a tender spread to banks, one needs to deduct from the MRO allotment volumes (average MRO allotment in 2005 was EUR 290 billion) the aggregate reserve requirements (which averaged at EUR 147 billion during 2005), as the reserve holdings are remunerated with the marginal MRO rate. So, the price of the tender spread (5.25 basis points on average during 2005) and the spread between the weighted average and marginal MRO rate (0.9 basis points) amounted to some EUR 100 million.[40] This cost (of the allotment uncertainty) seems rather high, when compared to the aggregate cost of the end of period liquidity imbalances, that amounted cumulatively to mere EUR 0.5 million in 2005.[41]

Yet, even if one considers the aggregate cost of the tender spread to the banking sector to be high, this is not necessarily the case from a single bank's perspective when it decides its bid rates and volumes. The cost resulting from an extra basis point (above the marginal rate) is less than EUR 2 per operation for each million of refinancing. Thus, one basis point could easily be regarded as a reasonably low 'insurance fee' for the security of the allotment volumes, especially if the allotment ratio was rather volatile (Figure 7).

[40]That is, banks would have paid EUR 100 million less for the liquidity, had they bid only at the marginal rate. Note that the eurosystem remunerates the reserve holdings with the average marginal MRO rate.

[41]The sum of all end of RMP liquidity imbalances was slightly below EUR 20 billion.

Figure 7: The allotment ratio; ie the allotment/bid volume at the marginal rate.



5 Conclusions

The volatility of the difference between the effective price of central bank liquidity and the policy rate applied in the ECB main refinancing operations (tender spread), has decreased significantly since the latest changes to the ECB monetary policy implementation framework in March 2004. Hence, aligning the timing of the reserve maintenance periods with the Governing Council interest rate decisions has probably enhanced the clarity of the signals of monetary policy stance conveyed by the monetary policy instruments.

However, contrary to theoretical ex ante expectations, the changes to the framework did not decrease the average size of the tender spread. Consequently, the shortest money market rates have also carried a premium over the policy rate. Prior to the March 2004 changes, the non-zero average tender spread was resulting mainly from banks' expectations of interest rate changes within a reserves maintenance period. Yet, after the adjustments this factor should no more affect the EONIA levels.

A tender spread can naturally result from tight liquidity conditions created by the central bank. Yet, the benchmark rule used by the ECB to determine the allotment volumes in the MROs is aimed to be a neutral one; although its derivation is quantity oriented. The benchmark allotment volume aims at minimizing the end of reserve maintenance period liquidity imbalances of the banking sector. That is, the benchmark liquidity equals the amount of reserves that is needed to meet the reserve requirements. With efficient money markets and risk neutral banks this volume should be neutral also in the interest rate sense (ie the expected market rate should equal the policy rate which is also the mid-point of the interest rate corridor). Furthermore, according to the ex post data, the liquidity provision of the ECB has been abundant; ie, the allotted volumes have on average been more than enough for the banks to comply with their reserve requirements.

A model of the banks behaviour in the ECB main refinancing operations was developed in section 3. It was argued that due to risk aversion, quality of collateral possessed or credit line limits, banks have a target value for their central bank liquidity allotments. When the total bid volume exceeds the central bank's intended allotment volume, the bids are pro rata rationed at the marginal rate. Due to incompleteness of banks' information set (eg a bank does not know the bid volume of the other banks when it prepares its own bid), a bank may be willing to secure its share of the liquidity provision by bidding at a rate higher than the expected marginal rate. Consequently, the marginal MRO rate and the weighted average rate of the accepted bids can turn out to be higher than the minimum bid rate (ie the policy rate). Furthermore, the allotment uncertainty may result in a dynamic path for the marginal rate, where it is constant for a period of time, but following a change in allotment uncertainty the rate keeps drifting up from one operation to another, until the cost of the tender spread is large enough to give incentives for the banks to face the allotment uncertainty and rely more on the interbank market.

The effect of the allotment uncertainty was shown to depend significantly on the size of the operations - the larger the MROs are, the more banks have incentives to bid at rates above the minimum bid rate. The structural liquidity deficit in the euro area banking sector has been widening rapidly due to the increases in the outstanding volume of banknotes. Moreover, the average size of the main refinancing operations was almost doubled following the reduction in their maturity in March 2004. These increases may have been significant contributing factors behind the widening of the tender spread; in 2005, the average spread was wider than in any other (full) year since the ECB started to conduct the MROs as variable rate tenders, and it seems not to have reduced in the first half of 2006. There is some initial empirical evidence, according to which banks have started after the March 2004 reform to bid at higher rates, the larger the size of the operations. However, some more empirical analysis on the banks bid behaviour is still needed for a clear view on whether the allotment uncertainty can be regarded as a major contributor behind the tender spread.

If the tender spread in the ECB main refinancing operations is indeed stemming from the allotment uncertainty as suggested in this paper, it could possibly be resisted by reducing the size of the main refinancing operations. Another option could be to increase the allotment volumes above the benchmark volume. If banks knew that the intended allotment volumes exceed the neutral allotments, they would not be willing to borrow all the reserves made available. In such a case, each bank would know that it will receive all the liquidity it bids for even at the minimum bid rate, and hence, the tender spread should narrow down and ultimately disappear totally. This kind of liquidity policy would result in an outcome similar to the case where MROs are conducted as fixed rate tenders with full allotment (ie no rationing).[42] Finally, it would be useful to study, whether an increase in the accuracy of the bid rates (eg banks could use three decimal places while placing their bids) could be used to resist the marginal MRO rates from drifting upwards (or at least to slow down the pace at which the marginal rate increases) after a stable equilibrium is disturbed.

[42] See Välimäki (2001) for analysis of fixed rate tenders under different liquidity policy rules.

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