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WORKING PAPER SERIES

PROBABILITY OF INFORMED TRADING ON THE EURO OVERNIGHT MARKET RATE

AN UPDATE

by Julien Idier
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**ECB WORKSHOP
ON THE ANALYSIS OF
THE MONEY MARKET**

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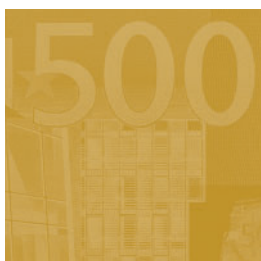
In 2008 all ECB
publications
feature a motif
taken from the
€10 banknote.

ECB WORKSHOP ON THE ANALYSIS OF THE MONEY MARKET

On 14 and 15 November 2007, Alain Durré, Huw Pill and Diego Rodriguez-Palenzuela of the ECB's Monetary Policy Stance Division organised a central bank workshop titled "The Analysis of the Money Market: Role, Challenges and Implications from the Monetary Policy Perspective". This workshop provided an opportunity for participating central bank experts to exchange views and foster debate, also in interaction with international organizations and academic institutions. The first day of the workshop addressed issues related to the macro-perspective of the money market, drawing on the experiences of a large number of countries. The second day adopted a micro-perspective on the money market, looking in particular at trading behaviour in the overnight money market and its implications for the evolution of spreads.

A first version of this paper was presented at this workshop. The papers presented at the time of the workshop did not consider the potential implications of the financial turmoil for the results of the paper, given that the tensions in money markets emerged in August 2007. The published version of these papers represents an update of the original paper, which incorporates the discussion which took place at the workshop and in most cases a discussion on the developments in the money markets since August 2007.

CONTENTS

Abstract

In this paper the probability of informed trading (PIN) model developed by Easley and O'Hara (1992) is applied to analyze the role and impact of heterogeneities in euro overnight unsecured market. The empirical assessment of the functioning of this market is based on the PIN which measures the ability of traders to interpret signals on the expected evolution of the overnight rate. Results show that between 2000 and 2004 a heterogeneous learning process of market mechanisms within participants could be observed, whereas such asymmetries have been sharply decreasing since 2005. This is reviewed against some significant events that occurred in the euro money market, such as the reform of the Eurosystem's operational framework in March 2004 and the recent financial market turmoil, which has represented a break in the steady decline of asymmetries as evidence suggest.

Keywords: Microstructure, PIN model, Money Markets

JEL Classification: G14, E52.

Non technical summary

In December 2007, in a speech about the financial market turmoil Mr. González-Páramo, member of the Executive Board of the ECB, gave the following comment: «when talking about information in the context of the financial turmoil, a key dimension of interest regards the role of informational asymmetries in the money markets», introducing in this way an interesting perspective in the context of the discussions not only about the turmoil but also for money markets. The role of information which is widely ackowledged and has been investigated extensively in financial markets such as stock markets. However, despite the role played by money markets for monetary policy, this dimension has been almost ignored or addressed rather marginally in the academic literature.

Focusing on euro money markets, information asymmetries may actually play a significant role on various dimensions related to how private banks refinance their short-term liquidity needs. Generally speaking, the central bank represents the main source which provides the liquidity which is necessary for this market to work. Banks, however, have two alternative channels to fulfil their liquidity needs (mainly stemming from required reserves and autonomous factors), namely relying on central bank's open market operations and/or on the interbank market.

As regards the first channel, liquidity is supplied directly by the central bank through auctions at which banks can participate by submitting bids generally consisting in a certain amount of demanded liquidity at a certain price which cannot be lower than a rate decided by the monetary authority. These operations, which may have various maturities, are secured and banks must possess adequate collateral in proportion to the amount of liquidity received from the central bank. As a consequence, the existence of these provisions aimed at covering risks may be discriminatory as they may exclude some banks which do not possess enough collateral or the collateral does not fulfil some 'quality' criteria. Moreover, banks are allowed to submit bid schedules which may (and often do) reflect strategic behaviour aimed at obtaining the necessary liquidity at the minimum price. In this respect, both the existence of rules and behaviours introduce discrimination among the population of banks which gives scope for the use of private information.

As regards the second channel, normaly indicated as interbank market, it represents the market where most transactions take place. Moreover, a significant amount of transactions are unsecured, i.e. it takes place through bilateral transactions without collateral. Transactions in the interbank market are typically not centralized and a significant proportion of contracts are traded over the counter. Market reputation for a bank is thus key to be able to get the necessary liquidity. Moreover, prices at which liquidity is traded may be rather different according to the typology and size of banks involved. In general, population heterogeneity appears to be central when one wants to analyse market price dynamics.

While auction behaviours and the role of private information have been investigated espcially in a number of theoretical paper, very scarce papers (if any) have analysed the role of information asymmetries in the price formation mechanism in the secondary market. This paper represents an attempt to adress the relevance of this issue in the euro overnight market. More concretely, the Probability of INformed trading (PIN) is estimated on data from the euro overnight market. Originally developed on the model by Easley and O'Hara (1992), the PIN has been initially estimated on stock markets and subsequently applied to a variety of financial markets (e.g. forex and bond markets) but never to money markets. This paper fills this gap and proposes an estimate of the standard PIN measure calculated on a high frequency dataset spanning most of the history of the single currency money market, i.e. the years between 2001 and 2008.

In the paper, various estimates are presented, including an estimated based on rolling samples to give an historical perspective and to assess the impact of some institutional factors on population heterogeneity. In particular, the effects of the operational framework on market behaviours through the various reforms and especially after 2004.

As concerns the results presented in the paper, the steady increase of the PIN measure between 2000 and 2003 points to the fact that a heterogeneous learning process of market mechanisms within participants took place. However, a transition phase characterised by a stabilisation of the estimated share of informed trading – followed the announcement of the operational framework reform and the actual implementation of the changes in March 2004. This reform appears to have modified the informational patterns of order flow in the euro area money market as informed trade has become more predominant especially between the last main refinancing operations and the end of the reserve maintenance period than it was before. A further turning point coincides with the increased frequency of FTOs at the end of reserves maintenance periods but especially after the ECB decided to allott consistently liquidity above the benchmark since October 2005. These measures appear to have reduced the impact of information asymmetries by reducing opportunities for strategic trade.

Finally, the PIN evolution is analysed after the events which took place in late summer 2007 and mainly affected money markets. As regards the evolution of information asymmetries, the progressive decline of banks' information heterogeneity started in 2004 came to a halt in April 2007, i.e. about four months before the emergence of the most visible effects of the turmoil (suggests a potential leading property of this index). Afterwards, it declined likely in response to the generous liquidity supplied by the European Central Bank. The decision to inject a massive amount of liquidity in the money market visibly reduced, among other effects, the potential for a strategic use of private information by banks.

1. INTRODUCTION

"When talking about information in the context of the financial turmoil, a key dimension of interest regards the role of informational asymmetries in the money markets"
José Manuel González-Páramo, member of the Executive Board of the ECB (December 2007)

The turmoil in late summer of 2007 triggered by US sub-prime mortgage crisis, produced many negative effects on the smooth functioning of various markets and on the financial stability of monetary and financial institutions. It attracted the attention of the community of both academicians and economic analysts onto a market which traditionally was either ignored or did not have great prominence in financial studies: the money market. During the turmoil, disruptions mainly affected the shortest maturities of the yield curve and caused swift interventions of major world central banks that tried to avoid severe financial market disruptions and provide the necessary financial support to limit negative effects to real economy. Overall, the main trigger was a massive confidence crisis among credit institutions, caused by a substantive lack of knowledge about liquidity or credit risks of potential partners in financial transactions, in particular on some crucial segments of money markets such as the overnight segment.

The goal of this paper is to shed some light on this market for the euro area and, in particular, to analyze empirically the role of information on pricing the asset traded in this market, i.e. the central bank's liquidity, using tools that have been developed in the context of the microstructure analysis.

Central banks regulate and influence the functioning of the money market owing to the special role this market plays for the implementation of monetary policy. As a matter of fact, institutional rules of the money market have a strong influence both on available liquidity in the money market and on the trading mechanisms between agents (banks).

In the euro area, money market is key since it represents the cornerstone of the architecture of the whole Eurosystem's operational framework and crucial for the process of steer interest rates along the yield curve and then transmitting the monetary policy impulse to the euro area economy.

This paper focuses on the euro overnight interbank market. The central bank is the primary source of its liquidity supplied through open market operations (OMOs). However, most transactions take place in the secondary market which is normally referred to as "interbank market". In this way, banks can actually fulfil their appetite for liquidity through two main channels: directly from the central bank at the OMOs, or from bilateral transactions with other banks.

In the academic literature on the euro money market, research mainly focused

on aspects related to ECB's auctions and their design to supply liquidity to the banking system. For example, in Ewerhart et al. (2005) banks' bidding behavior in the Eurosystem's main refinancing operations (MROs) is analyzed in connection with the situation in the secondary market. Other papers analyzed empirically the effects of the changes introduced to the operational framework in 2004 on various dimensions, in particular on bank's bidding behavior and on money market rates' level and volatility.[3]

In general, heterogeneity in banks' behavior is only addressed from a theoretical perspective, while empirical studies are still very scarce, especially for the euro area. This paper tries to fill this gap and analyses the effects of heterogeneous information on trade behavior in the interbank market. In the academic literature, several models has been proposed, all based on either stock or exchange rate markets. One of the first model addressing information asymmetries in a stock market is the sequential trade model of Glosten and Milgrom (1985). Based on this seminal model, Easley and O'Hara (1992) developed their probability of informed trading (PIN) model to measure information heterogeneity in populations of traders and to study its impact on price formation and market liquidity. The PIN model is built on the pattern of buy and sell orders, which is interpreted as stemming from heterogenous information flows in the market. The approach by Easley et O'Hara has inspired a relatively rich set of papers, most of which focuses on equity markets.[4] In this paper, a PIN model is applied for the first time to the money market to analyze the euro overnight interest rates and consider information flows, heterogeneity in population and market rules. Empirical results are derived from data publicly available to market participants over a time horizon spanning almost the entire history of the single currency money market including the recent financial turmoil in the summer of 2007. A simple PIN model is estimated to identify the nature of market belief over time and the days when informed trades are more likely to have occurred in the market. Moreover, some organizational aspects of the market - e.g. occurrence of MROs, periodicity of maintenance periods - are linked to order flows and the nature of days (whether informed or not). Finally, the historical evolution of the PIN is reviewed against the March 2004 reform and other significant events.

The paper is structured as follows. In Section 2, some features of the euro money market organization, market participants and the evolution of the operational framework are discussed. In Section 3, the microstructure model used to analyze the overnight market and the econometric application are presented. In Section 4, data and empirical results are illustrated. In Section 5, the historical

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[3] See Neyer (2004), Durré and Nardelli (2007), Jardet and Le Fol (2007).

[4] See Easley Kiefer O'Hara and Paperman (1996), who relate the PIN to the volume traded ; Easley Kiefer and O 'Hara (1997) use the PIN to test "cream skimming" between places in a fragmented market ; Grammig Schiereck and Thiessen (2001) who relate the PIN measure to the trading rules of the equity market ; Easley Hvidkjaer and O'Hara (2005) use the PIN measure as a factor in the Fama-French model.

evolution of the PIN is reviewed in particular against some significant events between the end of 2000 and the beginning of 2008. Finally, Section 6 concludes.

2. THE EURO MONEY MARKET STRUCTURE

The euro money market is characterized by the existence of an important institutional player (i.e. the central bank), a set of rules decided by this player based on its strategic objectives, and specific traders, i.e. banks. The amount of assets available in this market is supplied through OMOs conducted at a regular frequency by the central bank to meet demand and, in this way, to ensure an equilibrium price (interest rate) compatible with its monetary policy objectives.[5]

In the euro area, the size of operations and, then, the amount of financial assets (liquidity) consists of two main elements which concur to define the so called "liquidity deficit" of the Eurosystem, i.e. required reserves and autonomous factors. While the size of required reserves is decided by the central bank, autonomous factors include items which have an impact on the total liquidity amount but are not controlled by the central bank. Among these items, there are bank notes in circulation, domestic and foreign assets possessed by national central banks, deposits of governments in national central banks' accounts and other financial assets.

Banks can fulfil their liquidity needs through two main channels: (1) participating to central bank's refinancing operations [6] and/or (2) bilateral transactions in the interbank market.

2.1. Refinancing operations design

The two main instruments are the MROs and longer-term refinancing operations (LTROs) which differ for the maturity of refinancing.[7]

Banks can participate to OMOs by submitting bids, i.e. requesting a certain amount and offering a price (interest rate) which cannot be lower than the interest rate set by the monetary authority (i.e. the minimum bid rate). Bids are served starting from highest offered interest rate to the *marginal interest rate* resulting from the total amount of liquidity supplied by the central bank. At this rate,

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[5] For more details on the operational framework principles, rules and available instruments see European Central Bank (2006).

[6] In the Eurosystem, banks can also get liquidity at any time by borrowing funds directly from the central bank. Marginal lending and deposit are the two standing facilities The interest rates applied to these facilities the two other policy rates set by the monetary policy authority of the euro area.

[7] Until 2007, the bulk of liquidity (i.e. around 75%) used to be injected through weekly MROs, whereas the remaining quantity (i.e. around 25%) through monthly LTROs having a maturity of three months. Following the financial turmoil in the late summer of 2007, the share of longer-term liquidity significantly increased over time to above 50% of the total amount of outstanding liquidity. Moreover, longer-term refinancing operations with six-month maturity were also conducted.

liquidity is distributed *pro rata* to bidders all offering the same interest rate based on shares computed on the basis of individual demanded amounts.

To be able to participate to central bank's auctions, banks must comply with requirements on their financial soundness. Banks must possess adequate collateral in proportion to the amount of liquidity received from the central bank.[8] From the perspective of participation to direct refinancing, the existence of these provisions may actually be discriminatory, as banks not having sufficient or low quality collateral are excluded. In other words, existing rules that aimed at ensuring financial soundness may actually represent a barrier for some banks.

In addition to these two types of operations, another one has recently become rather frequent: fine-tuning operations (FTOs). FTOs are generally conducted at the end of reserve maintenance periods to resolve significant liquidity imbalances and to avoid marked departures of the overnight rate from the minimum bid rate or excessive volatility.

Unlike the previous two operations, FTOs can be conducted to either supply or withdraw liquidity, depending on the sign of the liquidity imbalances. Because of the need to act rapidly, the list of banks eligible to participate is more restricted, and participation is normally rather limited (between ten and fifteen banks usually participate). Efficiency, therefore, creates another potential barrier for the participation to this type of refinancing. In addition to operational rules, administrative costs may in some cases represent a disincentive, if not an obstacle, to participation in this primary channel of refinancing.

2.2. The interbank market

A secondary source of refinancing is represented by the interbank market. Liquidity in the interbank market is typically not centralized and banks deal on this market in various ways. A significant amount of transactions are unsecured, i.e. without exchange of collateral and central bank's liquidity is distributed across banks through bilateral transactions. In this way, all banks – including those not possessing adequate collateral or not able to get liquidity in weekly auctions – may satisfy their liquidity needs. As pointed out in Hartmann and Valla (2007), this market is characterized by both – and mainly – direct dealing (i.e. over-the-counter or OTC market) and electronic centralized platforms (e.g. eMiD). Being less regulated, the interbank market is therefore less discriminatory; nonetheless, there may be situations in which sophisticate agents are able to exert some market power, ei-

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[8]Financial assets must fulfil some criteria to be eligible as collateral. Criteria for eligibility impose that credit rating of certain type of assets must be above a threshold decided by the central bank. These criteria have also an impact on the amount of collateral which is requested as a consequence of the "haircut" imposed by the central bank which increases with the riskiness of the asset. The amount of collateral requested by the central bank is equal to the nominal value of liquidity received by the bank plus the interest rate plus the haircut.

ther because they can access various refinancing sources or because they can exploit more efficiently the information on aggregate liquidity conditions.

The euro money market has experienced a huge expansion since its creation in 1999.[9] This market is mainly organized around four main segments: (i) unsecured market; (ii) secured market; (iii) OTC derivatives swaps; and (iv) short-term securities.

The two first segments are particularly interesting. The unsecured market allows to trade lending and borrowing uncollateralised contracts. Since no collateral is requested for contracts, maturities are concentrated on the very short term to minimize default risk: in 2006, 96% of the contracts were less than one month, and 70% on the overnight as indicated in European Central Bank (2007). By contrast, the secured market requires that contracts are backed by collateral. Since banks have a guarantee on the subscribed contracts, the maturity breakdown of this market is less concentrated on the very short-term maturity: only 13% are overnight maturities while "tomorrow/next to one month" of this market accounts for 77% of total transactions. Recently, electronic platforms have started taking on an increasing market share for both secured and unsecured trade and, today, they account for around 17% of the unsecured and around 49% of the secured market. However, it appears more difficult to implement an electronic platform on the unsecured market.

"Reputation" is a key difference between secured and unsecured market. Unsecured contracts are traded over the counter on a direct basis. Since counterparties do not have any guarantee (i.e. contracts are not collateralized), it is crucial to know whom a bank is trading with. The anonymity of electronic platforms does not allow any control procedure on contracts, which may explain the different developments of electronic platforms between secured and unsecured market. In this respect, even if analyzing market behavior in an OTC market is more difficult as prices and volumes of transactions are only partially observed, the information from OTCs is undoubtedly more accurate from the point of view of representativeness[10].

A first element of heterogeneity is certainly the size of banks. Usually, big banks can trade more easily than small banks on the unsecured market.

A second element is the discrimination of counterparties induced by rules on the participation to the Eurosystem's liquidity auctions. As illustrated before, banks' eligibility is based on requirements on financial soudness that impose to possess adequate collateral. Since not all banks can participate to these operations, aggressiveness may arise on the secondary market from banks excluded from central

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[9]For more details on the characteristics of the euro money market see European Central Bank (2007).

[10]Tipically, the rules regulating the access to trade in e-MiD exclude many banks by imposing a net asset worther than USD 10 millions, which prevents smaller banks from becoming market participants and avoids any potential reputation problems.

bank's refinancing or may offer opportunities to only few banks to trade strategically in the secondary market.

A third factor is the location of the bank. Notwithstanding the fact that all banks in the euro area are entitled to participate to ECB's OMOs, a country bias can still be observed in trading activities in the sense that only 25% of transactions are still made between banks within the same country, while only 55% are cross-border transactions. As large market participants play the role of liquidity providers at a country level, uneven liquidity distribution affecting in particular countries traditionally less active in the weekly MROs may actually occur.[11]

Overall, several elements in the functioning of the euro money market are sources of asymmetries between agents. These asymmetries may stem either from the rules governing the functioning of the market or from factors characterizing individual banks (size, access to direct financing, geographical location). An attempt to reduce these asymmetries by increasing the amount of information disclosed to market participants and then reducing the scope for manipulation and strategic use of private information took place in 2004 when the operational framework of the Eurosystem underwent a reform. The detailed measures and their rationale are described in detail in the Appendix. This heterogeneity between banks has crucial effects on market dynamics as it is illustrated in the following sections.

3. THE MODEL

The empirical model presented below considers market information and the fact that traders (banks) do not perceive price signals in the same manner. To treat heterogeneity in terms of the characteristics outlined above, two groups of banks are considered: big banks are defined as informed bank, and small banks as uninformed banks.

The framework used for the empirical analysis is the same as in Easley and O'Hara (1992), adapted to fit some specific characteristics of the money market and estimated using data. In the next sections, the main features of the model are first illustrated together with some parameters derived from the basic model, i.e. the probability of informed trading (PIN) and the market liquidity. Then, a likelihood function is derived from the model and estimated on real-time data.

3.1. Model Structure

To qualify the model used for the exercise developed later in the paper, the most relevant features of the seminal model by Easleay-O'Hara (referred to as EO model thereafter) are first discussed and transposed to the money market.

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[11] An example is represented by Portuguese banks, which never participates to weekly MROs.

3.1.1. Assets

In the unsecured overnight market, assets are peculiar compared with other financial markets, since they are represented by contracts. Unlike in stock markets, it is not traded the property of a share value of a firm with some fundamental factors, but rather a cash transfer from one party to another. This transfer is negotiated at a certain interest rate, whose level determines the value of the contract and characterizes, at an aggregate level, trade patterns in the market. The value of the contract reflects the availability of the underlying asset in the market (i.e. market liquidity) but also individual knowledge about future developments of the asset and the central bank's liquidity management.

Money contracts are assumed to be underwritten at a fair value. In traditional applications of the EO model, the true unobservable value is the fundamental value of a financial asset. It may be more contentious to define the true value of the overnight interest rate. However, this value can be assumed to reflect in normal circumstances the aggregate liquidity needs in the money market.

3.1.2. Information on assets

On the role of information, two dimensions can be considered. First, a good knowledge of aggregate liquidity conditions in the money market gives an insight on central bank's expected supply and thus of the value of the asset. Second, most active banks may determine, or at least, influence demand because:

- the bigger the needs of liquidity are for a bank, the larger its share in global liquidity needs is;

- the more active a bank is, the better the tools it should have to perceive market information ;

- the more active a bank is, the more orders it centralizes.

As a consequence, if a bank has an active role in the market, its knowledge about market needs should be enhanced and, thus, its information.

A market signal can be defined as a piece of information that allows traders to update their beliefs on the true value of (overnight) liquidity, and to make the decision on wether to trade or to wait. If there is a signal, the type of the signal is assumed to be known by the pool of informed banks, and to remain constant during a given day. A signal can be classified as "high" (H) if contracts would be negotiated at a higher interest rate during the day, or "low" (L), if contracts would be negotiated at a lower rate. The model considers also days without signal (O).

3.1.3.   The population of traders

The population of traders is characterized by information heterogeneity. In the money market, traders are banks which can be classified as "informed", "uninformed" and "market makers". As in Neyer (2004), banks are motivated to trade mainly to comply with institutional rules (i.e. fulfillment of reserve requirements) and minimize the cost of handling liquidity.

Efficiently-informed banks meet two criteria. First, they have superior information and trade on the basis of this information. They represent the most active pool of banks: they acquire, understand and use market information. Second, they are supposed to have fulfilled their reserves requirements or to be not too far from the fulfillment of their reserves. Actually, a bank may interpret a liquidity deficit on the market but may not be able to trade on this information since it may still need to fulfil its reserve requirements. Unlike in the standard EO model interpretation, in this special case, trades opposite to the market signal might be rational, but are however considered as non informed trade.

Uninformed banks have no piece of information to trade. Their trade is mainly motivated by inventory constraints, i.e. reserves requirements imposed by the central bank.

Finally, the market-maker pool is assumed to be composed of banks which fulfil their liquidity needs mainly directly from the central bank. These banks provide liquidity to the secondary market and are assumed to be competitive. They set quoted spreads and the best quoted spread, i.e. the narrowest spread, is displayed publicly to the market.

3.2.   A sequential trade model

As in the EO model, banks arrive to the interbank market sequentially and make their decisions on whether to trade or not. Trade in the interbank market is motivated essentially by shocks in autonomous factors which may change individual positions with respect to reserve requirements. Due to the typical pattern in the fulfilment of reserves, the days between the last MRO and the end of the maintenance period appear crucial.[12] During these days, banks appears very active and information on aggregate liquidity has usually strong effects on the overnight interest rate.

The liquidity necessary to fulfil required reserves can be obtained in two ways, i.e. trading in the interbank market or making use of the existing central bank's standing facility (marginal lending). However, the latter alternative is more expensive (100 basis points above the minimum bid rate) than trading in the interbank

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[12]The typical pattern observed since 1999 was altered after the emergence of financial turmoil in August 2007 and the frontloading policy conducted by the ECB.

market. As a consequence, the increased activity in the interbank market during this period can be expected to reveal market participants' aggregate liquidity needs, and so imperfect information signals through price dynamics. More specifically, all banks observe the type of trade prevailing in the interbank market so that they can assign a probability to the type of order (i.e. whether it is more likely that some order comes from informed or uninformed banks) and, in case of informed trade, on the type of signal (high or low). As seen before, these signals are mainly driven by the aggregate liquidity situation which may only be witnessed by a pool of banks. The set of options for market agents can be summarized in a standard tree representing the trade process.
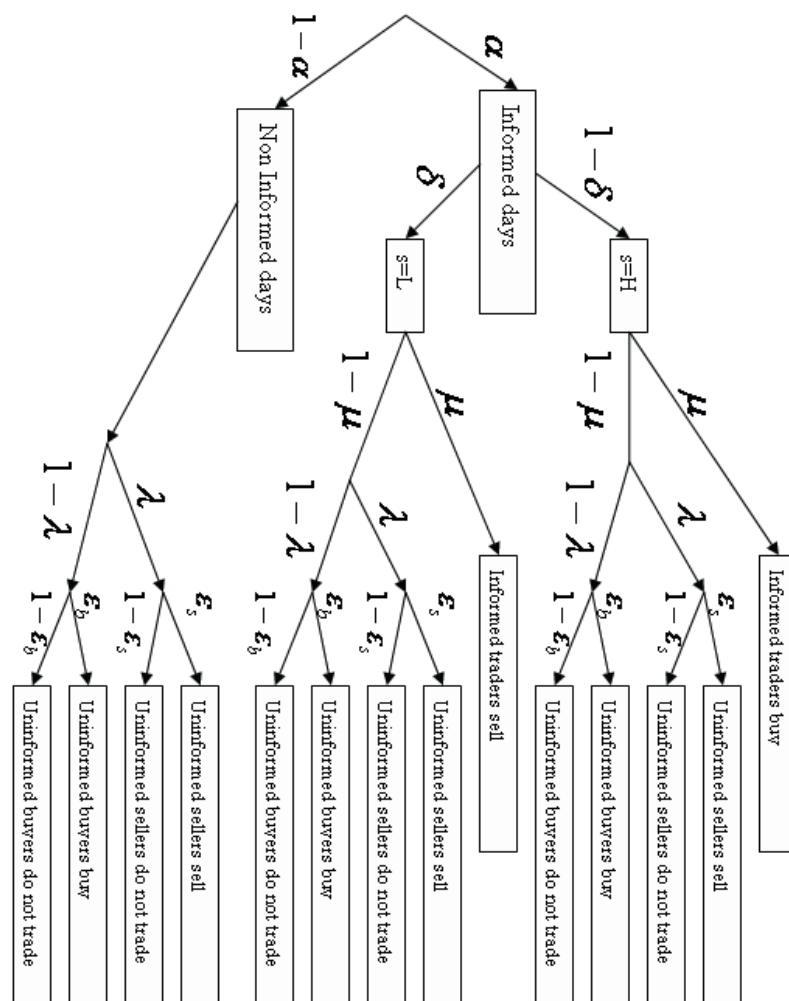

Figure 1: tree trade process

The structure of this market is characterized by the set of parameters $P=\{\alpha, \delta, \mu, \lambda, \varepsilon_s, \varepsilon_b\}$. The α parameter represents the probability that information occurs on the market during a given day.[13] In days with a signal (informed days), this information is expected to be linked with the direction of the interest rates on the borrowing (buy orders) or on the lending side (sell orders) of the market. The δ parameter measures the probability that signal is low, i.e. that information be perceived as driving the price lower than it actually is. Finally, the μ, λ, ε_s and ε_b parameters characterize the structure of the population of banks acting in the money market and their propensity to sell or buy given the nature of the day and the type of signal.

3.3. Informed trade vs. uninformed trade

Assuming that sequential trade models represent adequately the trading mechanism in the money market, it is possible to calculate the probability of being in an informed day with a low or a high signal, or the probability to be in a day without signal.

Large banks give information to the market about the interest rates they practice either on the lending or on the borrowing sides. However, a bank playing the role of market maker, adapts its bid and ask prices to comply with its own inventory constraints.[14] On the other side of the market, orders are lending-initiated (or a sell order if the counterpart hits the bid price) or borrowing-initiated (or a buy price if the counterpart hits the ask price). Based on the tree in Figure 3, the probability to observe B borrowing orders, S lending orders and N no trades, conditional to the intensity of the signal during a given day, are respectively:

$$\Pr(B, S, N \mid s = H) = (\mu + (1 - \mu)\lambda\varepsilon_b)^B \cdot ((1 - \mu)\lambda\varepsilon_s)^S \qquad (1)$$
$$\cdot ((1 - \mu)\lambda(1 - \varepsilon_s) + (1 - \mu)\lambda(1 - \varepsilon_b))^N$$

$$\Pr(B, S, N \mid s = L) = ((1 - \mu)\lambda\varepsilon_b)^B \cdot (\mu + (1 - \mu)\lambda\varepsilon_s)^S \qquad (2)$$
$$\cdot ((1 - \mu)\lambda(1 - \varepsilon_s) + (1 - \mu)\lambda(1 - \varepsilon_b))^N$$

$$\Pr(B, S, N \mid s = O) = \lambda^{B+S+N}[(\varepsilon_b)^B \cdot (\varepsilon_s)^S \cdot ((1 - \varepsilon_b) + (1 - \varepsilon_s))^N]. \qquad (3)$$

[13] Typically α is always quite high in financial markets. Easley Kiefer and O 'Hara (1997) estimate α to be around 0.75 for an asset traded on the AMEX, which indicates that very few days are non informed.

[14] The level of liquidity possessed by a bank in this context is assimiled to inventory constraints. It supposes it exists an optimal level of liquidity for banks to comply with reserve requirements and autonomous factors. The constraint represents the desire not to be too far from this optimal level.

Compounding these probabilities:

$$
\begin{aligned}
\Pr\left[(B, S, N) \mid \alpha, \delta, \mu, \lambda, \varepsilon_b, \varepsilon_s\right] & = \alpha\left(1 - \delta\right)\Pr(B, S, N \mid s = H) \qquad\qquad (4)\\
& + \alpha\delta\Pr(B, S, N \mid s = L) + (1 - \alpha)\Pr(B, S, N \mid s = O).
\end{aligned}
$$

Finally, considering a sequence of T days and assuming that days are independent from each other,[15] the likelihood of observing B buys, S sells and N no trades is:

$$
\Pr\left[(B_t, S_t, N_t)_{t=1}^{T} \mid \alpha, \delta, \mu, \lambda, \varepsilon_b, \varepsilon_s\right] = \prod_{t=1}^{T} \Pr\left[(B_t, S_t, N_t) \mid \alpha, \delta, \mu, \lambda, \varepsilon_b, \varepsilon_s\right] \quad (5)
$$

Some restrictions can be imposed to the set of parameters to simplify the model and to focus on the ability of banks to incorporate information. First, uninformed traders (sellers or buyers) are supposed to have the same intensity, i.e. $\lambda = 0.5$. A second restriction is to consider that being an uninformed seller has the same probability as being an uninformed buyer, i.e. $\varepsilon_s = \varepsilon_b = \varepsilon$. In this way, the set of parameters reduces to only four, i.e. $(\alpha, \delta, \mu, \varepsilon)$.

Based on the reduced form, the maximum likelihood function is as:

$$
\begin{aligned}
L(\alpha, \delta, \mu, \varepsilon) & = \Pr\left[(B_t, S_t, N_t)_{t=1}^{T} \mid \alpha, \delta, \mu, \varepsilon\right] \qquad\qquad\qquad\qquad\qquad (6)\\
& = \prod_{t=1}^{T}\left[(1 - \varepsilon)^N(1 - \mu)^N A^{B+S}\right] \qquad\qquad\qquad\qquad\qquad (7)\\
& \quad .[\alpha\left(1 - \delta\right)\left(\frac{\mu}{A} + 1\right)^B + \alpha\delta\left(\frac{\mu}{A} + 1\right)^S + (1 - \alpha)\left(\frac{1}{1 - \mu}\right)^{B+S+N}]
\end{aligned}
$$

where $A = \frac{(1-\mu)\varepsilon}{2}$.

To estimate these parameters, it is necessary to derive the structure of the trade flows i.e. the number of buy (borrowing), sell (lending) and no trade orders on a given day. Section 4 presents standard estimation procedures using a classification of trades which has been adopted, given the only partial information on the available dataset on the overnight interbank market.

3.4. Asymmetric information and market liquidity

To understand how banks consider the institutional framework, how they use the information disclosed by the central bank and how this influences their behaviors, it is interesting to calculate from the model the probability γ that trade is informed for any given day. The probability of informed trading (PIN) represents the implicit

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[15] Imposing this simplification prevents from analysing the effects of the averaging mechanisms of reserve requirements in the operational framework after the changes to the operational framework. However, since the paper is primarily focused on aspects related to information disclosure, this simplification does not appear to limit the validity of the results.

risk that a bank faces when trading with a better informed bank on the direction of the interest rate. The PIN depends crucially the total probability of trade during informed days (i.e. market liquidity), defined as Ψ. Based on the tree describing the trade process in Figure 1, the parameter Ψ is equal to ε in non-informed days, and during informed days:

$$\Psi = (1 - \mu)\varepsilon + \mu \tag{8}$$

hence the PIN is defined as:

$$\gamma = \frac{\mu}{\Psi}. \tag{9}$$

As in the classical EO model, the PIN γ measures the implicit risk for some banks to (unintentionally) create trade opportunities for other banks, because they are less informed than their counterparties. The PIN is low when Ψ is high, and inversely it is high when Ψ shrinks. During informed days, the parameter Ψ is key to measure asymmetric information but also the impact of ECB interventions when, for instance, liquidity is scarce.

From a time-varying perspective an increase in the PIN indicates a heterogenous learning process among banks. For instance, this would be the case of an increasing number of banks having fulfilled their reserve requirements knowing how to use information on the expected path of overnight interest rates. By contrast, a decline in the PIN indicates that opportunities to trade on individual information decline. In this case, the learning process among banks would be increasingly homogeneous with less opportunities on trading on information, and, therefore, a decreasing risk in trade.

4.   DATA AND RESULTS

4.1.   Dataset

As already described, the overnight unsecured market is mainly an OTC market, and therefore interest rates at which overnight contracts are actually traded are unavailable in general. An exception is represented by the electronic trading platforms such as eMiD, which, for instance, provides volumes and prices of each transaction between banks. This platform, however, only includes a limited set of large banks and, as such, it has severe limitations as far as generality of results is concerned.

As an alternative, data from Reuters have been used. Reuters provides best bid and ask quotes in real time that are known to the market, but actual transaction prices are not available. When financial markets are very liquid as it is the case of the overnight market, however, effective prices can be assumed to be very close to quotes prevailing before transactions.[16] This gives to all market participants the

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[16] See Brousseau (2006).

prevailing levels of proposed rates and, mainly for this reason, was preferred to the eMiD database. The available dataset used for the application presented in this paper, contains date, time and best bid/ask in the market at a 5-minutely frequency between December 2000 and March 2008 as displayed in Reuters's screen.

4.2. Trade classification

The second problem to solve was the identification of buy orders, sell orders or no orders for each day included in the sample to determine the order flow. Techniques such as in Lee and Ready (1991) are usually applied. Typically, if only transaction prices are known but not spreads, a spread is constructed following Roll (1984) and then every price is compared with the midpoint of the derived spread to determine whether market orders are buy- or sell-initiated.

To be able to apply this procedure, however, transaction prices must be known, whereas only spreads were available from the Reuters' dataset. To overcome this limitation, the following solution is adopted. In the literature,[17] quoted spreads are assumed to be made of three components: trading costs, information asymmetries and inventory constraints.[18] Due to the existence of reserve requirements, the inventory constraint component was assumed to be predominant. Hence, the classification of trade was based on the assumption that banks cannot be too far from their optimal inventory level and, therefore, movements of quoted spreads can be assumed to mainly reflect this fact.

Under this assumption, orders are classified analyzing changes in the bid and ask prices according to the following rule:

• A common rise in the ask and bid price suggests that the price of the previous transaction was at the ask, and that dealers are willing to sell the asset at a higher price. On the bid side, no revision or an increase indicates that the dealer offers a best price to buy the asset. This case represents the dynamics following market "buy orders", i.e. a borrowing unsecured overnight contract has been initiated in the market (case 1 in Figure 2).

• A common decline in the ask and bid price represents the opposite situation. Dealers are willing to sell the asset at a lower price to the market and worsen the bid price to limit the market sell orders. This can be interpreted as a market "sell order", i.e. a lending contract has been initiated in the market (case 2 in Figure 2).

• An increase in the ask and a decrease in the bid is interpreted as a "buy order" for bigger positive jumps in the ask (case 3 in Figure 2) or a "sell order" for bigger negative jumps in the bid (case 4 in Figure 2).

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[17] See, for instance, Ho and Stoll (1997), George, Kaul and Nimalendran(1991) or Harris(2003).
[18] This is a simplified view since many other factors on this special money market may influence the quoted spread.

- A decline in the ask and an increase in the bid, comparing absolute moves on each side, is classified as "buy order" if the increase in the bid is bigger than the decrease of the ask (these cases do not appear in Figure 2).

- Steady bid and ask prices or symmetric revisions characterize the absence of trade. This may only occur because of a change in market liquidity due to large volatility or to an increase in uncertainty (case 5 and 6 in Figure 2).

A summary of these various cases is given in Figure 2.
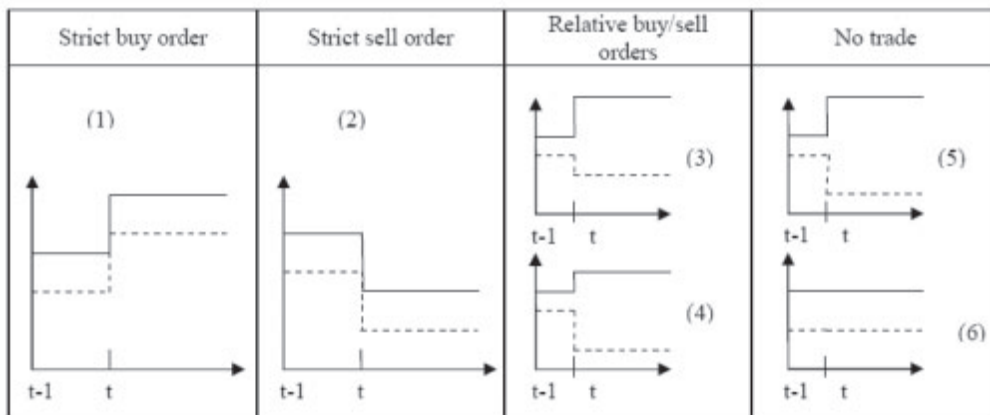
Figure 2: Classification of trades based on bid and ask variations

This classification is applied to more than 200,000 available quoted spreads. Daily sum of sell orders, buy orders and no trade orders are computed. Figures 3, 4 and 5 show the resulting distributions.[19]
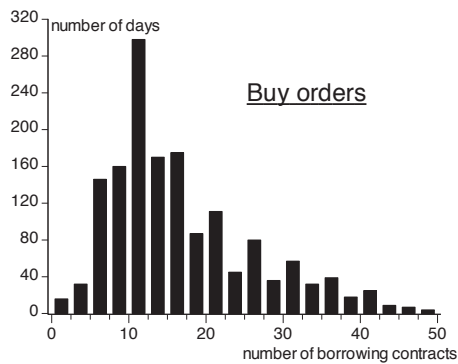
Figure 3: distribution of Buy orders
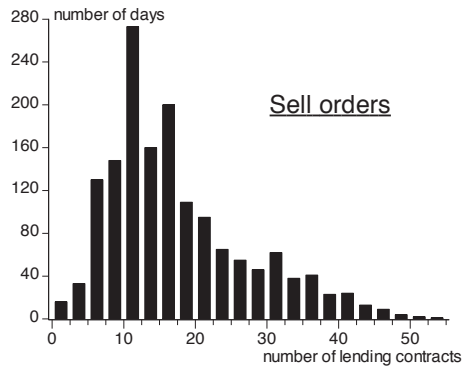
Figure 4: distribution of Sell orders

[19] In the whole sample, about 2/3 exhibited pure movements (i.e. common increase or common decrease in ask or bid quotes) and 1/3 relative movements (i.e. opposite movements for the ask and bid quotes).

Figure 5: distribution of no trade orders

Some stylized facts emerge from the results:

1. in the euro overnight market, a trade takes place every 20 minutes on average;

2. all distributions (including that for no-trade days) are skewed and leptokur-totic, which indicates that trade intensifies on some special days, namely during the last week of maintenance periods;

3. a slight bimodality is evident for all distributions, which points to a possible mixture of distributions in all cases. Thi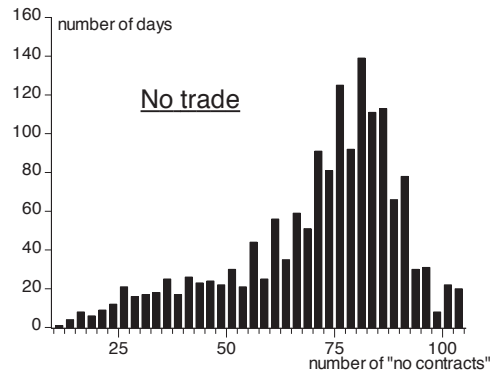s latter aspect is captured by the parameter α, which represents in concrete terms the mixture between informed days (the most active ones) and uninformed days.

4.3. Maximum likelihood estimation

The maximum likelihood estimation (equation 7) conducted on the complete sample gives the following results:

	Parameter	Standard error	t-Prob
α	0.240	0.016	0.00
δ	0.601	0.028	0.00
μ	0.208	0.002	0.00
ε	0.308	0.001	0.00
Likelihood	-157150.6		

Table 1: MLE estimation, 01/12/2000-01/04/2008

First, the estimate for the parameter α (i.e. 0.240) indicates that on average 1/4 of the days are information driven. Considering the average duration of a maintenance period (i.e. around four weeks), this corresponds to around 4 or 5 informed days in a maintenance period.

Second, during informed days, the signal is low [high] with probability δ $[(1-\delta)]$. Results suggests that a low signal is observed with an estimated probability of 0.60,

which means that orders are more likely to be sell-initiated (i.e. lending contracts during excess liquidity period on the market are relatively more frequent) than buy initiated. In other words, banks tend to believe that information-driven orders reveal excess liquidity supply on the market, rather than the opposite. This result confirms that banks are more exposed to risk when the liquidity is scarce than when liquidity is abundant.

Third, $\mu=0.208$ suggests that banks tend to believe that observed orders are information-driven with a probability of only 21.8%: 1/5 of orders observed in the market are deemed to come from efficiently informed banks. For the money market, the interpretation of the μ parameter is more restrictive than in the standard PIN model, since it only takes into account the banks that are informed and which have efficiently fulfilled their reserve requirements.

Fourth, $\varepsilon=0.308$ indicates that the probability of liquidity trade is only around 30%. During informed day, this parameter represents market liquidity which comes from uninformed banks, while during uninformed days, it coincides with total liquidity available in the market (because only uninformed traders are active on the market).

From Equation 8 the probability of trade during informed days is $\Psi = 0.45$, i.e. a new quote every 10 minutes. From Equation 9 the probability of informed trade, PIN, is $\gamma=0.48$ on the complete sample. This result suggests that a bank involved in an overnight contract faces a 48% probability to be trading with a counterparty which is better informed on the direction of interest rates.

5. MARKET LEARNING AND THE ROLE OF INFORMATION IN A HISTORICAL PERSPECTIVE

The next step is to analyze how some events which have taken place in the overnight market (including changes to the rules of the operational framework) may have affected the trading pattern. In particular, in order to assess the evolution of informed trades over time, the model parameters are estimated on rolling samples made of 200 overlapping days.

5.1. A break in the learning process?

The four panels of Figure 6 present the results of the parameters estimates computed from the rolling samples described before.
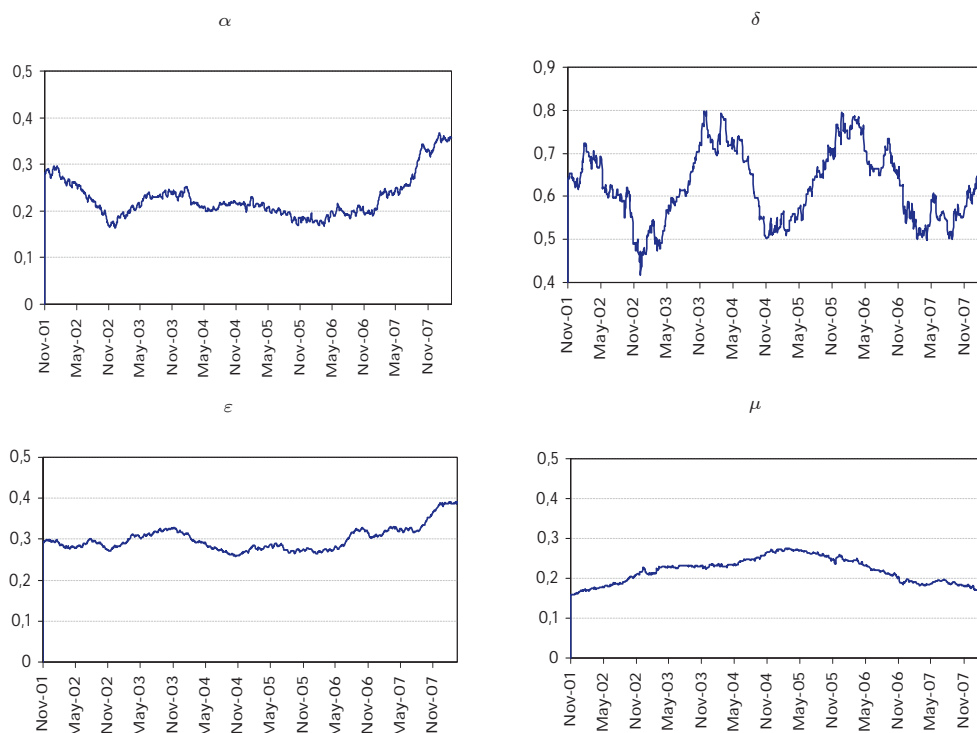
Figure 6: Rolling coefficients from the EO model

After an initial decline, the fraction of informed days (α) broadly stabilized at around 0.2 (corresponding to about 5 days in a maintenance period) until the end of 2006. In 2007, however, this parameter rose pointing to an increase in the share of informed days, in particular after May 2007, i.e. shortly before the onset of the financial turmoil. It is interesting to note that this parameter sharply rose in August and broadly stabilized at around 0.35 thereafter. The probability of low signal on overnight rate (δ) has been generally above 0.5 except between November 2002 and January 2003, between October 2004 and January 2005 and after December 2006. The share of informed banks (μ) grew until November 2004 and has declined steadily thereafter, including during the financial turmoil phase in the second half of 2007 (with only local peak in August 2007). After December 2006, however, the negative trend appears to have stabilized at a level slightly below 0.2. The share of non-informed trades ε has remained at around 0.3 for a relatively long period, with a significant decline between end-2004 and end-2005. This parameter increased towards the end of 2006 and accelerated after August 2007, i.e. after the response

of the ECB to the turmoil and the increase in liquidity allotment.

Finally, the historical evolution of the PIN γ is shown in Figure 7. In the same figure, some landmarks of the Eurosystem's operational framework are also indicated to assess whether some turning points in the trend of the PIN can be associated with major events which took place in the euro money market.
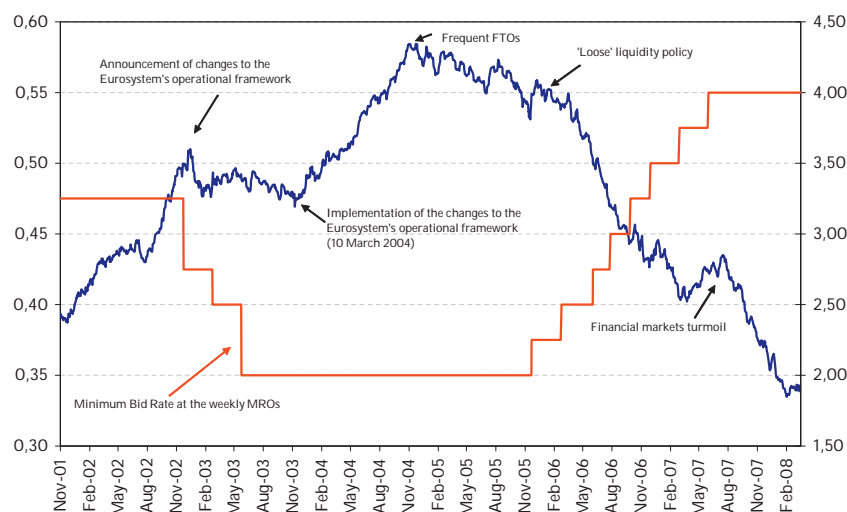

Figure 7: historical evolution of the PIN

Overall, an increasing trend is observable between 2001 and 2004, which reversed after 2004 and accelerated from the end of 2005. This negative trend came to an end towards the end of 2006 and it reversed again afterwards to reach a peak in the summer of 2007, i.e. at around the onset of financial market turmoil. It is interesting to observe that the reaction of PIN started well before the outbreak of the turbulence in the euro money market, thereby suggesting a possible leading property of the index which would deserve further research.

Five particular events appear to have exerted some influence on the historical developments of the PIN. The first coincides with the announcement made by the ECB on 23 January 2003 on the forthcoming changes to the operational framework. Following the period characterized by an increasing PIN, which mirrors the increasing heterogenous knowledge of the operational framework by market participants, the announcement of the new rules discontinued this process and the share of informed trade broadly stabilized.

This can possibly be related to the fact that most expert traders modified their trading behavior to anticipate and exploit some forthcoming rules of the reformed framework. From March 2004, i.e. from the actual implementation of the new rules, heterogeneity increased, possibly reflecting a different degree of assimilation of the new rules in the community of traders and the relative advantage in trade

of informed banks. From the perspective of the enhanced information provided to the market after the reform,[20] a possible explanation is that some traders' could better understand market mechanisms in some cases, whereas in many other cases banks were not fully able to process the information delivered to the market. This is especially evident until November 2004, i.e. six or seven months after the implementation of the new framework. After November 2004, the changes to the operational framework have helped attaining a critical mass of informed banks or, in other words, have reduced information asymmetries.

The effects of FTOs, from early 2005, may be twofold. On the one hand, FTOs involve a limited pool of banks and such operations may have increased banks' heterogeneity and increased opportunities to trade strategically to banks which can access to this channel. On the other hand, the need of fulfilling required reserves may be a disincentive to strategic trading, since the price to pay in liquidity withheld at the end of the period may be excessively high. In fact, looking at the developments after November 2004, this second effect seems to have prevailed which would explain the declining trend. An acceleration of the decline of heterogeneity is visible in coincidence with the start of relatively long phase started in October 2005, during which the ECB allotted systematically an amount of liquidity above the benchmark in response to the widening of the spread between EONIA and minimum bid rate. The explanation can be related to the fact that the increased in the liquidity supplied to banks reduced the margins for a strategic trading on information and, in this sense, decreased heterogeneity in the population of banks.

A discontinuity with respect to recent dynamics occurred clearly in 2007 with the materialization of the money market turmoil. Given its relevance also in explaining the recent dynamic in the model parameters, this event is analyzed separately in the remainder of this paper together with a closer look at the effects of the reform of the Eurosystem's operational framework.

Finally, an additional interesting parallel may be drawn between the evolution of the PIN and the cycle of monetary policy interest rate over the period considered (i.e. the red line in Figure 7). The increase in the PIN is associated to a stable period for the policy rates. By contrast, when the rate starts decreasing between 2002 and 2003, the PIN broadly stabilizes. This decline is possibly explained to the role of asymmetric information in particular on the uncertainty related to monetary policy decisions prior to the introduction of the March 2004 changes. In fact, the non perfect insulation of the overnight interest rate movements from ECB's decisions on key policy rates could have offered opportunities for informed trading as it is also witnessed by the strong link between expectations and MRO tender results on occasions. This link seems to have been broken in particular after 2005.

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[20]See Annex for more details.

5.2. The impact of the 2004 reform of the Eurosystem operational framework

This section offers a closer look at the effects of the changes to the Eurosystem's operational framework of March 2004 and of the other measures which followed, namely the conduct of almost systematic FTOs at the end of reserve maintenance periods and the loose liquidity policy conducted since October 2005. To do that, two non overlapping subsamples are considered : from December 2006 to March 2004 and from March 2004 until the end of 2006.[21]

Table 2 & 3 shows the estimates obtained for the four parameters on the two subsamples.

	Parameter	Standard error	t-Prob
α	0.272	0.028	0.00
δ	0.652	0.042	0.00
μ	0.152	0.002	0.00
ε	0.272	0.028	0.00
Likelihood	-75579.04	#obs	855

Table 2: Estimates prior to the reform of the operational framework (sample: 29/11/2000 to 9/3/2004)

	Parameter	Standard error	t-Prob
α	0.209	0.018	0.00
δ	0.585	0.031	0.00
μ	0.210	0.001	0.00
ε	0.279	0.001	0.00
Likelihood	-61722.83	#obs	722

Table 3: Estimates after the reform of the operational framework (sample: 10/3/2004 to 31/12/2006)

The results indicate that the probability of being in an event day declines after the 10 March 2004, as indicated by the decline of the α parameter from 0.27 to 0.20. This is in line with one of the goals of the reform, i.e. to insulate money market rates (in particular, the overnight rate) from non-technical factors related to liquidity or reserve management. The probability of being in a low signal day (δ) has declined : the parameter decreases from 0.65 in the period preceding the changes, to 0.58 after. The remaining parameters do not change significantly over the sample. Turning to the PIN γ, it has already been stressed before that information asymmetries appears to have declined after the introduction of the changes to the operational framework

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[21] The second subsample does not include 2007 and 2008 data to avoid any possible influence of the financial turmoil on the paramater estimates and to give a less blurred assessment of the effect of operational changes on the estimates of the model paramaters.

and, in particular, after the almost systematic conduct of FTOs at the end of the reserve maintenance period and the loose allotments.

Finally, a simple method to identify when exactly informed trading occurs within reserve maintenance periods has been applied. Such method consists in selecting the most-active days based on the estimate obtained for the parameter α. First, days are ranked in a decreasing order with respect to the observed number of contracts in every specific day and then a total of 230 days (or 150 after 10 March 2003) are selected and labelled as informed. As dates are known, the next step is to associate informed days to their occurrence within a reserve maintenance period using their position in the maintenance period (figure 8) before and after the 2004 reform.
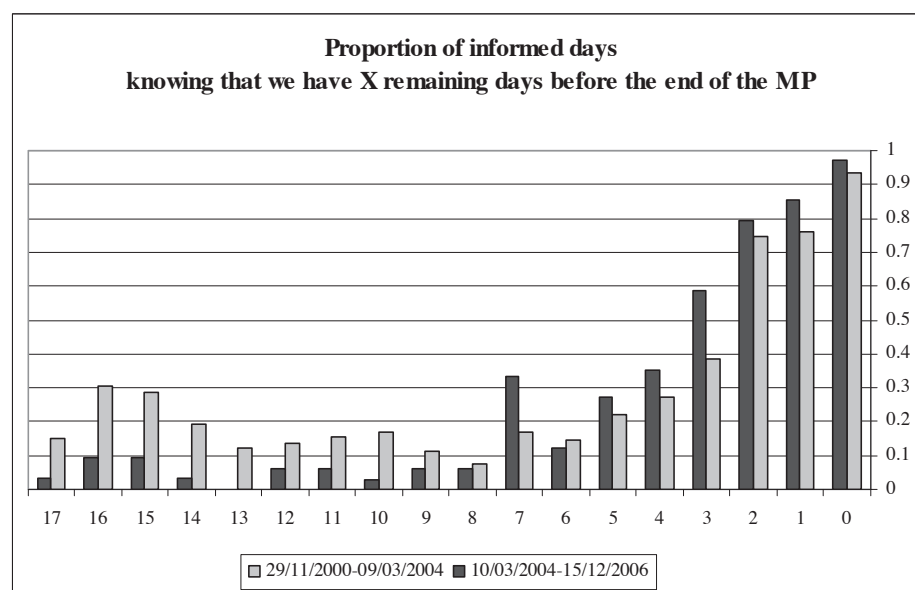
Figure 8: Information flows within maintenance periods

The information flow is relatively less concentrated on specific days before 10 March 2004, which might be explained by the fact that some events affecting the expected developments in the overnight interest rates lose their influence during the reserve maintenance period (e.g. monetary policy decisions). By contrast, informed days tend to be relatively more concentrated on fewer days after 10 March 2004, with a noticeable peak 7 days before the end of the period. This peak generally corresponds to the day preceding the last MRO of the reserve maintenance period and is likely to be related to increased importance of the last MRO for the fulfilment of individual liquidity needs after the changes.[22]

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[22] This is also visible in a more marked tendency of banks to bid more aggressively at the weekly MROs and, in particular, at the last refinancing operation of the maintenance period.

5.3.   The financial market turmoil

This turmoil mainly affected money markets and materialized in a marked and sudden reduction of market liquidity. As an immediate consequence, short-term interest rates rose by several basis points above policy rates and major central banks intervened with a number of exceptional measures to provide the necessary liquidity and thereby to avoid severe disruptions which could ultimately have economic detrimental effects.

At the microstructural level, a sudden lack of confidence among banks arrised from a substantive lack of knowledge about the financial soundness of trading partners (namely, banks most exposed in terms of derivatives instruments backed by sub-prime mortgage securities), affecting transactions on very short maturities such as overnight deposits. Central banks' response to counter the adverse effects of the turmoil was very swift. The ECB was very active to provide an extremely generous amount of liquidity through operations at various maturities.[23] Over the course of the following months, the ECB liquidity policy changed significantly with respect to the past in particular as regards two aspects: (i) a significant shift in the liquidity maturity from short-term (one week) to longer term refinancing (three months or more); (ii) a frontloading policy consisting on injecting a considerable amount of liquidity above the benchmark in the first MRO of the reserve maintenance period linearly reduced in the subsequent operations.

The effects of this policy are visible in the marked increase of the parameter Ψ reflecting the market liquidity after September 2007, as shown in Figure 9. This parameter broadly stabilized after January 2008, i.e. when operations tended to

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[23]Limiting to the sole euro area, starting from 9 August the ECB decided to conduct the following operations: three FTOs on 9, 10, 13 and 14 August of EUR 95 bn, EUR 61, EUR 48 bn and 8 bn respectively. On 6 September EUR 42 bn were allotted in another FTO. Moreover, the ECB allotted a significant amount above the benchmark in the first MROs of each reserve maintenance period as of August. Finally, in December 2007 a new set of operational measures was decided to contrast expected adverse effects ahead of the turn of the year. However, a significant amount of the liquidity injected in the banking system in the first weeks of December was absorbed in various FTOs which took place between 17 and 28 almost on a daily basis to prevent a marked decline of overnight interest rates below the ECB's minimum bid rate.

become more regular and so did the provision of liquidity to the money market.
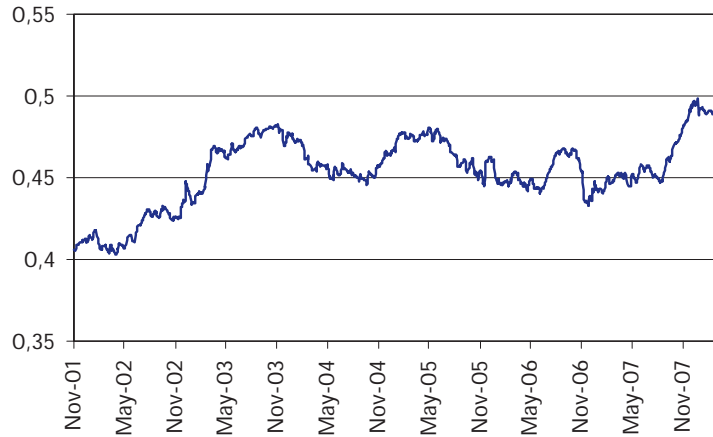
Figure 9: market liquidity Ψ between 2001 and march 2008

As regards the evolution of the PIN between January 2007 and March 2008 (Figure 10), the progressive decline of banks' information heterogeneity, which started in 2004, came to a halt in April, i.e. about four months before the emergence of the most visible effects of the turmoil.

Heterogeneity increased to reach a peak in coincidence with money market tensions around mid-August 2007. Afterwards, the PIN exhibited a steady decline which is likely related to the abundant injection of liquidity.

Figure 10: evolution of the PIN in 2007-2008

The decision to supply a massive amount of liquidity in the money market visibly reduced, among other effects, the potential for a strategic use of private information

by banks. Finally, considering no ECB intervention on liquidity allotment during the turmoil, i.e. with a constant ε the PIN would have increased from 0.38 to 0.45 in 2007. In other words, the risk of asymmetric information would have been almost 20% higher than it had actually been.
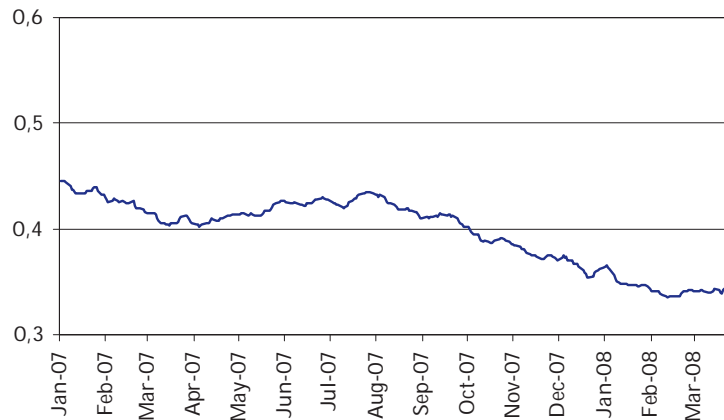
To conclude, a possible interpretation based on the PIN measure is that the ECB's response to the turmoil has apparently decreased the asymmetric information risk on the money market by easing transactions among banks.

6. CONCLUSION

The paper presents an empirical microstructure analysis of the euro overnight unsecured market based on the model of Easley and O 'Hara (1992). This is the first attempt to apply a simple sequential trade model to the money market to analyze the reaction between information asymmetries and the effects of the operational framework. The existence of institutional rules which are conditioning factors for trade makes our application somewhat original. In the money market, trades are mainly initiated owing to the existing requirements on reserves which drive banks' liquidity needs more than profit making considerations. Traders are also special. Banks are obliged to trade in a given time period (the reserve maintenance period) and have very strong "inventory constraints", since they face the threat of sanctions from the central bank or reputation issues if they do not fulfil reserve requirements. Finally, another peculiar aspect of this market is the presence and the role of the central bank. This institutional player has objectives different from those of commercial banks: monetary policy objectives are behind decisions on liquidity provision to the market through open market operations, which have an obvious influence on trade behavior.

The high-frequency data used in this analysis spans almost the entire history of the euro money market. Some significant changes have been introduced in the operational framework, and a *tâtonnement* process in the market, through modifications of rules, have influenced market conditions for trading over time. These changes are analyzed from various angles: market behavior, population of banks, information delivery and operational framework rules.

The conclusions are threefold. First, even if market rules on liquidity provisions exclude a pool of banks from participating (due to collateral requirements), heterogeneity has been decreasing since 2004 hence the smallest banks appear less marginalized, and do not trade overnight contracts on disadvantaged grounds. Second, the March 2004 changes of the operational framework appear to have improved market signals. By reducing both market tensions and opportunities for strategic trade, the increased frequency of FTOs at the end of reserve maintenance periods and the ECB's policy of allotting consistently liquidity above the benchmark

amount since October 2005 have reduced the impact of information asymmetries.

Finally, the use by the ECB of the available instruments during special events (as in the 2007 financial turmoil) have shown to be efficient in reducing information asymmetries and reduces market tensions in the interbank market.

In conclusion, empirical microstructure considerations may help to understand monetary policy issues and financial stability from a new perspective. In this sense, this paper is just a first step in this direction, but may motivate further research to assess the implementation of monetary policy rules from a microstructural point of view.

Annex.

The 2004 reform of the Eurosystem's operational framework

Focusing on the history of the Eurosystem after 1999, the most notable changes were introduced to overcome some issues emerged in the mechanisms in place to supply liquidity and to ensure a smooth liquidity provision to banks. Two elements were decisive to motivate the changes: overbidding, i.e. the tendency of banks to submit bids of increasingly sizeable amount at the weekly tender to avoid (liquidity) rationing, and underbidding, i.e. a phenomenon which took place when bids did not entirely cover the liquidity amount which the central bank intended to allot.

To stop overbidding, fixed rate tenders - i.e. tenders in which banks only requested quantities since the price was decided by the central bank - were abandoned in June 2000. They were replaced by variable rate tenders, i.e. auctions where banks offer a price in addition to the demanded amount of liquidity. This change did actually succeed in stopping overbidding and, with few exceptions. The rates resulting from weekly tenders have turned to be well anchored to the minimum bid rate. In this sense, the change to a variable rate system was successful since it has never hindered the transmission mechanism even if the ECB lose the direct control on prices (interest rates) paid for its liquidity. However, a new issue emerged: underbidding. Whenever the ECB failed to inject the liquidity necessary to the banking system, short-term money market interest rates reacted by rising markedly above the EONIA and increasing volatility. Before March 2004, underbidding took place 8 times and it was generally related to expectations on key ECB rate cuts.[24]

To overcome the occurrence of underbidding in weekly refinancing operations and, in this way, to stabilize money market rates, three major changes were introduced in the operational framework in March 2004:

1. The bulk of liquidity is supplied in only one operation and no longer in two outstanding operations. At the same time, the maturity of each main refinancing operation was shortened from two to one week.

2. Conditions on monetary policy interest rates are applied as of a new reserve maintenance period and no longer immediately after the decision is made.

3. The start and the end of reserve maintenance period is related to the date of the Governing Council meeting in which monetary policy decisions are made (i.e. normally on the first Thursday of each month), while before the change they always started on day 24 of each month and ended on day 23 of the following month.

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[24]Before March 2004, underbidding took place before interest rate cuts in three occasions, namely on 6 November 2001, 3 March 2003 and 3 June 2003. In the other cases, underbidding was caused by expectations on policy rate cuts or other technical reasons.

In this way, reserve maintenance period resulted better segmented and any interference of monetary policy decisions on liquidity management was removed and so were conditions for underbidding to take place.

These changes however have had some side effects which were addressed by other ad hoc measures. One effect is related to an expected increase of errors in autonomous factor forecasts due to the increase in the number of days between the last MRO and the end of the reserve maintenance period (normally five trading days after the changes, and on average three days before). To limit the impact on the expected higher uncertainty on autonomous factors' developments in the last days of the reserve maintenance period, it was decided to increase the information disclosed to the market before the weekly MRO. This change was also intended to reduce counterparties' uncertainty about the ECB liquidity management and to increase transparency vis-à-vis market participants. More precisely, the changes implied the publication of:

1. the benchmark allotment on the announcement day of the MRO;[25]

2. the updated benchmark allotment on the allotment day of the MRO (after making the decision on the amount of liquidity to inject);

3. the updated autonomous factor forecasts on the allotment day of the MRO after the allotment decision and

4. benchmark allotment and actual allotment amounts of the MRO

In practice, the information disclosed by the ECB changed from Figure 1.1 to Figure 1.2, which implied a substantive enhancement. In this way, at least in principle, ECB's decisions on allotment became fully transparent.[26]

A second measure was a marked increase in the frequency of fine-tuning operations conducted at the end of reserve maintenance periods to re-establish neutral liquidity conditions. From a microstructure perspective, these two events may explain more a discontinuity in the amount of informed trade as it will be shown in the empirical section of the paper. Unfortunately, due to the almost concomitant occurrence of these changes, it is difficult to analyze their effects separately on actual trade.

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[25] The benchmark amount is broadly defined as the sum of (net) liquidity absorbing autonomous factors, reserve requirements and excess reserves.

[26] The new information complemented the formula for the calculation of the benchmark published in the ECB Monthly Bulletin Box entitled "Benchmark allotment rule normally applied by the ECB in its main refinancing operations" (May 2002). Combining the enhanced information with the formula, market participants were able to calculate exactly the benchmark.

Reuters Screen ECB40


```
08:09 08FEB00    EUROPEAN CENTRAL BANK, FRANKFURT a.M.    GE66608    ECB40
Current account holdings of counterparties with the Eurosystem
Including holdings to fulfil reserve requirements. In million of euro.

As at 07/02/2000
(Maintenance period: 24/01/2000 to 23/02/2000)

Current account holdings (*)                                        109,057
Estimated reserve requirements (**)                                107,500
Average current account holdings in current maintenance period (*) 108,689

Use of the standing facilities of the Eurosystem:
Use of marginal lending facility                                        11
Use of deposit facility                                                 61

(*) Including minimum reserve holdings. For historical data see ECB41.
(**) Preliminary estimate of reserve requirements for the current MP
```

Figure 1.1: ECB40 screen before March 2004


```
ECB40    show ∨   do ∨
09:21 17APR07    EUROPEAN CENTRAL BANK, FRANKFURT a.M. GE66608        ECB40
Information on liquidity conditions in the euro area (in millions of euro).

Reserve maintenance period (MP): 14/03/2007  to 17/04/2007
Average reserve requirements for the current MP              181,839

Estimate on 17/04/2007 of average daily autonomous factors:
for the period 18/04/2007 to 24/04/2007                      248,000


Figures as at 16/04/2007
Average current account holdings in the current MP (1)       183,130

Outstanding open market operations                           430,002
Use of marginal lending facility                               1,976
Use of deposit facility                                           97
Autonomous liquidity factors                                 244,076
Current account holdings (1)                                 187,805
Please see page "Announcements on Operational aspects"


(1) Including minimum reserve holdings. Historical data on subsequent pages.
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Figure 1.2: ECB40 Screen after March 2004

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