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A survey of research into broker identity and limit order book

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A survey of research into broker identity and limit order book transparency

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Abstract

This survey summarizes and analyzes theoretical, empirical and experimental research that addresses limit order book transparency in securities markets. We conclude that changes in market design that alter transparency have far reaching but complex impacts on market quality, market efficiency and price discovery. We suggest that future research into the impact of transparency choices in market design should take a more holistic approach in which several aspects of market quality are considered, results are verified across different market segments impacted unequally, and, ideally, matching securities in other markets are used as controls. We consider what policy recommendations can be made based on current evidence and suggest what more research needs to be done.

JEL Classification: G10, G15, G18

Keywords: Transparency, Opacity, Broker ID, Market Efficiency, Limit Order Book

1. Introduction

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Despite the significant attention that limit order book transparency has received in the literature on securities market design, the effects of transparency on market quality are still poorly understood. More transparency is generally considered to be related to greater fairness, more efficient information acquisition and better governance, thus at first glance a benefit to all market participants. The marginal investor and his or her broker would accordingly be expected to prefer a transparent limit order book.[1] Below the surface the impact of limit order book [LOB] transparency is more complicated, for example large fund managers [2] are often concerned that other market participants may front-run, quote match or piggy back [3] their orders in a fully transparent environment. Hence this category of large buy side investors and their brokers support a less transparent order book design. This article aims to review relevant theoretical, empirical and experimental studies with focus on limit order book transparency and suggests directions for future research.

"Microstructure models generally originate from the fact that markets can differ in a number of aspects including the typology of participants, their attitude towards risks, the existence of fixed entry costs, the organizational structure of trades and the degree of transparency" (Jong and Rindi (2009)). At the heart of microstructure research, transparency is

[1] Australian broker-dealers often complain about how hard it is to find counterparties to trades in the anonymous trading environment after broker IDs were hidden in November, 2005, when they compare to the preceding period when brokers showing their interest in the orderbook could be contacted to negotiate trades.

[2] The authors discussed with traders at one of the largest pension fund managers in Australia shortly after the move to an anonymous orderbook in 2005 and they emphasized how much easier it is for them to execute large trades as they do not have to be concerned about their orders being exposed in the market.

[3] Front running is when a participant enters an order in front of another order in the same direction, e.g. when a broker-dealer trades ahead of large client orders either on behalf of other customers or themselves, quote matching is when a participant enters and order at the same price as another order in the same direction, piggy backing is when a participant enters and order at a price level close to another large order to benefit from its impact on liquidity.

defined as “the ability of market participants to observe information about the trading process” (O'Hara (1995)). The concept can be also partitioned into *pre-trade* and *post-trade* transparency. Pre-trade transparency refers to the current quoted prices and quantities, market depths, and/or to the market participants’ identities, and may be directed to all the agents present in the market or to a subset (i.e. brokers/dealers). Post-trade transparency refers to the public and timely disclosure of the size and direction of the executed orders and the identity of the traders. There are different nuances of both pre-trade and post-trade transparency depending on the structure of the exchange and the type of information provided, for example how widely the *identities of market participants* is disseminated and *how many price levels of the limit order book* are visible. The opposite to a transparent LOB is often called opaque or anonymous.

The LOB is the collection of unexecuted orders, normally relatively small orders submitted by numerous and diverse traders. The unique feature of the book is that the trader who places a limit order does not know the total size of the incoming order that will cause his own order to execute. A large marketable order will ‘walk through the book’, with the first quantity executing at the most favorable price and successive portions on less favorable terms (Hasbrouck (2007)). If the limit order book is transparent it is easier for a trader to estimate what the likely execution outcome will be, as the available limit orders are visible. This article focuses on the impact of displaying or not displaying broker identification, in the following *ID transparency*, and the impact of changing the number of levels of the LOB that are displayed, in the following *LOB transparency*. We investigate what the literature has uncovered about how these market transparency choices impact market efficiency and market quality, indicated by among others transaction costs, liquidity and price discovery. While we discuss the distinction between pre-trade and post-trade transparency, this is not the main focus of this survey.

Although there have been a large number of studies on the effect of disclosure of participants' identities, the studies assume one state of the market, either 'Anonymous' or 'Transparent', while they largely ignore that the information often is only available to certain participants, typically the broker and dealers that are exchange members. The unequal access of market participants to the traders' identities and other information in the LOB might notably influence the market efficiency and trading volume, as well as other aspects of market quality. Thus, there is an urgent need for better understanding of how different degrees of disclosure of LOB information, including broker identities, affect market quality. In addition, there are also markets, such as the Toronto Stock Exchange, that allow traders to decide themselves if the broker identity is to be disclosed or not, which creates a market where the broker identity is public for some orders and hidden for others. Comerton-Forde and Tang (2007) report that most market participants choose to keep the broker ID for their orders public when there is a choice. They find that anonymous orders are used more frequently by proprietary traders than by their clients, their overall use is low and there is no evidence that they are commonly used to conceal front running.

An efficient market is a public good that benefits all individuals and organizations in the market. Informational efficiency discussed here is not to be confused with allocational or Pareto efficiency, as informational efficiency refers to the extent that share prices reflect the information available to investors. An informationally efficient market plays a crucial role for all market parties, given that in such a market, a share price reflects all that is known in relation to the prospects of the company and the collective view of the market as to what it is worth. Astonishingly, given the prominence of market efficiency in market policy initiatives, there has been a policy gap due to a failure to fully address relevant issues, such as the gains from trade

and market efficiency within a framework of utility maximizing agents, hence making the assumption that market participants trade to maximize their utility.

There is still little theoretical or empirical consensus in the literature about the effect of transparency on traditional market quality metrics, such as quoted and effective spreads, volatility, depth and volume, likely due to that current empirical research typically ignores the endogeneity in these variables. Many empirical studies investigating the impact of transparency/opacity alterations begins by pointing out that the change altered a whole variety of metrics such as volume, volatility, effective and realized spread (for example Foucault, Moinas and Theissen (2007); Comerton-Forde, Frino and Mollica (2005); Comerton-Forde and Tang (2009)). Empirical studies in market microstructure almost exclusively use one of these metrics as a dependent variable and treat the remaining market quality metrics as exogenous control variables. The apparent endogeneity raises a question about the eligibility of some of the control variables in the models that have been applied to assess the impact of transparency. One notable exception is Eom, Ok and Park (2007), who examine the impact of expansions of the best bid and ask levels revealed to the public controlling for variable endogeneity. Thus, there is a need for a thorough discussion on how to best measure market quality and for empirical research to select appropriate exogenous variables to explain market quality changes.

This survey begins by reviewing theoretical work that hypothesizes on the market quality effects of a publicly transparent limit order book and transparent or anonymous broker identities; we then review empirical studies that assess the impact of transparency on market quality proxies. We finally discuss experimental studies on the topic. The article finishes with a summary of the conclusions and suggests directions for future research.

2. Transparency of Broker Identification

2.1. Theoretical Review ID Transparency

Madhavan (1996) compares markets with different levels of transparency (the model applies to both ID and LOB transparency) based on a game-theoretic model. He comes to the conclusion that transparency may induce a form of market failure because traders are unwilling to reveal their information to others and are less willing to share risk by trading. However, this applies only to linear equilibria, and a linear equilibrium may not exist if the market is too transparent. He shows that in a transparent mechanism, price volatility might be lower if the market is sufficiently competitive, or higher if markets are sufficiently thin where the effects of the reduction in the perceived level of noise trading are the greatest. Thus, transparency has a mixed effect on security prices. He concludes that greater transparency may, in less liquid markets, induce lower liquidity and higher implicit transaction costs.

Rindi (2008) constructs a model based on Madhavan (1996), but she clarifies the effect of transparent trader or broker identities on adverse selection costs by assuming that liquidity providers are risk averse; in her model all market participants, including both informed and uninformed, can simultaneously submit limit orders and can enter and leave the market at their convenience. Rindi (2008) emphasizes the assumption that market participants are endogenous. Under full transparency, uninformed traders recognize liquidity traders and so are ready to offer liquidity. Thus, ID transparency increases liquidity. However, when information acquisition is endogenous, ID transparency reduces the incentive to buy costly information and so reduces the number of informed traders. It follows that the initial result on the effect of pre-trade ID transparency on liquidity in Rindi's model is reversed and ID transparency ultimately lowers the number of informed agents who enter the market and thus reduces liquidity. Green, Hollifield

and Schürhoff (2007) developed a simple theoretical model that distinguishes three components of the dealer's gains on a trade: the commission for facilitating the trade, a zero-mean forecast error and a measure of the dealer's market power. They find that increased ID transparency reduces cross-subsidization from smaller traders in favor of larger traders. The greater ID transparency leads to a reduction in costs by encouraging smaller traders to submit larger orders, and thus increases liquidity. Timely reporting of price information is found to reduce bargaining power for dealers in their trading with small traders.

In summary one theoretical model indicates that ID transparency may have both positive and negative effects on market quality depending of liquidity, one model indicates negative effects in the limit order book while another model indicates positive effects in a dealer market.

2.2 Empirical Review ID Transparency

The theoretical literature is valuable in providing insights into the expected effects of market design choices. However, the strategies applied by market participants in markets of different design are often too complicated to be modeled and assumptions and simplifications in theoretical models may not apply to real markets. A significant number of empirical studies have been implemented in different stock exchanges. The first category of studies investigate the impact on bid-ask spreads of the removal of pre-trade ID transparency, the second category looks how delayed reporting of trades, hence post-trade removal of ID transparency affect spread. Finally a few studies look at the impact of the removal of ID transparency on trading volume and market efficiency.

2.2.1 Evidence against ID Transparency

Simaan, Weaver and Whitcomb (2003) examine the impact of pre-trade transparency on the quotation behavior of NASDAQ market makers. Their findings support Rindi (2008) assertion that allowing anonymous quotes could improve price competition and narrow spreads further because market makers would have a much higher propensity to actively narrow the spread than they do when quoting directly in the NASDAQ quote montage.

Foucault, *et al.* (2007) study the pre- and post-periods surrounding April 23, 2001, when the LOB for stocks listed on Euronext Paris was made anonymous. They propose a theoretical model where informed bidders exploit the transparent market by bidding as if the cost of liquidity provision was large, when in fact it is small. This strategy is less effective when traders cannot distinguish between informative and uninformative limit orders. Hence informed bidders act more competitively in an anonymous market where average quoted spreads and volatility decline significantly. However, the 40 stocks they examine in this paper were the only ones subject to the change in pre-trade transparency (unlike other Paris stocks). It would be interesting to see what happens to the overall market, something that is partly addressed in Majois (2007).

Comerton-Forde, *et al.* (2005) investigate Euronext Paris, the Tokyo Stock Exchange and the Korean Exchange [KRX]. While their findings are consistent with Foucault, *et al.* (2007) in case of Euronext Paris, they find a decrease in relative bid-ask spreads and effective spreads at Euronext Paris, little change at the TSE and the reverse effect at the KRX. Comerton-Forde and Tang (2009) examine the effects of the removal of broker identifiers from the central LOB of the ASX. They find that spreads and order aggressiveness decline, and order-book depth increases, with the introduction of anonymous trading. Other studies of the Australian case include Lepone and Mistry (2011) who find that the removal of broker identifiers does not provide consistent

evidence of any changes in the short-term information content of large dollar volume orders. This suggests that disclosed orders provide more information to the market than do broker identifiers.

Maslov and Mills (2001) find that corporations with larger market capitalization and higher trading frequency tend to narrow down the price gaps between their successive bid and ask on average, and that the average size of a limit order decreases with the level of the order book. Menkhoff, Osler and Schmeling (2010) conduct an empirical investigation of the difference between informed and uninformed traders' aggressiveness in a pure limit-order market. They find that informed traders are more sensitive and respond more rapidly to changing market conditions than the uninformed, which boosts the dominance of the informed over limit-order submissions. To this we suggest that if the brokers' IDs are public, the impact of such asymmetry in order flow may be less severe as participants can infer the expected impact of the orders causing asymmetry when they know the origin of the order.

Gemmill (1996) examines the impact of reducing market transparency by postponing the time of price disclosure for block trades on liquidity in the London Stock Exchange, and finds negative effects. The analysis uses standard event-study methodology in three different revelation regimes: immediate, 90 minutes and 24 hours. They find that the size of spreads is affected by market volatility rather than speed of publication. Furthermore, they do not document any significant effect of timely publication on speed of adjustment, smoothing or ultimate price level. Board and Sutcliffe (2000) strengthen Gemmill (1996) conclusion by implementing an empirical study on the same stock exchange but in a different time period. They investigate the effect of the change in trade publication rules on January 1, 1996 that reduced the proportion of

major traders delaying publication. They find that this more transparent regime leads to no evident negative change in market quality. With greater transparency, information asymmetries are reduced, and Board and Sutcliffe (2000) conclude that "neither the volume nor the traded bid-ask spread has been adversely affected".

2.2.2 Evidence in favor or ID transparency

Porter and Weaver (1998) study delayed post-trade reporting on the NASDAQ National Market System, and reach the opposite conclusion to the London Stock Exchange research. They discover a substantial number of out-of-sequence trades following delayed post-trade reporting using the 90-second rule in the NASDAQ. They argue that this rule could create an environment where some traders use late trade reporting to delay the release of strategic information, which would impede the price discovery process and increase transaction costs.

A limitation of existing empirical literature is the lack of study of the role of broker identities on the informational content of trades and market efficiency. A recent study of Frino, Johnstone and Zheng (2010) examines the price and market impact of consecutive buyer/seller-initiated trades by the same brokers. This paper finds that the identity of brokers contains information, and concludes that disclosure of the broker identification is likely to result in more efficient markets.

Lepone, Segara and Wong (2012) who investigate the lead up to takeover announcements and find that informed traders are less easily detected when broker IDs are concealed, an indication that transparent broker IDs improve market efficiency in this context.

Linnainmaa and Saar (2012) use the detailed investor level data from Finland to show that there is valuable information contained in the broker identity, and that traders make use of this information to infer which brokers are more likely to represent informed traders. The market has since followed the suite of other limit order-driven exchanges and ceased displaying broker IDs pre-trade, but still reveals this information post-trade except for the most liquid companies.

Pham, Swan and Westerholm (2013) investigate the move to anonymous broker IDs on the ASX in November 2005, and find that traded volume in the limit order book falls relative to the traded volume off market when variables with endogenous effects on volume are replaced by instrumental variables. They also show that prices follow a random walk in the transparent environment and that the serial correlation in prices increase in the opaque environment. Pham, *et al.* (2013) demonstrate that the effect on spreads is minimal and that the change in ID transparency has a more significant effect on other metrics for market quality.

2.2.3. Challenges to these empirical findings and summary of analysis

Current empirical research into ID transparency can be challenged on many points, but it has to be emphasized that researchers only have a limit number of natural experiments to work with and often do the best they can with what they have. We already pointed out that all of these studies are potentially affected by endogeneity in the controls that are utilized. Another caveat of the empirical research is that "they compare anonymous automated market structures with separate non-anonymous market structures where liquidity suppliers can selectively participate after observing the identities of other participants" (Tang (2008)). Consequently, these studies constitute joint tests of the effects of both market structure and anonymous trading.

In addition to the above, most studies investigate one-off transparency events in the unique markets which may limit general application of their results. Using the first major market to make broker IDs anonymous, Euronext, as an example for our argument, the outcomes of Foucault, *et al.* (2007) are limited to CAC-40 stocks, which are subject to pre-trade transparency changes, and full post-trade opacity. The transparency of LOB and broker IDs after trading these very large stocks theoretically makes a significant difference in market quality, while the impact may be different in the other market segments. Finally, the results in the literature regarding Euronext may also be driven by a global liquidity trend during the investigated period, as shown in Majois (2007), who investigates the effect of anonymity on spreads using a large sample of Euronext Paris stocks, and compares the results to trends in spreads on the NYSE during the same period.

Finally since most events studied are a change from ID transparency to ID opacity, often in combination with an increase in LOB transparency, it is very likely that what is picked up is a secular trend of increased liquidity over time, driven by among other things increased automation of the trading process and a continuous increase in execution speed. Future research needs to either include an equal number of events that increase and decrease transparency or sufficiently deal with the issue of trending changes in the investigated variables.

In summary empirical studies of the effect of ID transparency are divided. The reason is that these studies are investigating different aspects of market quality. In most studies bid-ask spreads decrease when broker IDs are hidden, but some studies find decreased trading volume in the centralized LOB in favour of off-market and alternative trading platforms and decreases in

market efficiency. This is why it is important to analyze these incremental results across studies with the purpose of obtaining some consensus on the effect of ID transparency.

3 Transparency of the Limit Order Book

3.1 Theoretical Review LOB Transparency

Pagano and Roell (1996) propose a model to study the effect of different degrees of order flow visibility on liquidity in an anonymous environment. Thus, market makers are assumed to be able to infer information by observing order flows only. Pagano and Roell (1996) set their bid-ask spread so as to protect themselves against an adverse selection problem potentially generated by insiders rather than to cover their inventory holding costs, as in Biais (1993). They prove that even if prices are less favorable over some range of order sizes, the implicit bid-ask spread of noise traders will be tighter in a more transparent auction market, as the more information traders learn about the order flow, the better they can protect themselves against losses to insiders. Biais (1993) models the bidding strategies of risk-averse agents who are market makers or limit order traders in a centralized market, and dealers in fragmented markets, competing for one market order. Centralized markets are regarded as more transparent mechanisms, as market makers or limit order traders can observe the quotes of their competitors; meanwhile, dealers can only assess the positions of their competitors in fragmented markets. With the assumption of asymmetric information between dealers and liquidity traders, he shows that the expected spread is equal in both markets with different market structures.

Two later studies, following a model of market making with inventories based on Biais (1993), arrived at diametrically opposite conclusions. Slightly modifying the market model with risk-averse dealer assumption, Frutos and Manzano (2002) show that “greater transparency may

have detrimental effects on liquidity" because of less competition among risk-averse dealers for the order flows, and thus higher spread. In contrast to Biais, Hillion and Spatt (1995), Frutos and Manzano (2002), and Yin (2005) introduce a tiny searching cost and find that the expected bid-ask spread in a fragmented market is greater than in a centralized market, which is more transparent. In a fragmented market, which is less transparent, the public investors can acquire transaction information by visiting dealers and obtaining quotes from them. Although dealers pass their own quotes to their clients at no explicit cost, liquidity traders still incur some implicit cost, for example, time spent on connecting with dealers, other direct costs or opportunity costs, in searching for favorable prices. The theoretical finding of Baruch (2005) is in line with Yin (2005). Baruch (2005) models a specialist's single price auction market, similar to the auction that the NYSE uses, to open the trading day under two different market mechanisms, in which the LOB is open in the first and closed in the other. He states that when the book is open, the transitory component is lower, due to the increase in competition for liquidity provision. Thus, the informed trader trades more aggressively, releasing more of his private information. However, the decrease in the transitory component of the spread offsets the increase in the adverse selection component, so that overall trading costs are lower and prices are more informative in the open-book environment. As a result, increased transparency can improve liquidity and informational efficiency of stocks markets.

A number of theoretical studies on post-trade transparency have been performed. Chowdhry and Nanda (1991), extending Kyle (1985) and Admati and Pfleiderer (1988) models, study a situation where a security trades at multiple markets simultaneously, and informed traders have several venues to exploit their private information. They consider two scenarios: one assumes that the private information possessed by the informed trader is short lived; the other

assumes that the insider's information is long lived and incorporated into price after each round of trading. For the former, they argue that small liquidity traders will favor the market where liquidity traders, who are unable to move between markets, contribute most to the trading volume, as their expected trading costs are minimized. The informed and large liquidity traders are also attracted by this market. Chowdhry and Nanda (1991) extend Admati and Pfleiderer (1988) finding that trading patterns are sensitive to the proportion of market traders who do not have the flexibility to trade in their expected market locations. In the latter scenario, they find that the informed traders would not prefer a location where market makers can disclose the price information to public, as a timely release of price information may deteriorate the expected gains of informed traders in other market locations as well. Their results imply that competing market makers in a multiple market setting will voluntarily make price information public to deter informed trading at their location due to reduced adverse selection; eventually, this market will attract the largest proportion of large liquidity as well as informed trading.

This view is advocated by Madhavan (1995), who develops Glosten and Milgrom (1985) model of a dealer market with three types of traders, including noise traders, larger liquidity traders and informed traders, in which successive traders' arrivals are not independent. He analyses two transparent mechanisms: in the first system, dealers have homogenous information where trade disclosure in mandatory and individual trades may be executed in different market centers. In another system, they consider that trader disclosure is voluntary for dealers; thus dealers have heterogeneous beliefs, and prices may differ across market centers at a given point in time. In the first scenario, they found that spread narrows over the day where information is compulsorily disclosed, because market makers learn from order flow, thereby facilitating price discovery. In a fragmented market where disclosure of trading information is optional, large

liquidity traders and informed traders can obtain better trades through dynamic strategies, creating a demand for non-transparent trading systems. Non-disclosing dealers may benefit from their private information on past trades by selectively participating in future trading because of less price competition. Yet these gains come at the expense of noise traders. Madhavan (1995) concludes that bid-ask spreads become narrower in a transparent market, and the opposite is observed in an opaque market. This research also implies that a market without post-trade disclosure results in higher price volatility and inefficient prices.

In contrast to previous advocators for transparency, Naik, Neuberger and Viswanathan (1999) state that the effects of release of post-trade information are ambiguous. Their paper analyses a two-stage model of trading in a dealership market, where a public investor trades with an arbitrarily chosen market maker in the first stage, and the market makers offset their position by trading with other market makers. They find that greater transparency reduces adverse selection and hence enhances the sharing of quantity risk. However, "disclosure reduces the ability of the market to offer insurance against price revision risk to investors who wish to hedge their endowment shocks", and worsens price revision risk sharing. In contrast, "a lack of trade disclosure worsens quantity risk sharing but improves price revision risk sharing", which leads to an ambiguous welfare comparison. The limitation of this model is that the number of market makers is assumed to be exogenous, and the public investor acquires information exogenously. If public investors have to expend effort to collect information, different disclosure regimes would stimulate different incentives for gathering information.

3.2 Empirical Review LOB Transparency

3.2.1 Evidence in favor of LOB Transparency

The informative value of revealing deeper degrees of LOB is reinforced in Cao, Hansch and Wang (2009). Using order-book information from the ASX, they find that the LOB allows more accurate estimations of a security's value than simply the best bid and offer, and that the order book beyond the best bid and offer contributes approximately 22 per cent to price discovery. Essentially, the following empirical studies show that making different levels of the LOB transparent can affect market quality in distinctive ways.

Boehmer, Saar and Yu (2005) support the theoretical outcome of Baruch (2005) above, and find that increased transparency can improve the liquidity and informational efficiency of stock markets. Boehmer, *et al.* (2005) investigate how pre-trade transparency affects investor trading strategies, specialist behavior, market quality and the informational efficiency of prices. This is an empirical study following the introduction of NYSE's Open Book service with charge, which shows the aggregate limit-order volume available in the NYSE Display Book system at each price point. Using a variance decomposition methodology proposed by Hasbrouck (1993), Boehmer, *et al.* (2005) conclude that greater pre-trade transparency is a win-win situation. Investors do change their strategies in response to the change in market design: they submit smaller limit orders and cancel limit orders in the book more rapidly and more frequently. Effective spreads decrease and liquidity improves following the introduction of Open Book. However, since they did not observe the complete trading strategy of each investor, they were unable to judge whether the trading costs of investors who utilized both market and limit orders in the new regime were lower than the trading costs when traders did not have information about the book.

How transparency affects the behavior of market participants may depend on the degree of information asymmetry in the market. Hedvall, Niemeyer and Rosenqvist (1997) conclude that the underlying assumption in much of the previous research is a symmetrical market in respect to the buy and the sell side; however, the potential asymmetry may lead to aggressive sequences of order submissions. They also find that oversized trades seem to induce new provision of liquidity from the opposite side of the LOB. Several studies address the asymmetry of orders. Large (2007) test the resiliency of order books after significant events (such as big trades), specifically in Barclays on the London Stock Exchange. He concludes that the resiliency response is fast when it does occur, but it occurs infrequently.

Hendershott and Jones (2005) show that price discovery declined when the Electronic Communications Network (ECN) Island stopped providing order-book information for exchange traded funds. Eom, *et al.* (2007) correct for endogeneity in market quality metrics used as dependent or control variables, and find that two Korean increases in the level of order-book information displayed to the public have positive effects on market quality. Bessembinder, Maxwell and Venkataraman (2006) and Green, *et al.* (2007) investigate the effect of public transaction reporting on trading costs, before and after introduction of the TRACE reporting system, using a sample of institutional trades in corporate bonds. They find that when the TRACE system started to publish their prices, trade execution costs fell, after controlling for the effect of interest rate volatility and trading activity. Edwards, Harris and Piwowar (2007) examine a similar event, but use a record of US over-the-counter secondary trades in corporate bonds to examine the impact of price transparency on transaction costs. They utilise an improved method and more comprehensive data and find stronger evidence of the benefits of transparency to market liquidity. Execution costs are found to be less for bonds with transparent trade prices

than for similar opaque bonds, and the costs reduce when bond prices are switched from opaque to transparent.

Bessembinder and Maxwell (2008) and Chung and Chuwonganant (2009) examine markets after a transparency altering 'event' has taken place: specifically, the introduction of TRACE (a program developed by the National Association of Securities Dealers (NASD) which allows for the reporting of over-the-counter (OTC) transactions pertaining to eligible fixed-income securities); and the introduction of the trading platform SuperMontage on NASDAQ, respectively. Both the introduction of Trace (Bessembinder and Maxwell (2008)) and the introduction of Supermontage (Chung and Chuwonganant (2009)) were found to increase transparency and increase market quality. The TRACE was found to narrow the bid-ask spread, while the SuperMontage also narrowed effective and quoted spreads and additionally led to faster executions and higher fill rates, and lower return volatility

3.2.2 Evidence in against LOB Transparency

Other researchers have the opposite viewpoint. Madhavan, Porter and Weaver (2005) compare the market performances prior to and after the Toronto Stock Exchange instituted a computerized system to disseminate the depth and quotes for the current inside market (as well as the depth and limit order prices for up to four levels above and below the current market), and find that the increase in transparency reduces liquidity and increases execution costs and volatility.

Bortoli, Frino, Jarnecic and Johnstone (2006) find a decrease in the best depth when more levels of the LOB are displayed at Sydney futures markets. Aitken, Berkman and Mak (2001) found two regulation changes on the ASX that forced traders to display more of their orders discouraged primary liquidity suppliers, resulted in a fall in trading volume. The regulation

change increased transparency but led to deterioration in market quality in terms of trading volume. Changes in the bid-ask spread were found to not be statistically significant.

3.2.3. Summary of Analysis

Several studies prove that the LOB contains valuable information for other market participants including market makers and specialists without directly addressing changes in LOB transparency. Jiang, McInish and Upson (2009) examine trading halts and their effects on informationally related stocks in the limit order book. They conclude that when stocks are informationally related, trading halts induce higher trade-based liquidity and lower quote-based liquidity. Fong and Liu (2010) document the regularity of limit order revisions and cancellations and examine their determinants. Harris and Panchapagesan (2005) investigate whether specialists can use limit order book information to predict future price changes. Hence, the dissemination of this information needs to be fair, and ideally, in our view, provided to all market participants to promote a fair and orderly market.

The case of LOB transparency is significantly more clear cut than ID Transparency. Both theoretical and empirical studies without exception conclude that displaying more rather than less information about the individual orders in the LOB is beneficial for market quality benefiting the overall welfare of all market participants. Naturally there are a few privileged functions such as specialists that benefit for the privileged access to the LOB information that will lose their advantage when it is publicly displayed and they may no longer be able to contribute to liquidity. Hence some dealership markets may operate more optimally with less LOB transparency.

3.3 Experimental Review

Studies also turn to experimental markets that have the benefit that the research environment can be simplified and designed to perfectly fit the model to be tested. Flood, Huisman, Koedijk and Mahieu (1999) support Yin's (2005) prediction about higher search costs in opaque markets that result in wider opening spreads and lower trading volume. However, Flood, *et al.* (1999) states that "higher search costs also induce more aggressive pricing strategies" resulting in faster price discovery in the opaque environments. It is important to mention that this experiment is assumed to affect pre-trade transparency only, not revelation of post-trade transparency in both scenarios. Thus, the outcomes may reverse when the entire order flow is transparent.

Bloomfield and O'Hara (1999) build up three different transparency regimes. In a transparent setting, both market makers' quotes and trades are published after each round of trading. In a partially transparent setting, quotes are displayed but trades are not. In a fully opaque setting, neither trades nor quotes are disclosed. Their findings are consistent with Madhavan (1995) and Pagano and Roell (1996), showing trade disclosure significantly improves the market efficiency. They also observe wider spreads in more transparent markets, which are explained by the market makers' reduced need to compete for order flow to derive information about security value.

Yamamoto (2011) investigates two artificial markets, each with different levels of transparency. He concludes that the level of pre-trade transparency is irrelevant to investors' trading frequency, as trading strategies are decided based on current order imbalances. His finding implies that "the strategy constructed by the state of the order book is a key for explaining long memories in many actual stock exchanges".

Table 1 provides a summary of the key investigated research articles, where the reader can obtain an overview of this area of research. The table also provides more detail of what market and market type has been studied as well as details of the investigated event.

4. Conclusion

In conclusion, the discussed theoretical and empirical studies together weave a complex but distinct pattern which helps us understand how modern securities markets function, and how they may be impacted by changes in design that alter the interaction between more and less informed market participants and larger and smaller orders. Both ID and LOB transparency of a market will have a great impact on the interaction between differently endowed market participants. The theoretical studies are evenly distributed between supporting of transparency vs. opacity, often predicting that increased transparency promotes higher bid-ask spreads but also more efficient price discovery and higher market efficiency.

The empirical literature shows that ID and LOB transparency increases spreads, while increased LOB transparency lowers spreads. Since spreads are endogenous to increased liquidity in the form of higher volume and faster price discovery some recent studies point out that markets participants may in fact be better off in an ID and LOB transparent market design. There are important exceptions to this, e.g., liquidity providers are shown to facilitate more trading when they have access to anonymous market venues, hence markets with a strong reliance on liquidity providers may need to provide lower degrees of transparency to their participants for optimal efficiency. Considering the results of theoretical, empirical and experimental studies and taking into account outlined weaknesses in the presented research, it is our view that *in the*

modern limit order book environment that relies on the externality of orderflow provided liquidity, higher ID and LOB transparency will generally attract more liquidity.

Empirical research on the effect of transparency on market efficiency, arguably an important aspect of market quality, is limited. Whereas there is theoretical and empirical evidence of improvements in price discovery in an open LOB, there is little discussion of the impact of revealed broker identities on strong-form price formation. Another area that needs attention is how different degrees of ID and LOB transparency affect the up-take of alternative off-market trading venues such as ECNs and dark-pools in today's increasingly fragmented market place.

As directions for future research into the impact of transparency choices in market design, we suggest a more holistic approach where several aspects of market quality are considered, endongeneity in market quality variables is controlled for, results are verified across different market segments impacted unequally, and, ideally, matching securities in other markets are used as controls. Investigating several global events simultaneously would be useful, but such a study would be difficult to implement with a convincing approach. A better approach may be to move away from event studies and focus on changes in investor and order level transaction behavior as a result of alternations in LOB transparency.

While the abovementioned extensions to the research are needed to make more detailed policy recommendation the evidence indicates that segments of large liquid stocks would benefit from an ID and LOB transparent LOB, while segments of less liquid shares may trade more effectively in an opaque order book, provided that trading is supported by liquidity providers.

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Table 1 Summary Table of Investigated Research Articles and Investigated Markets Including Event Dates

Research Article	Investigated Markets	Type of Market(s)	Event Date
Admati and Pfleiderer (1988)	NYSE	Hybrid	Theoretical
Aitken, Merkman and Mak (2001)	ASX	automated-order-driven	two regulation changes: 24 October 1994 and 16 October 1996
Baruch (2005)	NYSE	Hybrid	LOB made visible to public 24th January 2002
Bessembinder, Maxwell & Venkataraman	NYSE, OTC dealer Market	Quote driven/ 'Broker'	Regulation Change (TRACE) July 1st 2002
Bessembinder and Maxwell (2008)	NYSE, OTC dealer market	Quote driven/ 'Broker'	Regulation Change (TRACE) July 1st 2002
Biais (1993)	Centralised Vs Fragmented		Theoretical
Biais, Hillion & Spatt (1995)	Paris Bourse (Now called Euronext Paris)	automated-order-driven	Empirical
Bloomfield & Maureen (1999)	Artificial, varying degrees of transparency	Quote-Driven	Experimental
Board & Sutcliffe (2000)	LSE	Automated-order-driven	1 Jan 1996 Trade publication rules changed
Boehme, Saar & Yu (2005)	NYSE	Hybrid	Introduction of OpenBook on Jan 24th 2002
Bortoli, Frino, Jarnecic & Johnstone (2006)	SFE (now part of ASX)	automated-order-driven	Jan 2001 Increase in LOB depth
Cao, Hansch & Wang (2009)	Forex Market London	Electronic order book	Empirical
Chowdhry & Nanda (1991)	Artificial		Theoretical
Chung and Chuwonganant (2009)	NASDAQ, Control in NYSE	Hybrid	October 14th 2002 SuperMontage
Commerton-Forde, Frino & Mollica (2005)	Euronext Paris, TSE & KRX	automated-order-driven	Paris: April 23rd 2001, Tokyo: June 30 2003, Korea: Oct 25 1999
Commerton-Forde & Tang (2009)	ASX	automated-order-driven	28th November 2005 asx removed display of broker id
Edwards, Harris & Piwowar (2007)	NYSE, OTC dealer Market	Quote driven/ 'Broker Ma	TRACE (July 1st 2002)
Eom, Ok and Park (2007)	KRX	automated-order-driven	March 6th 2000, Jan 2nd 2002
Flood, Huisman,Koedijik & Mahieu (1999)	Experimental market		Experimental
Fong and Liu (2010)	ASX	automated-order-driven	Empirical
Foucault, Moinas & Theissen (2007)	Euronext Paris	automated-order-driven	April 23rd 2001

Research Article	Investigated Markets	Type of Market(s)	Event Date
Frino, Johnstone & Hui (2010)	ASX	automated-order-driven	Empirical
Frutos & Manzano (2002)	Artificial based on Biais (1993)		Theoretical
Gemmill (1996)	LSE	automated-order-driven	October 1986,Feb 1989 and Jan 1991
Glosten & Milgrom (1985)	Model Based	Pure Dealership market	Theoretical
Green, Hollifield & Schurhoff (2007)	Municipal Bond Market	Broker-Dealer market	Empirical
Harris and Panchapagesan (2005)	NYSE	Hybrid	Empirical
Hasbrouck (1993)	NYSE	Hybrid	Empirical
Hedvall et al (1997)	HeSE	automated-order-driven	Empirical
Hendershott & Jones (2005)	AMEX (now NYSE), NASDAQ	Hybrid	September 23rd 2002
Jianga, McInish and Upson (2009)	NYSE, NASDAQ	Hybrid	Trading Halts between 2003-2005
Kyle (1985)	Model		Theoretical
Large (2007)	LSE	automated-order-driven	Resiliency events
Madhavan (1995)	Model Based on Glosten & Milgrom (1985)	Pure Dealership Market	Theoretical
Madhavan (1996)	Model based on Kyle (1989)		Theoretical
Madhavan, Porter & Weaver (2005)	TSX	automated-order-driven	April 12th 1990
Majois (2007)	Euronext Paris	automated-order-driven	April 23rd 2001
Maslova and Mills (2001)	NASDAQ	Hybrid	Empirical
Menkhoff, Osler and Schmeling (2010)	MICEX	automated-order-driven	Empirical
Naik & Viswanathan (1999)	Model Based		Theoretical
Pagano & Roell (1996)	Model Based		Theoretical
Porter & Weaver (1998)	NASDAQ	Hybrid	Empirical
Rindi (2008)	Similar model to Focault et al (2006)	Quote-Driven	Theoretical
Simaan, Weaver & Whitcomb (2003)	NASDAQ	Hybrid	First Phase OHR pilot program Jan 20th 1997
Yamamoto (2011)	Artificial markets	automated-order-driven	Theoretical
Yin (2005)	Model, extension of Biais (1993)		Theoretical

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