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Competition Between Equity Markets: A Review of the Consolidation Versus Fragmentation Debate

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Non-Technical Summary

Financial markets in the US and Europe have evolved from a largely consolidated structure comprising the primary listing venues, regional exchanges and the OTC markets, to a highly competitive but fragmented structure comprising several exchanges and alternative trading systems like crossing networks, electronic communications networks, dark pools, and multiple broker-dealers offering internalization services. These changes have been fueled by an increase in computational capabilities, improvements in networking technologies and several regulatory initiatives like the Regulation-National Market System (Reg-NMS) in the US and the Markets in Financial Instruments Directive (MiFID) in the EU. While these changes have coincided with several benefits like reduced transaction costs, regulators and market participants have raised concerns about the potential adverse effects associated with an increase in execution complexity as well as the welfare implications of innovations like dark pools. In this article we review the theoretical and empirical literature which examines the reasons why markets fragment as well as the resulting impact on liquidity and price discovery.

The literature surveyed provides several important lessons: First and foremost, the reasons underlying market fragmentation need to be examined keeping in mind two opposing economic forces acting simultaneously in securities markets. On the one hand, due to the presence of strong network externalities and economies of scale, financial markets have a tendency to consolidate in space and time. On the other hand, given the heterogeneity of traders' preferences it is difficult to envisage a single market that can cater to the needs of all market participants at all times.

Second, while examining the larger welfare implications of market fragmentation, it is important to recognize that embedded in securities markets is the market for trading services as well as the market for the traded securities. While the reduced transaction costs resulting from competition in the market for trading services can be beneficial to market participants, competition in the market for the traded securities can be harmful as the efficiency of prices may be adversely affected. For example, the literature examining the impact of dark trading venues suggests that, as these venues cream-skim uninformed order flow away from lit venues, excessive dark trading may be harmful. On the other hand, Over-The-Counter (OTC) markets and dark pools may provide valuable liquidity to large, uninformed traders. In other words, maximizing welfare usually requires finding an appropriate balance between the impact on liquidity and price discovery.

The complex, subtle and simultaneous interactions of the forces discussed in this article make the task of designing optimal policy responses and regulatory interventions extremely difficult. Policy-makers, regulators and exchanges should carefully evaluate the impact of their decisions keeping in mind these issues.

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Abstract

Technological advances and regulatory initiatives have led to the emergence of a competitive, but fragmented, equity trading landscape in several markets around the world. While these changes have coincided with benefits like reduced transaction costs, advancements in trading technology, and access to a diverse array of execution venues, regulators and market participants have also raised concerns about the welfare implications of innovations like dark pools as well as the resulting increase in execution complexity. Exchanges are often viewed as natural monopolies due to the presence of network externalities and economies of scale. However, heterogeneity in traders' preferences means that no single venue can serve the interests of all investors. Fragmentation of the marketplace can be seen as a direct outcome of this heterogeneity. In this article we review the theoretical and empirical literature examining the economic arguments and motivations underlying market fragmentation, the resulting implications for liquidity and price efficiency, and the role for public policy. Beyond the concerns for equity markets, the lessons from this literature are relevant for other asset classes experiencing an increase in competition between trading venues.

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1. Introduction

Capital markets perform a vital role of aggregating savings and allocating funds. In order to efficiently perform these functions, the existence of well-organized secondary markets is critical. Stiglitz (1989) notes that equity markets are particularly attractive for this reason. The organization of exchanges and other venues where securities are traded, including the specific rules and protocols associated with the trading process, affect investors' trading costs and portfolio choices, in turn affecting asset prices, issuers' cost of capital and overall welfare in the economy.[1,2]

Until the 1980s, the trading of securities in most economies was organized along a simple architecture containing national/regional stock exchanges, typically operating as public utilities, and often provided with certain privileges such as New York Stock Exchange's (NYSE) Rule 394 which prohibited *members* from trading off-exchange. Over the past 30 years, this market structure has dramatically changed, primarily as a result of technological advances and regulatory initiatives such as Regulation-National Market System (RegNMS) in the US and the Markets in Financial Instruments Directive (MiFID) in the EU. These changes enabled the entry of new players who employed innovative market models differing with respect to their transparency, speed, fee structures, accessibility, and the granularity of permissible prices, to attract trading volume from incumbent exchanges. Today markets are increasingly complex and comprise competing for-profit exchanges, alternative venues, and large financial institutions bilaterally dealing with their customers. This is especially apparent in the US and EU where dozens of competing trading venues have significantly diminished the market shares of incumbent exchanges.[3]

Coinciding with the above changes in the competitive environment, a large body of academic literature examining the benefits and costs associated with a consolidated versus competitive structure of trading venues has emerged. The objective of this paper is to review this literature. Although academic research has mainly focused on equity markets, many of the economic issues that are addressed in this literature are also relevant for other markets. Many bond and derivatives markets nowadays are also characterized by increasing competition between competing trading venues. Existing literature such as O'Hara (1995), Madhavan (2000), de Jong and Rindi (2009) and Foucault et al. (2013b) briefly survey the topic of competition between trading venues within the larger context of the microstructure of financial markets. Our approach differs from these in three respects. First, we can provide a more detailed analysis by exclusively focusing on this issue. Second, we also link the literature focusing on the recent technological and structural innovations to the topic of market competition. Finally, our survey provides deeper connections with the recent public policy and regulatory debates concerning structural reforms in secondary markets globally. The creation of the SEC Equity Market Structure Advisory Committee in the US emphasises the importance of this debate.

Competition between trading venues is affected by two opposing forces. On the one hand,

[1] Throughout this article, we use the term "trading venue" to refer to any venue where a security is traded and "market" to refer to a collection of trading venues.

[2] We provide a definition of the technical terms highlighted using italics in a glossary (see Appendix B.).

[3] Appendix A. describes key milestones in the evolution of equity markets in the US and EU.

the main function of an exchange is affected by network externalities and economies of scale, such that traders benefit when trading is consolidated in space and time. This further saves ordinary investors costs they would incur when facing excessive complexity arising from an overly fragmented market.[4]

Even in the presence of these consolidating forces, trading in financial markets has always been fragmented such that no single market structure seems to serve the interests of all investors. This is because investors differ both with respect to their motivations to trade as well as the magnitude of their trading interests. A passive investor only trades for reasons unrelated to the fundamental value of an asset. For example, an index fund receiving inflows needs to invest them in a diversified portfolio. Such a fund may use its reputation as an uninformed investor and execute a block trade in the *Over-The-Counter (OTC)* market. An active mutual fund or a hedge fund invests significant resources in processing public information, such as financial statements, to generate novel insights about the fundamental value of an asset. Such an informed investor, interested in trading a large position based on these insights, attempts to hide her trading intentions by submitting several small orders to trading venues preserving her anonymity. Finally, retail investors, or their brokers, may choose a trading venue allowing them to minimize trading costs for a single, small order. The presence of multiple trading venues thus allows investors with different objectives to choose the best trading venue for their specific trading problem. Moreover, effective competition between venues fosters innovation, increases customer orientation, and eliminates rents.[5]

The choice of an appropriate policy response to market fragmentation is a challenging task. For example, Harris (1993) argues that fragmented markets serving similar investors require no or very little policy intervention as regulatory efforts to impose a consolidated structure risk choosing the wrong system and/or stifling innovation. On the other hand, Pagano (1989b) argues that in the presence of heterogenous investors and trading venues, policy intervention can improve welfare by balancing the benefits of competition and potential losses of network externalities and scale efficiencies.

Competition among trading venues may affect the liquidity and price discovery of a security. Kyle (1985, p. 1316) defines liquidity as *"encompass[ing] a number of transactional properties of markets [including] 'tightness' (the cost of turning around a position over a short period of time), 'depth' (the size of an order flow innovation required to change prices a given amount), and 'resiliency' (the speed with which prices recover from a random, uninformative shock)."* Foucault et al. (2013b, p. 3) define price discovery as *"the speed and accuracy with which transaction prices incorporate information available to market participants."* Liquidity and price efficiency, which is the outcome of the price discovery process, are positively associated with the ease of risk-sharing and the allocative efficiency of resources in the economy, respectively. High liquidity and high price efficiency are features of good markets. However, there can be a

[4]Network externalities are the effects on a user of a product or service, of others using the same or compatible products or services. For example, social networks like Facebook are more valuable to each user if there are more users. See Chapter 7 of Shapiro and Varian (1998) for further details.

[5]Angel et al. (2011) provide an overview of some of the benefits of today's market structure. For a regulator's perspective see, 'Focusing on Fundamentals: The Path to Address Equity Market Structure', speech given by SEC Chair Mary Jo White at the Security Traders Association 80th Annual Market Structure Conference, Washington D.C. on October 2, 2013.

trade-off between these two objectives.

We elaborate on these concepts by briefly reviewing the Kyle (1985) model. Kyle builds on the rational expectations equilibrium of Grossman and Stiglitz (1980) by introducing imperfect competition in a dynamic model of trading. The model features an informed trader who knows the liquidation value of the asset and uninformed noise traders, also called liquidity traders, who trade randomly. A *market-maker*, unable to distinguish between orders from informed and noise traders, provides liquidity by strategically setting prices based on the consolidated order flow. Intuitively, the order flow is informative because it contains the informed trader's order which, in turn, depends on the information the informed trader holds. Consequently, the price set by the market-maker will be a monotonic function of the consolidated order flow. The informed trader also trades strategically by taking into account the effect of her behavior on prices. Kyle shows that, in equilibrium, the liquidity supplied by the market-maker (measured by the sensitivity of the price to changes in the consolidated order flow) is a function of the ratio of the amount of noise trading and the variance of the liquidation value of the asset. In the specific setting of the model, price efficiency is unaffected by the amount of noise trading.

It is worth pointing out that Kyle (1985) models the price of a security in a single *specialist market* and does not incorporate the impact of competition between multiple markets. However, given its central role in explaining market prices in the presence of asymmetric information, the model has been subsequently extended by Chowdhry and Nanda (1991), Ye (2012), and other studies to examine competition between trading venues.

The rest of the article is structured as follows. Section 2 illustrates the two opposing views concerning competition between trading venues: the natural monopoly argument and the different markets for different trading problems argument. Section 3 describes the strategies employed by competing trading venues such as differing levels of transparency, alternative tick sizes, fee structures, and speeds. Section 4 discusses dark pools, a type of trading venue often combining multiple of the strategies presented in the previous section to distinguish themselves from public exchanges. Section 5 examines the role for public policy in a market where multiple trading venues compete with one another. Finally, Section 6 concludes.

2. Competition Between Trading Venues

This section examines the two major opposing strands of literature focusing on the role of competition in the provision of trading services. First, we discuss the literature viewing network externalities as the dominating force. The alternative argument, presented subsequently, views market fragmentation as a natural outcome arising from the heterogeneity of traders and their trading problems.

2.1 Exchanges as Natural Monopolies

Early studies like Stigler (1964) and Bloch and Schwartz (1978) view exchanges as natural monopolies due to the presence of network externalities and economies of scale. Stigler (1964, p. 129) argues that *"The performance of the main function of the exchange as a marketplace is subject to economies of scale. The greater the number of transactions in a security*

concentrated in one exchange, the smaller the discontinuities in trading and the smaller the necessary inventories of securities. As a result the price of a security will almost invariably be 'made' in one exchange." Bloch and Schwartz (1978) argues that in the securities markets the market for the provision of trading services accompanies the market for the traded securities. While increased competition would benefit investors by reducing the explicit costs of trading, the resulting fragmentation would damage price efficiency. This concept, formally developed in a series of papers by Pagano (1989a,b), Chowdhry and Nanda (1991) and others, rests on the argument that market participants obtain the best terms of trades when they trade on the venue with the highest liquidity. This, in turn, increases liquidity in that venue, further increasing incentives for other traders to trade there. This positive feedback loop between trading volume and liquidity eventually leads to concentration of trading in a single venue.[6]

Pagano (1989a) examines the behavior of risk-averse traders with different endowments who choose to execute their orders in multiple markets. In the case where each trader chooses between two identical markets with equal (and fixed) entry costs, the model results in concentration of trading in a single market. By extending the Kyle (1985) model to a multi-market setting, Chowdhry and Nanda (1991) arrive at the same conclusion even in the presence of asymmetric information. In their model, competitive market-makers provide liquidity to orders submitted to their individual markets. The model also contains an informed trader, a large liquidity trader and several small liquidity traders. The informed and the large liquidity trader split their orders across the different markets, whereas the small liquidity traders only trade in a single market. When small liquidity traders are allowed to choose their market, in equilibrium they choose the market with the lowest transaction costs, which also attracts the largest share of trades by the large liquidity trader as well as the informed trader, leading to all trading being concentrated in a single market.

The above studies either ignore the underlying market structure of trading venues or generally focus on competition between different *specialist markets*, i.e. markets where an official liquidity provider (the specialist) is responsible for matching buy and sell orders and for providing executable quotes to other market participants. An alternative to the specialist market is the electronic *limit order market*, i.e. a mechanism where all participants can directly trade with each other by submitting orders. In this market liquidity is supplied by traders who submit *limit orders* rather than by an official liquidity supplier. Many real-world markets are hybrid markets which combine features of specialist and limit order markets. According to Jain (2003), 78% of world equity market capitalization is traded on hybrid markets. Moreover, over the last two decades, the role of specialists in most markets has been considerably diluted such that they increasingly resemble a limit order market (see e.g. Hendershott and Moulton (2011)).

Glosten (1994) models an electronic open limit order book populated by rational risk-averse investors, who may be informed, and competitive risk-neutral *liquidity providers*. Due to its ability to average profits across informed and uninformed trades, a limit order book achieves the best possible outcome in the presence of extreme adverse selection problems, and hence is considered competition-proof as it mimics competition between anonymous exchanges.

While truly consolidated markets have rarely existed, empirical studies have shown that a

[6] Admati and Pfleiderer (1988) use the same argument to describe temporal concentration in trading.

single venue is typically responsible for the bulk of the overall price discovery. Garbade and Silber (1978, 1979) argue that in fragmented markets the level of price integration between venues and the speed with which prices converge is inversely related to transportation and/or communication costs. They examine the short-term behavior of prices on the NYSE on one hand, and the Midwest and Pacific Exchange on the other, and find that the relationship is consistent with a dominant-satellite market, with the NYSE playing the role of the dominant market. Hasbrouck (1995) finds that NYSE is responsible for more than 90% of the price discovery compared to regional exchanges for stocks with a primary listing on NYSE.

2.2 Why Do Markets Fragment?

Harris (1993) argues that traders are heterogeneous with respect to their level of sophistication, motives to trade (information versus liquidity), order sizes, level of patience, etc. In the models discussed earlier, upon relaxing some of the assumptions, the natural monopoly argument generally breaks down. For example, in the Pagano (1989a) model when the two markets differ in their liquidity and entry costs (such that trading in the market with high liquidity is costly), or in their trading mechanisms (the author considers a single centralized exchange alongside an OTC market where traders search for a trading partner for a fixed cost and uncertain outcome), a stable separating equilibrium does exist, and in the latter case fragmentation can potentially increase gains from trade. Moreover, Pagano (1989a) does not allow traders to split their orders across venues. In Chowdhry and Nanda (1991), when all liquidity traders are allowed to split their orders across markets, consolidation is not inevitable.

Parlour and Seppi (2003) analyze competition between two limit order markets, one of which includes a specialist who, as in Seppi (1997), has the option to improve upon the prices submitted by existing limit order traders after liquidity demanders submit their orders. They show that if liquidity providers have heterogeneous costs, competing trading venues can co-exist, and the effect on overall liquidity, as compared to a consolidated market, is ambiguous. It is ultimately an empirical question whether fragmentation is beneficial for market participants. We present the empirical literature on this topic in Section 3 in conjunction with the discussion on the different competitive strategies employed by trading venues.

3. How Do Venues Compete? Competitive Strategies

The increased competition between exchanges and other venues has brought about attempts to differentiate along a variety of dimensions with the objective of retaining or increasing market share. These competitive dimensions include parameters such as tick sizes (minimum price increments), trading fees, transparency (defined precisely below), as well as services such as co-location (hosting market participants' computer servers close to those of the exchange). This section provides an overview of these parameters and their implications.[7]

This overview will emphasize that it is important to recognize that trading venues can compete with each other on dimensions other than explicit costs. Some venues may attract

[7]This overview only focuses on the use of these parameters as competitive devices. A larger literature examines the effect of some of these parameters when they are imposed by regulators or chosen by a monopolist trading venue.

uninformed order flow by using *internalization* and *preferencing* agreements, others may use superior technology and trader anonymity to attract informed traders. While cost-based competition is generally beneficial for market participants, this may not always be the case with other forms of competition. The studies on the cream-skimming hypothesis discussed in Section 3.3.1 are cases in point.

3.1 Transparency

O'Hara (1995) defines market transparency as the ability of market participants to observe the information in the trading process. Market transparency is relevant because the information available in the trading process can affect the trading strategies of market participants. When examining the impact of transparency rules on market fragmentation, it is important to consider both what information is observable and by whom. For example, in limit order markets, depth can be disclosed to market participants along with best prices. Limit price and depth information at multiple levels of the book can also be disclosed. Additionally, some participants, e.g. market-makers on certain exchanges, could be given privileged access to certain information. In this context, another important question is whether information about trader identity should be kept anonymous or be disclosed to all or some market participants. Further, it is relevant to distinguish between *pre-trade transparency* and *post-trade transparency*, where the former refers to the availability of information concerning trading opportunities, e.g. *quotes* or the state of the limit order book, while the latter refers to information about a trade after it has been executed. We discuss the literature pertaining to markets with distinct levels of transparency, beginning with traditional exchanges, which usually provide the highest level of transparency.

3.1.1 Transparency on Traditional Exchanges

Strategies of liquidity providers may depend on their knowledge of past trading activity and the resulting portfolios held by their competitors. Biais (1993) shows that, if the liquidity providers are competitive, their expected quotes and *bid-ask spreads* are independent of such knowledge, though bid-ask spreads are more volatile in the case of lower transparency. Madhavan (1995) analyzes the impact of disclosing trading information to market participants when some traders spread their trading over multiple periods. He shows that a fragmented market can be obtained as the equilibrium outcome, if trade disclosure is voluntary. This is because large traders effectively front run their own trades, and thus they prefer not to disclose their trading information. By contrast, small traders, who trade only in a single period, prefer disclosure so as to obtain more information before they trade. If markets fragment because of the distinct preferences of market participants, prices are more volatile and less efficient than in a transparent consolidated market. Since the model is set up as a dealer market, dealers' preferences are also considered. Dealers prefer not to disclose their trades as that enables them to exploit their information pertaining to trades against large traders. Since this information is valuable to them, they are able to quote narrower bid-ask spreads than if they had to disclose their trades. Bloomfield and O'Hara (2000) design laboratory experiments containing two dealer markets with different levels of transparency and find that dealers in transparent markets find it difficult to compete

with non-transparent dealers. When dealers are free to choose their optimal level of transparency, most opt for the less transparent regime and only few profitable dealers survive in the transparent market.

Empirical studies of the effects of changes in transparency lead to inconsistent results. In September 2002, the *Electronic Communication Network (ECN)* Island decided to stop displaying its limit order book for three actively traded exchange-traded funds. Hendershott and Jones (2005a) find that this elimination of pre-trade transparency brought about a decrease in the competition for liquidity provision on Island, resulting in an increase in transaction costs and adverse selection and a decrease in Island's market share. At the same time, the venues that gain market share experience an increase in competition and a reduction in trading costs. However, overall Island's decision to go dark leads to increased transaction costs.

Boehmer et al. (2005) investigate an increase in pre-trade transparency on the NYSE where limit-order book information was provided to off-floor traders for the first time in 2002. The authors find that the bid-ask spread paid by *liquidity consumers* on their trades decline and price efficiency improves subsequent to the increase in transparency. Eom et al. (2007) investigate increases in the number of levels of the order book made available on the Korea Exchange. They also find beneficial effects of pre-trade transparency on liquidity and price efficiency, though those improvements appear to be concave as their incremental magnitude diminishes with additional levels of order book information. The results of Madhavan et al. (2005) contrast those of Boehmer et al. (2005) and Eom et al. (2007). They find that an increase in pre-trade transparency on the Toronto Stock Exchange, consisting in the distribution of inside quotes and the next four levels of the order book to the public, is followed by a deterioration of liquidity as limit order traders are more reluctant to provide a free trading option to other traders.

Simaan et al. (2003) are concerned with pre-trade anonymity. They find that Nasdaq market-makers provide more liquidity when they can post limit orders anonymously on ECNs. Foucault et al. (2007) provide consistent evidence from the Paris Stock Exchange where bid-ask spreads narrowed when the pre-trade disclosure of trader identity was abolished.

In an experimental study, Bloomfield and O'Hara (1999) consider the effects of both pre- and post-trade transparency. While they find no significant effects of the former, they find that trade disclosure leads to more informative prices, but also to increased bid-ask spreads at market open, thus benefiting market-makers. In an empirical study of block trade reporting on the London Stock Exchange (LSE), Gemmill (1996) does not find meaningful effects of delayed trade disclosure on either liquidity or price efficiency.

3.1.2 Upstairs and OTC Markets

The upstairs market, primarily used to trade large blocks OTC, comprised competing broker-dealers who either executed a customer order against their own account or searched for potential counterparties for their customers by shopping the block. Prices in this market were determined through bilateral negotiations.[8] We consider two models examining competition

[8]The nomenclature 'upstairs' market comes from the fact that these dealers used to be physically located above the floor of the NYSE. We use the term 'trading on exchange' to refer to trading on the exchange floor as opposed to the upstairs market.

between off-exchange dealers and on-exchange specialists and provide an overview of related empirical evidence. Seppi (1990) focuses on the lack of anonymity in the upstairs market and how uninformed traders benefit from this, and Grossman (1992) examines the role of upstairs dealers as repositories of unexpressed trading interest. While the upstairs market, as it existed in the 1980s and 1990s, does not exist anymore, these models are still relevant today, as a large fraction of trading takes place in OTC markets, some of which operate a similar structure. These markets are subject to less stringent regulation and are often dark, i.e., not pre-trade transparent.

Seppi (1990) analyzes the existence and properties of the equilibria in the presence of information-based block trading. The model features a market populated by competitive specialists, off-exchange dealers, a group of small noise traders and a single large investor who may or may not be informed. The model implies that for a block with size less than a critical threshold, a separating equilibrium exists in which the uninformed investor chooses to execute the block trade with the dealer but the informed investor prefers to trade using *market orders* on-exchange. The dealer market, as it does not provide anonymity, allows the uninformed investor to credibly signal to the dealer that she is uninformed by making commitments beyond the terms of trade, e.g., a no bagging commitment in which she agrees that she will not trade the stock again for a few days. Thus, the model provides a framework in which informed and uninformed block trades endogenously fragment across different venues.

Several empirical papers, using data from markets across the world, have found results supportive of the implications of Seppi (1990). Madhavan and Cheng (1997) analyze the role of upstairs and downstairs markets in providing liquidity for block executions in Dow Jones Industrial Average (DJIA) stocks. They find evidence consistent with the idea that traders who can credibly signal their uninformed status use the upstairs market. Smith et al. (2001) and Booth et al. (2002) find similar evidence for upstairs trading on the Toronto Stock Exchange and the Helsinki Stock Exchange, respectively. These studies conclude that the upstairs market provides substantial liquidity to large liquidity-motivated trades and plays a complementary role to the exchange without imposing costs on the overall market.

Grossman (1992) examines the role of the upstairs broker-dealers as a repository of information about unexpressed trading interest. Investors choose to trade with a specialist on the exchange or in the upstairs market with a dealer. Both the specialist and the dealer can observe the orders directed to their respective desks. However, as the dealer stays in contact with customers, she also observes the unexpressed trading interest. As this reduces the risk for the dealer, the upstairs market has better effective liquidity, which can potentially benefit customers. However, customers trading in the upstairs market are disadvantaged because they have to search for the best prices and have no assurance that the prices offered to them are the best. Depending on these costs and benefits, either or both market structures may exist in equilibrium.

There is substantial empirical evidence in favor of predictions implied by Grossman (1992). Smith et al. (2001) and Booth et al. (2002) find that a large number of trades in the upstairs market are executed at prices better than those available on the exchange floor, which is consistent with Grossman (1992) who argues that upstairs dealers are able to provide such price

improvements when they have information about customers' unexpressed demands. Grammig et al. (2001) find similar evidence in the German stock market, where the anonymous electronic limit order book, IBIS, competed with the Frankfurt Stock Exchange that operated a non-anonymous floor based trading system similar to the NYSE. They find that both the information risk and the corresponding component of the bid-ask spread charged by market-makers are significantly lower on the Frankfurt Stock Exchange compared to the anonymous limit order book.

While the above theoretical and empirical papers suggest a complementary role of OTC and exchange markets, there is also empirical evidence pointing towards the two also acting as substitutes. Fong et al. (2001) examine the determinants of off-market trading in a panel regression framework using data from the Australian Stock Exchange (ASX) between 1993 and 1998. They find that off-market trading is primarily driven by institutional trading interest (proxied by trading volume and index inclusion), primary market liquidity (proxied by bid-ask spreads and depth) and the existence of an options market. Large trades are more likely to be executed off-exchange where they have a lower *price impact*, and an order of a given size is more likely to be executed off-exchange if the primary venue is illiquid (higher bid-ask spread and/or lower depth). Friederich and Payne (2007) analyze the determinants of volume in the London equity market where a network of broker-dealer firms in the OTC market compete with a central electronic limit order book. Using panel estimations, the authors find that the market share of the order book is low when execution risk is high, asymmetric information risk is high, and when liquidity (proxied by high bid-ask spreads and/or low depth) is low. This is because the liquidity service supplied by the dealers is valuable in such circumstances.

3.2 Tick Size

The tick size is the minimum amount by which the price of a security can change. It affects liquidity and transaction costs through two primary and opposing channels. It represents a lower bound to the bid-ask spread. The tick size also impacts the incentives of liquidity providers. A large tick size encourages submission of limit orders as it provides a large compensation to such orders. It also concentrates depth at a given price thereby creating a deeper market. In the US the tick size on regulated, lit markets is fixed at one cent for stocks priced above $1. However, there are several exceptions to this rule like the NYSE Retail Liquidity Program.[9] *Dark trading venues* are also free to execute trades at sub-penny prices. Hatheway et al. (2016) argue that dark trading venues use this exemption to cream-skim uninformed order flow away from *lit trading venues*, harming overall market liquidity in the process. In the EU, each venue is free to choose its optimal tick size. However, since June 2009, European venues have agreed to a harmonized tick regime that was compiled by the Federation of European Securities Exchanges.[10] MiFID II, the revision of MiFID, will bring about regulated tick sizes. In Japan, the Tokyo Stock Exchange (TSE) reduced tick sizes for stocks contained in the blue chip TOPIX

[9]Under this scheme orders submitted by Retail Member Organizations who are approved by the NYSE can be executed at prices better than the best quotes.

[10]In 2011, NYSE Euronext unilaterally decided to change its tick regime for Dutch and French blue chip stocks, a decision that was later reversed. See Financial Times article by Jeremy Grant dated January 28, 2011 "Euronext sparks outrage with tick size reduction."

100 index twice in 2014 and made further adjustments in 2015. From shortly before the first tick size change until before the second, TSE managed to gain market share as the rival Proprietary Trading Systems shrank from 8.9% to 3.4% of the market[11].

The rather limited amount of literature on tick size as a determinant of liquidity in a setting of competing markets has found beneficial effects of a reduction in tick size. Buti et al. (2015a) study both theoretically and empirically the competition between an exchange operating a public limit order book (PLB) and an alternative trading venue (sub-penny venue or SPV) capable of undercutting the regulated tick size prevalent on the exchange. Their model contains broker-dealers who have the exclusive right to post limit orders on the SPV and regular traders who supply liquidity only on the PLB. The SPV attracts both limit and market orders away from the PLB. The model predicts trading on the SPV to improve liquidity for liquid stocks and to worsen liquidity for illiquid ones. Empirically, the study confirms the predictions for large cap stocks but does not find significant results for small stocks. Biais et al. (2010) examine the effect of tick size decimalization on NASDAQ on liquidity both on NASDAQ and on its competitor Island ECN that had already been operating a decimal pricing grid. They find that NASDAQ bid-ask spreads reduced dramatically. At the same time Island bid-ask spreads also decreased, suggesting that liquidity provision there was not competitive. Liquidity providers were earning oligopoly rents before the tick size change, leading to the conclusion that theoretical models should not assume competition among liquidity providers is perfect.

3.3 Fee/Rebate Structures

In this section we discuss two competitive strategies involving broker payments: the first strategy pertains to incentives for the provision of uninformed order flow, and the second one involves incentives for liquidity provision or liquidity consumption.

3.3.1 Payment for Order Flow and the Cream-Skimming Hypothesis

Until the 1980s, several institutions in the OTC market competed with incumbent exchanges by charging lower commissions to non-member firms while member firms were operating under a regime of commissions fixed by the exchanges. In response to the removal of barriers to competition, several dealers in the OTC market specialized in providing liquidity to retail traders. Payment for order flow, a practice that evolved as a result, involves dealers compensating brokers to route retail order flow, which is generally uninformed and hence profitable to trade against, to them against a promise to execute them at the best price in the market, such as the National Best Bid or Offer (NBBO) in the US. Critics argue that this practice, commonly known as cream skimming, adversely affects the efficiency of prices as the remaining orders left over at the venue being skimmed are large, informed and difficult to execute. Glosten and Milgrom (1985) argue that the presence of liquidity-motivated traders allows specialists and market-makers to profitably continue providing valuable liquidity to the market. A high concentration of informed traders can lead to market failure as liquidity providers will be unwilling to trade at reasonable prices. Furthermore, if the venue being skimmed is also providing the

[11] See Credit Suisse, The TSE Tick Size Reduction Phase I – A Month in Review.

best prices in the market, the price on the cream-skimming venue is also adversely affected. Such rebates also introduce conflict of interest especially if brokers do not pass them on to their customers.

Easley et al. (1996) analyse this practice. Informed and uninformed traders are modeled to arrive randomly and execute their orders on one of two venues based on exogenous execution probabilities. In the absence of cream-skimming, there are equal proportions of informed and uninformed traders on each venue. Based on data from the NYSE and the Cincinnati Stock Exchange, the authors find that the information content of trades on the two venues is significantly different and consistent with the notion that the Cincinnati Stock Exchange cream-skims uninformed orders.

However, Battalio (1997) shows that payment for order flow need not always coincide with cream-skimming. Examining the entry of Madoff Securities in NYSE-listed securities, his results suggest that its main advantages are on the cost side. Bessembinder and Kaufman (1997) examine trades and quotes for NYSE-listed securities on the NYSE, NASDAQ, and other regional exchanges, and find that, while bid-ask spreads show only a modest increase for trades executed off-NYSE, trading profits earned by market-makers are two to three times larger for off-NYSE trades. This is consistent with the notion that NASDAQ and the regional exchanges attract uninformed order flow from the NYSE. More recent empirical studies like Degryse et al. (2014) and Hatheway et al. (2016) have also observed that dark trading venues successfully cream-skim uninformed order flow from the primary listing venues in US and European equities markets, leading to deterioration in overall liquidity.

Barclay et al. (2003) provide a positive view of fragmentation based on informed and uninformed order flow. They study competition between NASDAQ market-makers and ECNs for 150 NASDAQ stocks and find that trades on the ECN are more likely during times when volume and price volatility is high. The authors also find that ECN trades have a 50% higher price impact than NASDAQ trades, and they also contribute to about two-thirds of the fundamental price variance, suggesting that ECN trades are more informed. Finally, the authors also observe that NASDAQ trades are larger and uninformed as NASDAQ market-makers use internalization and preferencing agreements with brokers to attract uninformed order flow. The authors conclude that ECNs use anonymity and speed of execution to attract informed order flow and make significant contributions to price discovery.

3.3.2 Maker-Taker Pricing

Another incentive scheme offered by some trading venues is the so-called maker-taker pricing scheme where market participants consuming liquidity (taker) are charged a fee and those participants providing liquidity (maker) are given a rebate. Venue operators using maker-taker pricing typically rebate almost the entire fee charged to liquidity demanders, keeping a small proportion for themselves. Some venues also operate an inverted or taker-maker model in which liquidity providers are charged a fee and liquidity demanders are offered a rebate. The introduction of such incentive schemes has been controversial due to the potential redistributive effects, especially those involving retail investors who are generally charged a flat fee (Battalio et al., 2014). Cardella et al. (2013) estimate that approximately $2 billion are transferred from

liquidity consumers to liquidity providers annually. On the other hand, Malinova and Park (2015) analyze the introduction of maker-taker pricing at the Toronto Stock Exchange and find that although quotes adjust, cum-fee transaction costs for liquidity demanders do not change. However, as bid-ask spreads decline, the use of market orders becomes cheaper, leading to an increase in their use and a reduction in adverse selection costs.

Angel et al. (2011) and Colliard and Foucault (2012) argue that in the absence of market frictions, prices can fully adjust to reflect the maker-taker fees, and hence only the total exchange fee has an economic impact and the split between liquidity providers and liquidity demanders is irrelevant. However, Brolley and Malinova (2013) argue that typically investors do not pay taker fees directly and are charged a fixed fee by their brokers. In such a case, holding total exchange fees constant, an increase in the maker rebate lowers trading costs, increases trading volume, decreases market participation by investors, yielding, on net, an increase in gains from trade. Foucault et al. (2013a) highlight that the presence of a non-zero minimum tick size is another source of friction due to which prices cannot fully adjust.

3.4 Speed-enhancing technology and co-location

Hasbrouck and Saar (2013, p. 647) define a trader's latency as "*the time it takes to learn about an event (e.g., a change in the bid), generate a response, and have the exchange act on the response. Specifically it includes the time it takes for information to reach the trader, the time it takes for the trader's algorithms to analyze the information, and the time it takes for the generated action to reach the exchange and get implemented.*" In recent years, exchange operators worldwide have made considerable investments in their technological infrastructure in order to reduce order execution and communication latencies and attract market share from competing venues.[12] A controversial latency-reducing practice that has emerged in recent years is that of co-location, i.e., allowing firms to rent server space next to an exchange's *matching engine*. Co-location rents on various exchanges can vary from $50,000 a year to $500,000 a month.[13] Reductions in latency achieved through technological innovation and the offering of co-location are among trading venues' competitive choices aimed at attracting *high-frequency traders* (HFTs) whose trading activity benefits the venues' profits, either directly or because other traders are attracted by the increased market activity. HFT has been controversially discussed by the general public[14] and there is a rapidly growing academic literature, both theoretical and empirical, on HFT. Since HFT is facilitated by trading venues' improvements in technology, this literature is indirectly related to the topic of this survey. However, it is beyond the scope of our paper to discuss this literature because it generally does not directly relate to speed enhancements or the competition between markets or fragmentation. Biais and Foucault (2014), Jones (2013), and Menkveld (2016) provide recent surveys focused entirely on HFT.

The literature directly related to competition via speed, and considering the effects of speed enhancements, is very limited. Pagnotta and Philippon (2013) examine the impact of trading speed, level of fragmentation and market regulation on asset prices, investor participation and

[12] See Pagnotta and Philippon (2013) for a list of investments made by exchanges all over the world.

[13] See Time Magazine article by Kristi Oloffson and Stephen Gandel dated August 5, 2009 "High-Frequency Trading Grows, Shrouded in Secrecy."

[14] See, e.g., Lewis (2014) versus Kovac (2014).

net gains from trade. Heterogeneous liquidity-motivated investors trade on multiple competing venues which differ in their trading speed. Investors assign different private values to the asset and they differ in the volatility of those private values, such that high volatility investors prefer faster venues (who also charge higher prices). Competition among venues increases investor participation, trading volume and allocative efficiency, but can lead to socially excessive levels of speed. The model provides a consistent interpretation of some of the experiences observed since the implementation of Reg-NMS in the US and MiFID in the EU.

Empirical literature on the impact of exchange technology is limited to studies of individual trading venues while the effects in fragmented markets have not been studied.

4. Dark Pools

The term *dark pool* is generally used to refer to an electronic dark trading venue that combines the absence of pre-trade transparency with automated execution. Additionally, such venues typically compete with other trading venues via additional market design choices. Dark pools usually apply smaller tick sizes than applicable on transparent markets and they may restrict access to certain market participants. Dark pools nowadays comprise a substantial share of trading volume in many equity markets. Shorter and Miller (2014) report that dark pools' market share in the US increased from 4% in 2008 to 15% in 2013. In Europe, the market share of dark pools reached 7.5% at the end of 2015.[15] However, the official European figures are generally considered to be an underestimate because of limited enforcement of reporting obligations. Even in the Asia-Pacific region, where dark pools' market share is lower, the number of dark pool operators has increased consistently over the last few years. For example, Comerton-Forde and Putniņš (2013) report that the number of broker-operated dark pools increased from 4 in 2008 to 16 in 2011 in the Australian market.

Most theoretical studies consider the coexistence of a *crossing network* (one specific type of dark pool) and a dealer market. Crossing networks are venues without pre-trade transparency crossing buy and sell orders periodically or as they arrive in the system, typically at the *mid-quote* of a reference market. Hendershott and Mendelson (2000) analyze the trade-off between a dealer market (certainty of execution but positive bid-ask spread) and a crossing network (reduced cost but uncertain execution). Their model contains informed and liquidity traders, competitive dealers, and a crossing network where traders directly trade with each other and orders are matched at the dealers' mid-quote. Informed traders can either be momentum traders who must trade before the crossing network crosses (short-lived information), or fundamental traders who can wait until after the cross (long-lived information). The introduction of a crossing network has two opposite externalities. Initially, as the crossing network gains market share, it induces a positive externality through improvements in overall liquidity benefiting all trades. Once it obtains a critical mass, an increase in orders by low liquidity preference traders induces a negative effect as it leads to a crowding out of other traders on the same side of the market. This happens due to the absence of price priority on the crossing network. Traders' use of the dealer market as a market of last resort leads to wider bid-ask spreads and more efficient

[15] See Bloomberg article dated 14 January 2016 titled "European Dark Pools Expand, Spiting Regulators' Ambitions."

prices when information is short-lived and order submission costs are low. On the other hand, if information is long-lived, the introduction of a crossing network has the opposite effect. Another theoretical study of the competition between a dealer market and a crossing network is Degryse et al. (2009) who focus on different levels of traders' ability to see past order flow from both markets. They find that these variations in the level of transparency lead to differences in the order flow predictability, and neither the introduction of a crossing network nor an increase in transparency necessarily increases gains from trade. Ye (2012), in an extension of Kyle (1985), analyzes the trading strategy of an informed trader when a security trades in a crossing network alongside a dealer market. The model implies that price discovery is reduced in the presence of the dark pool as the informed trader finds the option to hide her trades in the dark pool valuable. As a result, a policy granting everyone the same access to participate in the dark pool is harmful to price discovery. Zhu (2014) also examines the impact of competition between dealer market and crossing network on price discovery in a model featuring risk-neutral liquidity and informed traders. Differently from Ye (2012), liquidity traders are also allowed to endogenously choose a trading venue. Liquidity traders are attracted to the dark pool, whereas informed traders prefer to trade on the transparent exchange. This is because these traders act upon positively correlated information and thus their orders have a higher non-execution risk on the dark pool than uncorrelated uninformed orders. This self-selection results in information-based trading being concentrated on the exchange which enhances price discovery. However, this also leads to an increase in adverse selection risk and wider bid-ask spreads on the exchange.

In contrast to the previous studies, Buti et al. (2015b) analyze the interaction of a crossing network and a limit order market, rather than a dealer market, using a model that contains small and large traders, with only the latter being able to send orders to the crossing network. Their model predicts that the introduction of the crossing network leads to a decrease in liquidity of illiquid stocks, measured by bid-ask spread and depth, and a decline in gains from trade, while trading volume increases. For liquid stocks, bid-ask spreads increase to a smaller, but inside depth to a larger extent than for illiquid stocks, and total trading volume decreases. The gains from trade of those traders capable of using the crossing network increases. Variations of the model show that the results are magnified if trading in the crossing network takes place continuously rather than periodically and if the tick size on the limit order book is large.

In one of the first empirical studies on crossing networks, Conrad et al. (2003) use a proprietary dataset of executions between 1996 to 1998 on primary markets, ECNs and crossing networks and find that crossing networks are mainly used to trade NYSE-listed securities whereas ECNs mainly focus on NASDAQ stocks. This is because crossing networks need a good primary market price discovery mechanism and a sufficiently large pool of liquidity, both of which are present for NYSE-listed stocks. On the other hand, ECNs provide good price discovery for fragmented stocks with high bid-ask spreads on primary markets (also shown in Barclay et al. (2003)). The execution costs on crossing networks (ECNs) are, on average, 30bps (66bps) lower than on primary markets. The authors argue that given best execution obligations,[16] in equi-

[16]Best execution obligations mandate broker-dealers to provide the best possible terms of trade to their customers. In the past the phrase 'terms of trades' was generally applied to prices. While this is still the case in the US, since the operationalization of MiFID in 2007, the EU has materially departed from this position by including additional characteristics like likelihood and speed of execution in the definition. See Macey and O'Hara (1997)

librium these differences should be zero. They find evidence that lower costs on ECNs result from the fact that such a transition towards an equilibrium has not been completed. Costs on crossing networks are underestimated due to a downward bias in opportunity costs as the dataset used by them does not contain completely unfilled orders. Naes and Ødegaard (2006) also find similar evidence using data containing the Norwegian Government Petroleum Fund's trades in the US stock markets for the first six months in 1998. The competition between London Stock Exchange's SEAQ dealer market and the POSIT crossing network is examined by Gresse (2006), using data from July 2000 to June 2001 that allows the distinction between trading on the crossing network by dealers and institutional investors. There is a strong negative (weak positive) correlation between bid-ask spreads and crossing network volume for dealers (institutional investors). This suggests that dealers get substantial risk-sharing benefits from trading in the crossing network, which outweigh a possible cream-skimming effect resulting from institutional investors conducting uninformed trading in the crossing network.

Ray (2010) models and empirically examines the decision of a liquidity trader to send market orders to an exchange or use a crossing network, using realized monthly crossing network volumes from POSIT, Liquidnet, and Pipeline Trading between June 2005 and June 2006 for NASDAQ listed stocks. The study finds, in the cross-section, an inverted U-shaped relationship between crossing network market share and market liquidity. Ready (2014) uses the same dark pool data source as Ray (2010) but extends this to September 2007. Through panel data regressions and the estimation of a structural model, he finds that for stocks with the lowest bid-ask spreads, the dark pool market share is particularly small. He conjectures that this results from investors' so-called soft-dollar agreements that link payment of trading commissions with the provision of brokerages' investment research. Ready (2014) suggests that, in order to receive such research, investors choose to artificially accumulate trading volume with their brokers, and that they choose to do so in stocks with low bid-ask spreads so as to minimize transaction costs.

Buti et al. (2011), using a data set of daily dark pool trading volume reported voluntarily by eleven dark pools from the United States in 2009, analyze the determinants of dark pool market share, and the effect of dark pool trading on liquidity and price efficiency. Their results show that dark pool trading focuses on liquid stocks, and NASDAQ stocks have higher dark pool market share than NYSE stocks after controlling for liquidity. In the time series, they find that dark pool market share is positively related to overall trading volume, inside depth, bid-ask spread, and inversely related to intraday stock price volatility, absolute returns, and relative order imbalance. Cross-sectionally, they find that bid-ask spreads, price impact, and stock price volatility decrease with dark pool activity. However, their results with respect to price efficiency are less clear. Nimalendran and Ray (2014) analyze high-frequency transaction data provided by an anonymous crossing network that offers algorithmic and negotiated executions. They find that for illiquid stocks, trades executed using algorithms appear informed, as inferred from large bid-ask spreads and price impacts of exchange trades in the respective stocks for periods of up to two hours after the trade in the crossing network.

In the US and EU, trade sizes in dark pools have been continuously decreasing over the years

for the legal and economic aspects of the duty of best execution, and Petrella (2010) for the different approaches to best execution taken by the US and EU post the implementation of Reg-NMS and MiFID respectively.

and are now similar to those in lit trading venues. This has coincided with an increase in the market share of dark pools. These changes suggest that dark pools today may fulfill a different purpose as compared to the original crossing networks. Higher market shares and smaller trade sizes may also be indicative of a changed composition of investors active in the dark pools. In addition to crossing networks, there are several other types of dark pools such as internalization pools and ping destinations (Mittal, 2008). It is plausible that the impact of dark pools on liquidity and price discovery is not uniform across all the different types. However, evidence on this is almost non-existent as studies have largely focused only on crossing networks.

5. Public Policy in Fragmented Markets

Stoll (1992, p. 99) argues that "*Increased competition reduces the need to regulate conduct of brokers, dealers, and exchanges or to oversee the actions of exchanges. A competitive market tends to be self-regulating. On the other hand, the need to set standards (for example, as to transparency, clearing procedures, trading priority rules) increases because a large number of competitors increases potential confusion.*" In fragmented markets one area where public policy potentially has a critical role is in ensuring that trading venues are sufficiently well integrated and the interests of end-investors are well protected. For example, trading venues in the US have been explicitly integrated through regulation whereas in the EU, regulators have assigned this task to the brokers by imposing best execution obligations. This section first presents evidence on welfare effects of market fragmentation before discussing two relevant policy choices, those pertaining to priority rules and to the ways markets are interlinked.

5.1 Welfare Analysis of Market Fragmentation and Competition

Market structure affects social welfare primarily through its impact on liquidity and price efficiency. High liquidity i.e. low trading costs allow investors to easily optimize their portfolio allocations thus enhancing gains from trade. Price efficiency affects social welfare through its impact on investment and capital allocation decisions in the real economy. Most of the literature discussed in the previous sections has focused on the former. Recent empirical literature, discussed below, more generally analyzes the impact of market fragmentation on both dimensions affecting social welfare.

O'Hara and Ye (2011) consider the effect of total fragmentation on liquidity and price efficiency in the US equity markets for the first six months of 2008. The authors find that transaction costs are lower and execution speed is faster for stocks with more fragmented trading. Furthermore, while short-term volatility increases with fragmentation, so does price efficiency in the sense that future price changes are less predictable. Finally, small cap stocks experience the largest improvements in liquidity. They conclude that, due to the presence of a single *consolidated tape*, sophisticated order routing technologies and prohibition of *trade-throughs*, equity markets in the US are virtually consolidated into a single market with multiple points of entry. Other empirical studies like Hengelbrock and Theissen (2009), Chlistalla and Lutat (2011) and Gomber et al. (2011a) also observe a positive impact of competition between similarly organized limit order markets on liquidity. Additionally, Boehmer and Boehmer (2003) document a

similarly positive impact on liquidity of increased competition in the Exchange Traded Funds (ETF) market after the NYSE started trading ETFs primarily traded on the AMEX.

Degryse et al. (2014) analyze transaction data comprising Dutch large- and mid-cap stocks from 2006 to 2009 and find that fragmentation among lit trading venues benefits overall liquidity, but harms primary market liquidity effectively restricting the benefits to investors connected to multiple lit trading venues. Moreover, they also find that an excessively high share of dark trading is harmful due to the ability of dark trading venues to cream-skim uninformed order flow. However, the authors include diverse venues without pre-trade transparency under the definition of dark fragmentation and do not comment on the differences across multiple dark trading venues. Hatheway et al. (2016), using a proprietary dataset from NASDAQ for 120 stocks and the first quarter of 2011, find that the different regulatory structure applicable to dark trading venues in the US (exemptions from fair access requirements and use of sub-penny pricing) allows them to cream-skim uninformed order flow from lit markets. Based on this, the authors conclude that dark trading is detrimental to investor welfare because its benefits with respect to liquidity are overshadowed by the detrimental effect on the price efficiency in lit markets. The only exception to this are large trades on dark markets which experience both lower transaction costs and higher price efficiency.

Two empirical observations stand out from the above discussion: first is the potentially detrimental impact associated with some dark trading venues cream-skimming uninformed order flow away from lit markets, and second is investors' ability to better manage price impact and adverse selection while trading large blocks in dark trading venues. While potential endogeneity issues between liquidity and price efficiency on the one hand and trading volume on the other hand in the above studies has meant that a causal interpretation is probably questionable, it is reasonable to expect that lit and dark fragmentation likely has a differential impact on social welfare.

5.2 Priority Rules

Individual markets use different priority rules while ranking orders and matching buys with sells. The price of an incoming order is used as the primary priority rule in most markets around the world. This means that orders are ranked based on their prices such that higher (lower) priced buys (sells) have a higher priority in the order book. If two equally priced orders are submitted to the limit order book, then secondary precedence rules - typically based on the order's time of arrival, but sometimes its visibility or its size - are applied. In fragmented markets, secondary priority rules usually are not used, and sometimes even the price priority rule is violated. Violations of priority rules, especially the price priority rule, are generally considered harmful. Stoll (2001) argues that a strict price priority across venues increases the incentives to post "good" prices. However, enforcing strict time priority across venues artificially attracts market orders from other markets by protecting limit orders even in the smallest and least liquid venues. This creates incentives to form new venues. Moreover, enforcing time priority is likely to be extremely costly.

Foucault and Menkveld (2008) model competition for order flow in a market with multiple competing limit order books, focusing on the impact of trade-throughs. They examine London

Stock Exchange's entry (EuroSETS) in the Dutch equity market and observe that the consolidated order book is deeper after EuroSETS's entry due to the absence of time priority across markets. They also observe that a higher trade-through rate on EuroSETS coincides with less liquidity in this market. On the other hand, Hendershott and Jones (2005b) examine the introduction of an exemption to the trade-through rule in the US ETF market, and observe no change in the frequency of trade-throughs and no impact on liquidity and price discovery. As of today, trade-throughs are generally prohibited in the US. In the EU, while there is no such regulator imposed prohibition, the burden of ensuring that price priority is not violated is on market participants based on best-execution obligations imposed by MiFID. These obligations require investment firms to achieve the best result for their clients based on price and other parameters. However, trading venues in both US and EU have introduced schemes which allow them to circumvent price priority rules. Examples include maker-taker pricing (changing the net-costs of trades at a given gross price level) and alternative tick sizes (making it cheaper to obtain price priority).

5.3 Market Linkages

Another issue relevant for public policy is that of free flow of information between venues. This issue is important to ensure that prices and liquidity conditions on the different venues do not materially diverge. In the absence of free flowing information, prices on each venue would depend on the local supply and demand characteristics leading to an adverse impact on liquidity and price discovery. In the US, the implementation of NMS in the 1980s led to the introduction of an Intermarket Trading System (ITS) and the Consolidated Quotation System (CQS). These systems linked different trading floors and consolidated transactions and quotes before releasing them to the market participants. Reg-NMS substantially overhauled these systems by requiring trading venues to provide their data to a centralized Securities Information Processor (SIP). However, the design of these systems and rules have also raised several concerns. HFTs subscribe to raw data feeds from the different venues, use their speed to process this data before the SIP, and profit from small arbitrage opportunities arising as a result of differential latencies. Ding et al. (2014) note that there were more than two such price dislocations per second on a single day in May 2012 for Apple.

On the other hand, a consolidated tape does not exist in the EU.[17] Free flow of information is ensured through timely publication of post-trade information and wide-ranging transparency requirements for trading venues. However, specific exemptions to these rules are also provided by MiFID. For example, dark pools are exempt from providing pre-trade transparency under various so-called waivers, e.g. a large-in-scale waiver for big orders or a reference-price waiver for crossing networks. To a large extent, in the EU the burden of ensuring markets are linked is on market participants. HFTs employing arbitrage strategies are important players in ensuring this by trading the same security in multiple markets (Brogaard et al., 2014). Additionally, sophisticated investors and brokers use smart order routing technologies (SORT) to send their

[17] MiFID II plans to introduce an EU-wide consolidated tape by requiring trading venues to report real-time trade data to approved Consolidated Tape Providers (CTPs) in a standardised format. However, as market participants are required to register themselves as CTPs, the future of this initiative remains unclear.

orders to the venue offering the best terms. van Kervel (2015) examines the impact of investors using SORT in a fragmented market. In his model, high-frequency liquidity providers supply liquidity by duplicating their limit orders on multiple venues (high execution probability) and immediately cancel their orders on one venue when the other venue is hit. He shows that a naive aggregation of liquidity across venues leads to an overestimation of quoted depth across venues. Further, an increase in the proportion of investors using SORT leads to an increase in adverse selection costs for the liquidity providers.

6. Conclusion

Financial markets in the US, Europe and other countries have evolved from a largely consolidated structure comprising primary listing venues, regional exchanges and the OTC market, to a highly competitive but fragmented structure comprising several exchanges and alternative trading systems like dark pools, ECNs, and multiple broker-dealers offering internalization services. These changes have been fueled by an increase in computational capabilities, improvements in networking technologies and several regulatory initiatives like Reg-NMS and MiFID. In this article we have reviewed the literature examining the reasons why markets fragment as well as the resulting impact on liquidity and price discovery.

The literature surveyed in this article provides several important lessons. First and foremost, the reasons underlying market fragmentation need to be examined keeping in mind two opposing economic forces acting simultaneously in securities markets. On the one hand, due to the presence of strong network externalities, financial markets have a tendency to consolidate in space and time. Additionally there are also economies of scale in concentrating order flow on one exchange, as it allows that exchange to amortize fixed costs over more trades. On the other hand, due to heterogeneity in traders' preferences, it is difficult to envisage a single market that can cater to all market participants at all times. Trader heterogeneity mainly includes differences in trading motives, order sizes, and patience levels.

The overall welfare implications of market design choices can generally be captured by the impact of such choices on liquidity and price discovery. It is important to recognize that embedded in securities markets is the market for trading services as well as the market for the traded securities. While the reduced costs resulting from competition in the market for trading services can be beneficial to market participants, competition in the market for the traded securities can be harmful as the efficiency of prices may be adversely affected. For example, the literature examining the impact of dark trading venues suggests that, as these venues cream-skim uninformed order flow away from lit trading venues, excessive dark trading may be harmful. On the other hand, OTC markets and dark pools may provide valuable liquidity to large, uninformed traders. In other words, maximizing welfare usually may require finding an appropriate balance between the impact on liquidity and price discovery.

Today's trading venues differ from one another on several trading parameters such as tick sizes, fee structures and trading speeds. Due to trading venues' efforts to attract heterogeneous groups of traders by designing innovative market models using such parameters, and because of cost reductions and improvements in technology resulting from competitive pressures, investors

can access their preferred venues at a diminished cost. However, today's markets are also very fragmented and complex, and it remains unclear whether these innovations have uniformly benefitted all types of issuers and market participants. For example, policy-makers and some groups of investors have expressed concerns on whether the current market structure, including the level of fragmentation, is optimal for stocks of small and medium enterprises. This issue is discussed by the SEC's Advisory Committee on Small and Emerging Companies and is also relevant in the context of European Commission's Capital Markets Union initiative. Public policy has the important role of setting standards and incentives for trading venues. This includes setting appropriate priority rules while handling orders, transparency requirements, and ensuring efficient market linkages.

The literature discussed above also leaves several questions unanswered. The reasons why trading of different stocks fragments to a different extent, are not yet clear. For example, as per LiquidMetrix (2010), in 2010 LSE's market share in FTSE 100 stocks ranged from 50% to 80% whereas the market share for BATS ranged from 2% to 15%. Similarly for DAX stocks, Deutsche Börse Xetra had a market share of 37% for Siemens and 75% for Commerzbank in 2010. Empirical studies have also observed that OTC market share in equities is significant. For example, in Europe it is around 40% as per Gomber et al. (2011b, 2015). The reasons for such a large share of the OTC market are not clear, especially given the diversity of venues available to market participants. Last, but not the least, as compared to equities, research examining the impact of order flow fragmentation in other asset classes is scant, and in some cases non-existent. This question is especially important in light of the MiFID II proposals in the European Union, which plan to impose increased transparency requirements and regulatory oversight for a significant portion of OTC trading in all asset classes.

It is clear that the issues involved in the design of financial markets are extremely important in helping financial markets to achieve their core objectives. This is not just true for equity markets but also markets for other instruments such as derivatives, bonds and energy products, which are experiencing increased competition due to technological developments and regulatory initiatives such as central clearing for derivatives or increased transparency requirements in trading of bonds, structured finance products, emission allowances and derivatives. The complex, subtle and simultaneous interactions of the economic forces discussed in this article make the task of designing optimal policy responses and regulatory interventions difficult. Policy-makers, regulators and venue operators should carefully evaluate the impact of their decisions keeping in mind these issues.

Appendix

A. Key Milestones in the Evolution of Equity Markets

1969	Instinet, the world's first electronic trading system goes live. It becomes part of the "fourth" market, competing with NYSE by allowing non-members to trade NYSE-listed stocks
1971	NASDAQ begins trading 2,500 over-the-counter securities.
1975	As part of a directive from the US Congress to reduce barriers to competition, the SEC proposes establishing a National Market System (NMS) comprising the Composite Quotation System (CQS) and the Intermarket Trading System (ITS).
1980	NYSE Rule 394 (and AMEX Rule 5), which prohibited exchange members from trading listed securities off-exchange, is repealed by the SEC.
1993	European Union (EU) adopts the Investment Services Directive granting securities firms, licensed by respective home states, to conduct cross-border operations in the EU. Additionally, several rules like price transparency are proposed to promote competition.
1997	SEC introduces order handling rules to increase competition among NASDAQ dealers and Alternative Trading Systems (ATS) like ECNs, as well as to improve transparency.
1999	SEC approves Regulation-ATS, giving ATS' an option to register themselves either as national securities exchanges or as broker-dealers. Further rules are imposed on ATS' registered as broker-dealers to better integrate them into the NMS.
2001	All US stock markets convert to a decimal system of quotation, leading to a decrease in bid-ask spreads.
2007	Regulation National Market System (Reg-NMS), introduced by the SEC in 2005 with the objective of promoting efficient and fair price formation across securities markets, becomes operational.
2007	Markets in Financial Instruments Directive (MiFID), proposed in 2002 to harmonize provision of trading services by promoting competition and consumer protection in investment services in the EU, becomes operational. This leads to the introduction of two new categories of trading venues - Multilateral Trading Facilities (non-exchange lit trading venue or a dark pool) and Systematic Internalizers (internalizers self-certifying themselves as such) - which start competing with Regulated Markets for order flow.
2007	NYSE merges with Euronext to form NYSE-Euronext.
2007	Nasdaq merges with OMX to form Nasdaq-OMX.
2011	BATS Trading and Chi-X merges to form the venue with the largest markets share in European equities.
2013	Intercontinental Exchange completes its acquisition of NYSE-Euronext.
2014	SEC approves the merger between DirectEdge and BATS.
2014	The European Union publishes the final MiFID II texts which are planned to become operational in 2018.

B. Glossary

Bid-ask spread	Difference between best available prices to buy and sell a security, often measured relative to the mid-quote.
Consolidated tape	Mechanism for the market wide dissemination of the best quotes and trades reported by participating trading venues.
Crossing network	Dark pool which crosses buy and sell orders periodically or as they arrive, typically at the mid-quote of a reference market.
Dark pool	Electronic dark trading venue that combines the absence of pre-trade transparency with automated execution.
Dark trading venue	Venue without any market-wide pre-trade transparency.
Electronic Communication Network	Lit trading venue competing with exchanges in the US.
High-Frequency Trading (HFT)	Trading activity which relies on computer algorithms to generate a large number of orders and trades on a daily basis. HFT firms use high-speed links to trading venues, sometimes by colocating their trading servers in the venues' premises.
Internalization	Service provided by a dealer where client orders are executed against the dealer's own inventory as opposed to on the public market.
Limit order	Instruction to trade at a price better than or equal to the limit price specified by the trader.
Limit order market	Market mechanism where all participants can trade by directly submitting orders which can execute against existing orders of other participants. A limit order book is a collection of all unexecuted orders available to trade against at any point in time.
Liquidity provider	Participant who pre-commits to trade, typically by providing a price and quantity, at which an incoming order can be matched.
Liquidity consumer	Participant who trades against the order of a liquidity provider.
Lit trading venue	Venue with at least some level of pre-trade transparency in contrast to a dark trading venue.

Market-maker	Broker-dealer firm in charge of providing liquidity and facilitating trading for a security.
Market order	Instruction to trade at the best available price.
Matching engine	Exchange computer server matching buy and sell orders with each other to determine trades that take place.
Mid-quote	Average of best available price to buy and sell a security.
Member	Market participant registered to directly trade on a trading venue.
Over-The-Counter market	Market for off-exchange bilateral, often non-anonymous, trading.
Post-trade transparency	Availability of information about a trade after it has been executed.
Preferencing	Routing customer orders to another dealer for internalization.
Pre-trade transparency	Availability of information concerning trading opportunities, e.g. quotes or the state of the limit order book.
Price impact	Change in price measured typically over a short period of time after a trade. It is typically measured from the perspective of the trader executing against an order of the liquidity provider.
Quote	Price of an order submitted by a liquidity provider.
Specialist market	Market where an official liquidity provider, known as the specialist, is responsible for matching buy and sell orders as well as providing two-way executable quotes to other market participants.
Trade-through	Trade executed at a price that is worse than the best price available to the liquidity consumer.

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