Specialists as Risk Managers: The Competition between Intermediated and Non-Intermediated Markets

Wen Mao
Villanova School of Business
Villanova University

and

Michael S. Pagano*
Villanova School of Business
Villanova University

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* Correspondence can be sent to: Villanova School of Business, Villanova University, Department of Finance, 800 Lancaster Avenue, Villanova, PA 19085. Phone: (610) 519-4389 E-mail: michael.pagano@villanova.edu.

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Abstract

We develop a model that analyzes competition between a non-intermediated market (such as an Electronic Communications Network) and an intermediated market (such as via the market specialist's structure within the NYSE) when both markets are allowed to trade the same securities. Specialists are viewed as providers of a "volatility dampening" service, a mechanism for reducing round-trip trading costs, as well as an "order execution risk management" service. The economic value of these three specialist services is determined by five key factors (the difference in spreads between the two financial market types, investors' holding periods, the specialist's quoted spread in relation to the asset's price, the probability of executing an order in the intermediated market, and the short-term risk-free rate).

Securities markets provide important services that go beyond the specific private benefits of facilitating the exchange of assets between investors and helping companies raise financial capital.[1] In particular, well-functioning financial markets produce a public good in the form of timely information about the market value of numerous marketable securities which all members of society can use to manage scarce resources, allocate funds for investment, and plan for the future. Given the important externalities and public good attributes of a securities market, it is not surprising that governments regulate these financial markets fairly closely and that regulatory activity in the U.S. has increased over the past 10-15 years.

In addition, entirely new trading systems such as Electronic Communications Networks (ECNs) have also sprung up since the change in Nasdaq order handling rules during 1997. The ECNs' market structure is a "non-intermediated" one because there is no designated market maker / specialist or dealer that is charged with maintaining a "fair and orderly" market for trading stocks on this type of system.[2] In contrast to ECNs, older, more established stock markets such as the New York Stock Exchange (NYSE) typically employ an "intermediated" market model where a market specialist, or designated market maker, stands ready to use his/her own capital to maintain a fair and orderly market in the trading of NYSE stocks.[3] In fact, the NYSE has rolled out its "Hybrid Market" which combines the traditional floor-based specialist system with the automated matching and electronic order book systems of Direct + and NYSE ARCA.[4]

[1] See Harris (2003) for a detailed discussion of the private and public benefits of a financial market and the role of regulation and social welfare in relation to these benefits.

[2] In addition to the ECNs noted above, crossing networks and block trading systems such as Liquidnet, Pipeline, and ITG's Posit (commonly referred to as Alternative Trading Systems, or ATSs) have also garnered a growing share of the market for trading U.S. equities.

[3] Recently, the NYSE has begun to refer to specialists as designated market makers. For brevity, we use the traditional (and more concise) term, "specialists," throughout this paper when referring to these designated market makers.

[4] The stated intention of this combination of intermediated and non-intermediated markets at the NYSE is to provide greater choice to traders and let the customer decide which of these competing models they

Thus, the competition between intermediated and non-intermediated markets we analyze here exists even within the NYSE organizational structure itself.[5]

In light of the above issues, we develop a model that analyzes the type of competition that exists between a non-intermediated financial market (such as an ECN) and an intermediated market (such as the specialist structure of the NYSE) when both types of markets are allowed to trade the same securities. We examine the costs and benefits of the two competing market structure models: 1) a potentially faster, non-intermediated market which might be subject to larger price fluctuations due to the absence of a designated market specialist, and 2) an intermediated market where a market specialist oversees trading in one risky asset and is required to dampen excessive price volatility by posting a relatively tight bid-ask spread that helps maintain a fair and orderly market for this asset. The specialist's function thus might be valuable to an investor or trader who buys this asset at some point and is concerned about the future resale value of this security because an illiquid market could cause the asset's resale price to differ from the asset's fundamental or 'true' value. In turn, this concern could potentially lead to a demand for less volatility in bid-ask spreads.

In this context, one can view a market specialist as a supplier of a unique "volatility dampening" service to risk-averse investors that want to be protected from undue price volatility. Specialists can also compete by providing an "order execution risk management" service that reduces the risk that an order will not be executed (compared

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prefer. Interestingly, Hendershott and Moulton (2008) report that the advent of the NYSE Hybrid Market has led to a significant decrease in specialists' floor-based participation rates. However, despite some analysts' predictions that specialists will become obsolete, there is growing evidence across many markets around the world (detailed later in Section I) that designated market makers can improve market quality in comparison to a non-intermediated market.

[5] Beyond the equity markets, we now also see new electronic markets such as eSpeed competing with the traditional network of primary dealers in the area of U.S. Treasury securities. Like a specialist in an equity market, these primary dealers are in a unique position to identify the supply and demand conditions for a large number of marketable securities and make markets in these securities by providing competitive bid and ask prices.

to a non-intermediated market). This novel interpretation of the specialist's role enables us to estimate the economic value of these risk management services and compare it to the specialist's reduction in "round-trip" trading costs.[6] This characterization of the benefits from the specialist's volatility dampening service is similar in spirit to Stulz's (1984) and Smith and Stulz's (1985) analysis of how risk management / hedging activities can increase value for widely held corporations.

By providing more competitive prices than in the non-intermediated market, the market specialist creates a tighter bid-ask spread that not only reduces short-term return volatility by reducing the "bid-ask bounce" but also decreases an investor's round-trip trading costs (thus boosting the investor's net investment returns).[7] As noted above, the specialist can also compete via better order execution risk management by providing greater certainty that orders routed to the specialist market will get executed. In contrast, non-intermediated markets such as an ECN attempt to compete with the specialist by offering a potentially faster, alternative order-matching service (referred to as an automated limit order book). Thus, the investor faces an important trade-off in terms of

[6] Round-trip trading costs typically include easily measurable, "explicit" costs of initiating and then liquidating an investment in a specific security. The conventional approach to measuring these costs is to focus on brokerage commissions, taxes, and the bid-ask spread as the primary sources of round-trip trading costs. There are, however, less easily measured, "implicit" trading costs such as the cost of: one's order moving the market price (adverse market impact), delays encountered in the execution of one's order, and the opportunity cost of not executing one's complete order. See Harris (2003) for more details on these implicit trading costs.

For our purposes, we refer to round-trip trading costs as those pertaining strictly to the bid-ask spread and treat these costs as a form of "tax" that affects investors' net returns and can vary between the intermediated and non-intermediated markets. In effect, we hold brokerage commissions and income taxes constant across the two types of markets. With respect to the implicit trading costs, we allow these to vary between the two markets by allowing the probability of executing a trade to differ in the intermediated and non-intermediated markets.

[7] The "bid-ask bounce" refers to the fact that, in the absence of any new information, observed transaction prices will still fluctuate because market buy (sell) orders that randomly arrive at the specialist will be paired with the best ask (bid) prices on the specialist's book (or a price in between the best bid and ask if the specialist provides price improvement). Thus, transaction prices will "bounce" between the bid and ask prices even when there is no new information released to market participants. See Blume and Stambaugh (1983) for an early analysis of the impact of the bid-ask bounce on observed stock returns.

bid-ask spreads, order execution certainty, and intraday price volatility when deciding to route orders to one of these two types of markets.

Our key findings are threefold. First, a specialist within an intermediated market can remain viable by providing three potentially valuable services to investors: a) volatility dampening for the underlying asset's price, b) lower round-trip trading costs via the maintenance of a tighter bid-ask spread, and c) higher order execution probability (i.e., execution risk management). That is, an intermediated market can remain viable in the face of competition from a possibly faster, non-intermediated market as long as the specialist can generate revenue for the above services that covers his/her costs associated with asymmetric information, order processing, and inventory management.[8] The intuition underlying this result is that the specialist is less risk-averse than other market participants and thus can provide a risk management, or insurance-type, service which can be valuable to risk-averse investors. In addition, our analysis suggests an alternative way to compensate a specialist, with a portion of the compensation paid in the form of a fixed fee and the remainder paid as a variable charge that is adjusted dynamically to reflect current market conditions for the underlying security.[9]

Second, the value of the above specialist services is a function of five key factors (the difference in spreads between the two types of financial markets, investors' holding periods for the asset, the specialist's quoted spread in relation to the asset's price, the relative probability of executing an order in the intermediated market, and the short-term risk-free rate). Variations in any or all of the above factors can affect an investor's

[8] As Cohen, Maier, Schwartz, and Whitcomb (1986) noted, a specialist's volatility dampening function has attributes of a public good because all risk-averse investors benefit from reduced volatility but not all investors bear the cost of the specialist's activity. Similarly, in our model, we find that the value of the specialist's risk management service for any individual investor can be relatively small but, in the aggregate, this service is quite valuable when cumulated across all investors. We discuss this point further in Section II and in the Conclusion.

[9] Consistent with our model, designated market makers at the NYSE and other exchanges such as the Borsa Italiana have begun compensating these liquidity providers with a fixed, periodic stipend in order to insure a certain minimum level of liquidity in their respective markets.

maximum willingness to pay for the specialist's services. In particular, the difference in spreads and order execution probabilities between the two markets, investors' holding periods, and the specialist's spread as a percentage of the asset's price are likely to have the largest impact on investors' perceived value of the specialist's services.[10]

Third, the relative value of the specialist's volatility dampening function (in comparison to the round-trip cost savings) can vary greatly due to differences in investors' holding periods, as well as due to differences in market- and security-specific factors such as the general price level of the asset, the risk-free rate, and the specialist's quoted spread. For example, we use numerical illustrations in Table 1 to demonstrate that for a security with a high relative spread of 100 basis points, the value of the specialist's price risk management service is 0.37% of the total value of the specialist's services for those investors with a 1-day holding period. In contrast, this risk management service represents 98.2% of the total value for risk-averse investors who focus on daily price movements even though they have an infinitely long investment horizon.[11] Thus, the economic value of the specialist's volatility dampening activity varies greatly depending upon investors' anticipated holding periods and their attention to short-term price fluctuations.

Based on the above findings, our model suggests some short-term "high frequency," or "day traders," might not find much value in the specialist's risk-reduction service but many long-term "buy and hold" investors could derive significant value from this risk

[10] These results corroborate O'Hara (2001), which suggests that a good market structure design should reflect the characteristics of the firms listing on a financial market, as well as address the needs of the types of investors in these firms' securities. Consistent with this notion, Comerton-Forde and Rydge (2006) examine 10 Asian-Pacific stock exchanges and describe how, for example, the market structure of the more institutionally focused Australian Stock Exchange differs from the more retail-oriented Korea Exchange.

[11] In computing these figures, we assume that neither the intermediated nor the non-intermediated markets has an advantage in terms of price discovery and therefore the quote mid-point for the security is the same in both markets. These calculations are described in more detail in Section III and Table 1.

management activity.[12] The intuition underlying this observation is that volatility dampening is not as valuable for a short-term investor because an asset's price does not typically experience large fluctuations over a very short time horizon such as one day. In contrast, a risk-averse long-term investor is more likely to be willing to pay the specialist to reduce this short-term volatility because even a relatively small reduction in, say, daily volatility can lessen the "market friction"-related cumulative risk inherent in an asset's price over his/her longer investment horizon.[13]

In effect, one can identify three broad classes of investors: 1) short-term, high frequency traders who are primarily focused on trading cost savings, 2) long-term "buy and hold" investors who are relatively insensitive to short-term (e.g., intraday / daily) price volatility, and 3) long-term investors who plan to hold securities for more than a few days but are still sensitive to short-term volatility because they face institutional frictions such as daily mark-to-market and margin requirements related to leveraged stock purchases, the liquidation and transaction costs related to handling investor redemptions and new investments, and costs associated with reporting daily performance information such as net asset value data (e.g., these costs are typically borne by mutual fund and other institutional investors). The above results, coupled with the fact that a non-intermediated electronic market can be faster than an intermediated market, suggest that many short-term investors could prefer the non-intermediated market while a substantial number of long-term investors still might gravitate to the intermediated market (assuming the round-trip cost savings of the intermediated market are not that large).

[12] Note, however, that more frequent traders would still place considerable value on the intermediated market's ability to reduce round-trip trading costs. Thus, the overall decision of where an investor directs his/her trades will be determined not only by the specialist market's risk management and trading cost reduction services but also by the investor's own characteristics (e.g., investment horizon, level of risk aversion, etc.).

[13] This conclusion is robust even when, as we do, the volatility of the asset's price from "fundamental" factors is assumed to be: a) the same in both the intermediated and non-intermediated markets, and b) independent of any market friction-related volatility.

In general, every security has attributes that favor either the intermediated or non-intermediated market but the composition of investors (and their investment horizons) can play a key role in influencing which market ultimately receives the majority of the security's order flow. Our results indicate that investor demographics can help determine the value of the two competing market designs but we do not make explicit predictions regarding the relative market shares between the two markets because we assume, for simplicity, a representative (or homogeneous) investor in our model. Thus, one possible path for future research is to estimate "equilibrium" solutions for a specialist market by relaxing the assumption of a common (or representative) investor so that the actual demographics of a market's heterogeneous investors can be used to gauge potential changes in the relative market shares of the intermediated and non-intermediated markets.

Despite the relative simplicity of the model, its main properties (as described by the four propositions in Section II) such as the importance of relative spreads and relative order execution probabilities in the two markets are consistent with recent trends in global equity markets, such as the specialist's increased role in less-liquid securities, the general decline in specialist's overall participation rates, the subsidization of specialist revenues by exchange operators and/or corporate issuers through fixed fees / stipends, the greater reliance on electronic non-intermediated markets for more-liquid stocks, the heavier usage of block trading services via ATS networks, and the more frequent breaking up of large orders into smaller orders (commonly referred to as "slicing and dicing"). As we show in Section IV, both numerical simulations and an empirical analysis of SEC order execution data from the NYSE floor and ARCA ECN systems confirm our model's key predictions related to spreads, execution quality, and relative market shares.

Our model can also be used as a guide for market participants and policy makers in understanding how variations in the costs and benefits of intermediated and non-intermediated markets lead to changes in the way investors choose to trade. As O'Hara

(1997) has noted, there is a paucity of rigorous economic models that address the central question of optimal market structure and the trade-offs inherent in the two types of markets described above. In subsequent years, theoretical research on market design such as Seppi (1997), Foucault and Parlour (2004), Bessembinder, Hao, and Lemmon (2006), and others has examined some of these trade-offs in more detail.[14] Our paper contributes to this growing literature by providing an analytic solution that can help quantify the economic value of a specialist's services when faced with competition from alternative trading systems.

The paper is organized as follows. Section I discusses some of the relevant literature while Sections II the basic model. Section III provides some numerical examples of the basic model and Section IV presents our conclusions.

I. Related Literature:

Research on the role of specialists and market makers has progressed substantially over the forty years that have passed since Demsetz's (1968) analysis of transaction costs and liquidity provision. The subsequent research is simply too voluminous to document it all here. However, we can identify three basic types of market microstructure models that have been developed since Demsetz (1968) in roughly chronological order: 1) inventory-based, 2) information-based, and 3) strategic trader-based.[15] In the inventory-

[14] See Biais, Glosten, and Spatt (2005) and Madhavan (2000) for excellent recent reviews of the market microstructure literature. For example, Biais et al. (2005) discuss how competition between markets can reduce spreads and increase incentives to innovate relative to a monopolistic specialist-only market. Thus, competition between markets can be beneficial from a social welfare perspective. In contrast, our focus here is on the specific value a specialist can provide given that a competing market does exist. That is, in our analysis, both types of markets are assumed to exist and the question is not to determine whether one market structure will survive and the other market will disappear. Rather, we examine how valuable a specialist's services are when competing markets have alternative benefits / advantages over the specialist market.

[15] O'Hara (1997) uses a similar taxonomy of market microstructure models and is an excellent reference on the development of these models.

based models, the focus is on minimizing the market maker's costs associated with order processing and the management of an inventory of risky assets.[16]

Next, the problem that asymmetric information posed to market participants was first introduced by Bagehot (1971) but was not formally modeled until papers such as Copeland and Galai (1983), Glosten and Milgrom (1985), and Glosten (1989) appeared in the literature. This strand of research realized that securities markets could fail (i.e., no market clearing price could be determined and no trading would occur) if some traders possessed superior information about risky assets and other traders (e.g., market specialists) knew that these better-informed investors existed. As shown in Glosten (1989), the key solution to this problem is that social welfare can be enhanced by letting the market maker capture economic rents from uninformed traders in order to offset any expected losses the market maker incurs when trading with informed traders.

Lastly, strategic trader models were introduced in the literature. These models still rely on informational asymmetries but enable traders to react dynamically to order flow and quoting behavior. For example, the first set of strategic trader models allowed informed traders to exploit their information by trading directly with naïve, uninformed "liquidity" traders (as first noted in Kyle, 1985). Later models developed more complex interactions between informed and uninformed traders by permitting these uninformed traders to also trade strategically (as in Admati and Pfleiderer, 1988, 1989, and Seppi, 1990, among others). In addition, "noise" traders that attempt to learn about the informed trader's superior information were added to the model so that a "trichotomy" of informed,

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[16] Early research in this vein include Demsetz (1968), Garman (1976), Ho and Stoll (1981), Stoll (1978), and Cohen, Maier, Schwartz, and Whitcomb (1981). Cohen, Maier, Schwartz, and Whitcomb (1986) extend this literature further by examining the public good externality that a specialist can provide in terms of price stabilization (i.e., volatility dampening activity in our terminology). That is, lower price volatility can be a benefit to all risk-averse investors although not all investors need to pay for this "good". In our model, the specialist's trading activity contains some elements of a public good (in terms of risk management's benefits for all investors) but also contains private good attributes (e.g., the round-trip trading cost savings only accrue to those investors who trade in the specialist market). Thus, the combined value of the specialist's risk management and trading cost reduction services can be viewed as the private value of these services to investors (net of any public good benefits).

liquidity, and noise traders now comprise the typical market microstructure framework (e.g., Easley and O'Hara, 1992, and Black, 1989).

We build upon this literature by examining the role of a specialist when he/she faces competition from a non-intermediated market which might be able to execute transactions with greater speed. Bid-ask spreads can be affected by order processing, inventory management, and information-related costs but the viability of the specialist's role is ultimately driven by his/her ability to extract economic value by dampening short-term return volatility, increasing the probability of filling investor orders, and reducing round-trip costs for risk-averse traders. By acting as a price and execution risk manager for investors, it is possible for the specialist's role to remain viable even when a possibly faster non-intermediated market exists.[17]

Our approach is most directly related to recent theoretical work by Bessembinder, Hao, and Lemmon (2006). In their investigation of the affirmative liquidity provision obligations of designated market makers, they find that social welfare can be enhanced when these market makers provide tighter quoted spreads because such behavior encourages more traders to become informed about the asset's true value. Thus, the focus of Bessembinder et al. (2006) is the market maker's impact on the price discovery process and social welfare. In contrast to this research, our model focuses on the economic value that a market maker generates by fulfilling his/her affirmative obligations, with an explicit examination of the specialist's risk management services and the role of investor demographics (such as differences in investment holding periods). Thus, our work serves as a complementary analysis of the value of a market maker's quoting and liquidity provision behavior.

[17] Note that with a non-intermediated market as a competitor, the specialist's viability is not guaranteed. As we will show later, viability is determined via the value the specialist generates from his/her risk management and trading cost reduction services.

The notion that designated market makers (and specialists, in particular) might be able to enhance the efficiency of a market's operations is generally supported by recent empirical research. For example, Chung and Kim (2006) confirm that a NYSE specialist system "provides more resilient liquidity services than the NASDAQ dealer market for riskier stocks and in times of high return volatility when adverse selection and inventory risks are high." They attribute this finding to the fact that the NYSE specialist is solely responsible for maintaining liquidity in a specific stock whereas Nasdaq dealers do not have this "liquidity provider of last resort" obligation.[18] Boehmer (2005) finds that orders are typically executed more slowly on the NYSE (versus Nasdaq) but that the overall cost of these trades is still lower than the cost of trading on the Nasdaq Stock Market. The author confirms a significant positive relationship between trading cost and the speed of execution (i.e., faster executions generally cost more than slower trades).

Cao, Choe, and Hatheway (1997) find that NYSE specialists might remain competitive in terms of order processing and inventory management costs by allowing the cash flow from more active stocks to "subsidize" inactive stocks. Eldor, Hauser, Pilo, and Shurki (2006) find that the introduction of option market makers within an electronic market can increase liquidity, improve price discovery (i.e., generate more reliable transaction prices), and raise overall social welfare well beyond a non-intermediated market. Anand, Tanggaard, and Weaver (2009) show that market quality improved when issuers listed on the Stockholm Stock Exchange were permitted to pay liquidity providers directly in exchange for greater liquidity provision in the issuers' stock. Perotti and Rindi (2008) also document positive effects on market quality (due to improved information

[18] Other papers which document the value of using a specialist system over a non-intermediated market structure include Anand and Weaver (2006) in the U.S. options market, Venkataraman and Waisburd (2007) in the French equities market, and Barclay, Hendershott, and Kotz (2006) in the U.S. Treasury debt market. Davies (2003) finds that designated market makers at the Toronto Stock Exchange can improve opening price discovery even when they operate within an open, automated pre-opening system. In contrast, Conrad, Johnson, and Wahal (2003) find that realized trading costs on ECNs are lower than on other trading venues but they also note that this cost advantage has diminished due to changes in tick sizes and new order handling rules.

disclosure) when specialists are introduced for the Borsa Italiana's "STAR" group of small- and mid-cap stocks. This finding is also consistent with Charitou and Panayides (2009), which reports that several equity markets around the world have recently been introducing (or re-introducing) designated market makers, particularly for less-liquid stocks. Further, Handa, Schwartz, and Tiwari (2003) examine the economic viability of the American Stock Exchange's trading floor and estimate that the market specialist's floor-based activity provides substantial economic benefits to investors.

In contrast to the above findings, Jain (2005) finds that the introduction of electronic trading (versus traditional floor trading) for a large sample of exchanges leads to an increase in liquidity, greater informativeness of prices, and a subsequent reduction in the cost of capital (most notably in emerging markets). In addition, recent evidence from Hollifield, Miller, Sandas, and Slive (2006) based on the limit order book (LOB) system used at the Vancouver Stock Exchange suggests that a pure LOB design could be approximately 50% more efficient than a market based on a profit-maximizing monopolist.

In sum, the empirical literature suggests a specialist can provide significant economic value even in an industry that is becoming increasingly automated. However, given the benefits of automated trading reported in Jain (2005) and the potential benefits of a LOB shown in Hollifield et al. (2006), the viability of an intermediated, specialist market structure is not guaranteed. We now turn to a model that can help explain some of the main factors influencing the competition between intermediated and non-intermediated markets.

II. The Basic Model:

As noted in the Introduction, we develop a model which examines the costs and benefits of two competing market structures: 1) a non-intermediated market which can be subjected to larger price fluctuations due to the absence of a designated market specialist, and 2) an intermediated market where a market specialist oversees trading in one risky asset and is required to reduce excessive price volatility to maintain a fair and orderly market in this asset. More specifically, one can view the market specialist in the intermediated market as a risk-neutral, profit-maximizing monopolist that posts relatively tight bid-ask spreads which, in turn, provides a unique volatility-dampening service for trading in a financial asset that is attractive to at least some risk-averse investors.[19] Because the specialist is risk-neutral and therefore less risk-averse than other investors, the volatility dampening service can be provided only by a market specialist within an intermediated market and that non-intermediated markets (such as an ECN) attempt to compete indirectly with the specialist by offering a potentially faster, or more reliable, alternative order-matching service. It should also be noted that even though our basic model begins with the assumption of a fixed (and lower) bid-ask spread in the intermediated versus the non-intermediated markets, this assumption can be relaxed to allow for the difference in spreads between the two markets to vary stochastically and to even reverse sign (so that the bid-ask spread can be lower in the non-intermediated market).

Beyond the volatility dampening service described above, the potentially tighter spread quoted by the specialist also leads to lower round-trip trading costs (relative to the non-intermediated markets) and thus yields higher net investment returns for those investors that route their orders to the intermediated market. The lower volatility and reduced trading costs are directly attributable to the specialist's ability to tighten the bid-ask spread and thus decrease the well-known bid-ask bounce.[20] Our basic model shows

[19] Although it is frequently assumed that a specialist, particularly for publicly traded common stock, acts as a monopolist (e.g., as in Glosten, 1989), it should be noted that real-world specialists such as those at the NYSE are not true monopolists as they do face competition from limit order traders and floor brokers. However, these specialists still have at least some market power due to their privileged position.

[20] We refer to the quoted bid-ask spread throughout the paper, but we can (without loss of generality) substitute effective or realized spreads in our model. Both the effective and realized spreads compare the bid and ask prices to actual transaction prices in order to estimate what investors might actually pay in terms of round-trip trading costs.

how the economic value of a specialist's service is explicitly linked to both volatility dampening and lower round-trip trading costs.[21] In effect, the specialist's value is tied directly to how a smaller bid-ask bounce can reduce "market frictions" which, in turn, lead to higher net returns and less volatility for investors.

We suggest that it is reasonable to refer to a specialist as a risk manager because he/she can reduce the volatility of security returns for risk-averse investors by providing liquidity on an as-needed basis. For example, the specialist operates in an intermediated market and can reduce the volatility of returns not only by providing tighter spreads but also by taking positions that offset temporary buy/sell order imbalances. For simplicity, we focus on the specialist's ability to reduce the spread and hold the specialist's buy/sell order rebalancing function constant in our analysis. Because investors are risk-averse, they may prefer the lower return volatility and potentially smaller round-trip trading costs of an intermediated market as long as the fee charged by the specialist / liquidity risk manager is not too costly. Thus, the key trade-off in our model is between the marginal benefits of a specialist's risk management and trading cost-reduction services and the marginal costs of delivering these services (relative to the costs of routing one's orders to a non-intermediated market where these services are not provided). In general, depending on an investor's level of risk aversion and investment holding period, different investors might prefer the intermediated market over the non-intermediated market (or vice versa).

II. a) The General Problem

To begin, we start with a general form of the problem and then impose some further structure on the model to illustrate the model's key implications via a numerical exercise. Each risk-averse, utility-maximizing investor (denoted by *i*), having already

[21] The specialist's order execution risk management service is an extension of our basic model and is discussed later in Section II.

determined whether to buy or sell the risky asset, focuses on his/her next trade in a single risky asset over a pre-specified time horizon and must decide whether to submit a market or limit order either to a potentially less-volatile intermediated market (operated by a risk-neutral, monopolistic specialist) or to a possibly faster non-intermediated market.[22] If investor *i* sends the order to the intermediated market, he/she must pay a fee, f_i, for using the specialist's service. The upfront fee, f_i, is above and beyond the spread quoted by the specialist (denoted as S_M).[23] Because the specialist is a risk management monopolist, the specialist can charge up to the *maximum* amount that investor *i* is willing to pay, $\overline{f}_i$. The risk-averse investor, *i*, is willing to pay $\overline{f}_i$ because he/she wants to maximize the utility form a concave personal utility function which places a positive economic value on volatility reduction. Since the specialist is a risk-neutral monopolist and if the specialist's marginal revenue is greater than zero while its marginal cost is zero, then the specialist should charge an equilibrium price, f^*, based on the marginal investor who is the *least* willing to pay and thus the least risk-averse.

However, because the specialist faces competition from a non-intermediated market that charges a spread (denoted as S_N), the economic viability of the specialist market depends, in part, on whether he/she can charge enough for the service so that $\overline{f}_i$ *plus* the specialist's spread, S_M, are sufficient to cover the costs of making a market in the

[22] Note that the trader can be of any of the three types discussed earlier (i.e., either an informed, uninformed, or noise trader). Issues related to asymmetric information and strategic behavior are captured within the spread variables (denoted as S_M and S_N and described in detail later). At this point, we take both S_M and S_N as derived from a Bayesian updating scheme described later in this section. By doing so, we can focus on the task of identifying the determinants of the specialist's fee for providing his/her risk management services to risk-averse investors.

[23] This fee could be in the form of a security-specific specialist commission or an exchange fee collected from investors by the market center and remitted to the specialist. The basic point is that this fee should be separate and distinct from the specialist's quoted spread because this spread is influenced by other factors (notably, the costs associated with order processing, inventory management, and asymmetric information which will be discussed in more detail later).

risky asset yet not so great that they put the specialist at a significant cost disadvantage relative to the non-intermediated market's spread, S_N.[24]

Order execution is another dimension in which different market structures compete. Namely, the probabilities of order execution in both markets may not be the same. For example, the order execution probability in the specialist market can be greater or less than the probability of executing an order in the non-intermediated market (e.g., due to the specialist's ability to handle large, block-size orders or possibly via differences in the two markets' order execution speeds). Hence, we allow the probabilities of order execution to differ between the intermediated and non-intermediated markets and relate the two probabilities to each other by dividing the intermediated market's probability by the non-intermediated market's probability (denoted below as α).[25] Thus, α equals 1 when the order execution probabilities are the same in the two markets.

The following analysis examines how $\overline{f}_i$ is determined and whether or not an intermediated market can remain viable when a non-intermediated market exists to trade the same risky asset. Each individual investor *i* might have a different maximum willingness to pay $\overline{f_i}$ due to various reasons. For example, investors' utility functions may vary from person to person. In addition, even if all investors have the same utility function, each may have a unique endowment of the risky asset, z_i. Thus, $\overline{f_i}$ can vary depending on individual *i*'s risk attitude, asset level, and the distribution of assets across various investment vehicles, among other things. Of course, the distribution of $\overline{f_i}$ across the population of investors will determine the exact shape of the demand curve for the

[24] Note that the non-intermediated market can also charge a fee like $\overline{f}$ but, for simplicity, we assume without loss of generality that this market's fee is set to zero.

[25] For simplicity, and without loss of generality, the non-intermediated market's probability is normalized to 50%.

specialist's services. To go beyond the general framework described above and generate more precise results, we consider two commonly used utility functions.

II. b) Application to a Specific Utility Function

Here, we use a quadratic utility function and allow the probabilities of order execution in the two markets to vary (i.e., $0 \leq \alpha \leq \infty$). This starting point makes the analysis more tractable and enables us to show some key properties of the demand function via a numerical example (details of this model's derivation can be found in the Appendix). What follows is a simple theoretical exercise that demonstrates how we can determine the profit-maximizing level of the specialist's fee, f^*.

$$u_i(z) = z - \frac{\gamma_i}{2} z^2, \ \ \gamma_i > 0,$$

where, z is the dollar value of the amount invested in the risky asset. That is, we assume investors are risk-averse and all have the same dollar amount invested in the risky asset. Specifically, $u_i'(z) = 1 - \gamma_i z > 0$ for $z < \frac{1}{\gamma_i}$ (and $\frac{1}{\gamma_i}$ is the satiation point); and

$u_i''(z) = -\gamma_i < 0$. Here, the degree of absolute risk aversion is measured by

$\lambda(\gamma_i) = -\frac{u_i''(z)}{u_i'(z)} = \frac{\gamma_i}{1 - \gamma_i z}$, and it is increasing with γ_i (i.e., the higher the value of γ_i, the more risk-averse investor i is). This specification allows us to observe directly the relationship between the investor's willingness to pay for the service provided by the market specialist, namely $\bar{f}_i$, and the degree of risk aversion.

Clearly, each individual investor's $\bar{f}_i$ is determined by the characteristics of the utility function which reflects the degree of risk aversion and the amount invested in the risky asset. One can derive a demand function based on the distribution of investors' maximum willingness to pay. Figure 1 is a rough sketch of this demand curve. The results presented in Figure 1 show the demand curve and marginal revenue function based on investors with quadratic utility and differing levels of risk-aversion, as well as a risky asset with a bid price of $39.975 and an ask price of $40.025 over a 1-year investment horizon.

Although this figure depicts a specific example of the demand curve to determine the specialist's profit-maximizing fee, f^*, the general properties of all concave utility functions can be seen in this graph. For example, the demand curve in Figure 1 is nonlinear and the marginal revenue function does not reach zero (even when the marginal cost of providing the specialist's service is zero), thus illustrating the specialist's incentive to increase its trading activity. Since the specialist acts as the monopolist, it will charge a price where marginal revenue equals marginal cost. If, as shown in Figure 1, marginal revenue is greater than zero and marginal cost is zero, then the specialist should charge a price f^* based on the marginal investor who is the *least* willing to pay and thus the least risk-averse. Of course, in the case where marginal costs are greater than zero, the optimal price of f^* will be determined where marginal revenue equals marginal cost. However, since the optimal price is based on the marginal investor in Figure 1, for simplicity, the profit-maximizing solution presented here focuses on the least risk-averse investor.

II. c) Further Applications of the Basic Model

Given that we do not have details on a specific market's investor demographics, we pin down the model's predictions more tightly by focusing on an even more specific example based on a logarithmic utility function:[26]

$$u(z_i) = \log z_i$$

where z_i is the dollar value of the amount invested in the risky asset by investor *i*. Specifically, the degree of absolute risk aversion is measured by $\lambda_i = -\frac{u''(z_i)}{u'(z_i)} = \frac{1}{z_i}$, and it is decreasing with z_i (i.e., the higher the wealth, the less risk-averse the individual becomes). Also, the log utility function is mainly used for illustration purposes because,

[26] Although this section concentrates on a specific utility function, the main results presented here will still hold as long as investors possess a monotonic, concave utility function.

as noted in the earlier example, the key results of the paper rely solely on the concavity of the utility function. In other words, the primary assumption necessary to obtain our results is that investors are risk-averse to varying degrees.

Let S_M and S_N be the bid-ask spreads for the intermediated market (denoted with subscript, *M*) and non-intermediated market (denoted with subscript, *N*), respectively:

$$S_M = a_M - b_M \text{ and}$$

$$S_N = a_N - b_N ,$$

where a_M , b_M , a_N, *and* b_N stand for the best asking price and best bid price for the intermediated and non-intermediated markets, respectively, for a particular security that an individual investor is considering to buy or sell via the market specialist or the ECN-type market.

A risk-neutral, profit-maximizing specialist in the intermediated market sets its bid and ask quotes based on the typical Bayesian updating scheme, as described in O'Hara (1997) and Bessembinder et al. (2006), among others. That is, the ask, *a*, is the expected value of the security in question, conditioned on observing a buy along with the history of buying and selling orders thus far. And the bid, *b*, is the expected value of the security conditioned on observing a sell, as well as the current history of orders in the market.[27] Specifically,

a_M = E(V| Buy, Z_M)

b_M = E(V| Sell, Z_M)

a_N = E(V| Buy, Z_N)

b_N = E(V| Sell, Z_N)

[27] Note that in the non-intermediated market, the best bids and offers are determined collectively by all traders that submit orders to this market's limit order book. These traders will also use a Bayesian updating scheme as noted above for b_N and a_N.

where, V denotes the value of the security and Z is the order history in the designated market (*M* or *N*).

By the dynamics of Bayesian learning, the prices would converge to the true value of the security in either the intermediated or non-intermediated markets. But this convergence will occur at different rates depending on variations in the level of information available in the two markets. Thus, we can argue that the market with more information would have a narrower bid-ask spread.

As an example, if a specialist provides superior price improvement relative to a non-intermediated market due to more (or better) information, then we would expect $b_M > b_N$ and $a_N > a_M$.[28] In this model, we assume that the quote midpoint (*QMP*) is the same for the intermediated market and the non-intermediated market, i.e., $½(a_M + b_M) = ½(a_N + b_N)$, or, $a_M + b_M = a_N + b_N$. This assumption indicates that neither market has an advantage in terms of price discovery even though, as noted above, one market might be able to offer better price improvement. A potentially important function of the market specialist as a risk manager is therefore to dampen volatility by providing competitive bids and offers which reduce the market's bid-ask spread relative to a non-intermediated market (so that $S_M < S_N$). We assume that $a_N - a_M = b_M - b_N = d$, where d is the reduction of the half-spread by the market specialist. That is, d represents the price improvement (e.g., in cents per share) a specialist provides on either the bid or ask sides of the market. And, $2d$ indicates the round-trip per-share cost savings associated with using the specialist's services rather than submitting an order to the non-intermediated market.

For tractability and without loss of generality, we assume a fixed investment horizon of *T* periods for each investor, all of whom possess the same level of initial wealth and a common personal utility function, which assumes all investors are risk-

[28] One possible reason for this type of situation would be if the specialist's access to private information about the total order flow (such as reserve orders placed on the limit order book) provides the specialist with more, or better, information and therefore can provide him / her with an information advantage relative to a non-intermediated market. However, it should also be noted that the non-intermediated market could, in contrast, provide better price improvement via a tighter bid-ask spread if order processing and other transaction-related costs are sufficiently lower in this market and thus can offset any potential information advantage of the intermediated market.

averse.[29] In addition, we assume that the price improvements for both the bids and offers are symmetric (i.e., $d_{bid} = d_{ask}$) and that d is a constant. However, our results also hold if d is stochastic, as long as the expected value of d is positive. In fact, the model's predictions can still hold even when d is negative (i.e., the non-intermediated market's spread is *lower* than the specialist market's spread) but this requires relaxing the assumption of an equal likelihood of order execution in both markets. Also, we could allow for asymmetry in the values of d (e.g., $d_{bid} \neq d_{ask}$) but this additional complication would still lead to our main results, as detailed later in this section. That is, ceteris paribus, investors: a) prefer the intermediated market when $d_{bid} \neq d_{ask}$ as long as both are greater than zero or b) prefer the non-intermediated market when $d_{bid} \neq d_{ask}$ as long as both are less than zero.The following graph depicted in Figure 2 helps capture the essence of our model. The graph plots the expected utility as a concave function of the investor's wealth invested in the risky asset (z). The quote midpoint (*QMP*) is the simple average of the bids and offers in the intermediated markets. As noted above, we assume the *QMPs* are the same for the two markets. Because the spread in the intermediated market is assumed to be smaller while the *QMP* is the same in both markets, the certainty-equivalent value of trading in the intermediated market (denoted as $\bar{x}$ in the graph) is greater than the certainty-equivalent value of trading in the non-intermediated market (denoted by $\bar{y}$). Thus, the certainty-equivalent economic value (in dollars) of the specialist's volatility dampening service is represented by the difference between $\bar{x}$ and $\bar{y}$ in Figure 2. In addition to the value of this risk management service, the investors also save the round-trip trading costs of $2d$ associated with the specialist market's tighter bid-ask spread. That is, in a single period, investors would be willing to pay up to $\bar{x} - \bar{y} + 2d$ to route their orders to the intermediated market in order to take advantage of the specialist's ability to dampen the asset's return volatility and reduce round-trip trading costs.

[29] We could allow each investor to have different time horizons, wealth levels, and utility functions but the added complications of such assumptions would lead to more extensive algebra and notation but not change our overall results. Thus, we focus on the more parsimonious model where all investors are homogeneous. In addition, within our set-up we can interpret one unit of time, t, to be a discrete period of, say, one day. However, the model can be modified to allow for trading in continuous time.

The above characterization of the benefits from the specialist's volatility dampening service is similar in spirit to the rationales of how risk management / hedging activities can increase value for widely held corporations, as first noted in Stulz (1984) and Smith and Stulz (1985). For example, these authors demonstrated that hedging can increase the market value of a corporation even under the assumption of risk-neutrality because risk management activities reduce the expected costs of various market imperfections such as tax liabilities, agency conflicts, and financial distress. Subsequent empirical work by Tufano (1996), Graham and Smith (1999), and Graham and Rogers (2002), among others, have confirmed the positive effects of hedging on firm value.

Our set-up is most similar to Smith and Stulz's (1985) analysis of the impact of hedging on firm value when a firm faces a convex tax schedule due to large tax loss carryforwards. By modeling the firm's problem using a linear derivative instrument such as a forward or futures contract, Smith and Stulz (1985) demonstrates that hedging can reduce the expected corporate tax liability and, consequently, increase the firm's market value. In effect, our model finds a similar conclusion for risk-averse investors by relying on the concavity of these investors' utility functions (rather than the convexity of a firm's marginal tax schedule in Smith and Stulz's model). In both Smith and Stulz (1985) and our analysis, the main point is that the reduction in volatility can generate economic value for those who choose to use these risk management services (via derivatives in Smith and Stulz's case and via the specialist's market making service in our case).

As shown in Figure 2, the equivalence of the *QMPs* in the two markets and the concavity of the utility function result in higher expected utility when using the intermediated market than that of the non-intermediated market. This result occurs because the reduction in the bid and ask spread decreases the variability of security returns when transaction prices "bounce" between the bid and ask prices. Note that this risk reduction limits both gains and losses and thus is similar to the effect of using a forward or futures contract to hedge a portion of an asset's underlying price volatility.

In Figure 2, the arrows identify the certainty-equivalents for the two markets, with $\bar{x}$ representing the certainty-equivalent of the utility obtained from using the intermediated market and $\bar{y}$ representing the non-intermediated market's certainty-equivalent. As we demonstrate below, the individual investor's maximum willingness to pay for the service provided by the market specialist over the *T*-period investment horizon can be defined as $\bar{f} = \sum_{t=0}^{T} \rho_t(\bar{x} - \bar{y}) + (1 + \rho_T)d$, where $\rho_t = \frac{1}{(1 + R_F/N)^t}$, R_F is the annual risk-free discount rate, and *N* represents the number of compounding periods per year.[30] This one-time fee can be viewed as the sum of two different present value terms. The first term on the right hand side of the above expression represents the present value of the certainty-equivalent value derived from the specialist's volatility dampening service over the entire investment holding period while the second term on the right hand side denotes the present value of the round-trip trading cost savings associated with the specialist's tighter bid-ask spreads.[31] Note that the first term on the right hand side of the above equation is a summation of the discounted certainty-equivalent values from volatility dampening for each sub-period, *t*, over the entire *T*-period holding period. The value, $\bar{f}$, is thus determined not only by the holding period and the risk-free rate but also by the quoted bids / offers in the two markets and the relative differences in these bids and offers, *d*. If we assume *t* is equal to one day, then

[30] Note that the appropriate discount rate is the risk-free rate because all of the variables in the numerator of this expression are expressed in certainty-equivalent dollar values. Also, we have expressed the discount factor, ρ_t, in discrete terms but we can easily modify this for continuous-time trading by specifying instead that $\rho_t = e^{-Rft}$.

[31] The present value of the total trading cost savings, $(1+\rho_T)d$, represents the amount (in dollars or cents per share) of the cost savings realized when the investment is first made, *d*, plus the present value of the cost savings realized when the investment is liquidated at time-*T*, $\rho_T d$.

the investor derives some certainty-equivalent value each day over the complete *T*-period time horizon.[32] That is, the investor benefits from the reduction in market structure-related volatility provided by the specialist over the entire holding period, and not just at the time the investment is liquidated.[33]

Given the quoted bids and offers in each market, we assume the quantities of buy and sell orders are in balance so that there is an equal likelihood that the next transaction price will either be at the bid or ask prices. This assumption works against the specialist's ability to add value via a tighter bid-ask spread and therefore a specialist's services might be more valuable when buy and sell orders are imbalanced. For brevity, we focus here on a balanced order flow and simply note that the current model most likely provides a conservative (i.e., low) estimate of the value of a specialist's services. Based on the assumption of a balanced order flow, it follows that the investor's expected utility is a simple average of the utilities associated with these bid and ask values. The following equations help summarize the model based on the market maker's Bayesian learning scheme for bids and offers outlined earlier.

[32] Note that, in addition to traders in the non-intermediated market that might "free ride" on the specialist's volatility reduction by valuing their portfolios using the specialist's less-volatile prices, there might be some long-term investors who do not focus on daily fluctuations in the asset's price. However, even these long-term investors will be concerned with the asset's price on the day the investment is first made (t=0) and when the investment is ultimately liquidated (t=T). For these investors, the value of the volatility dampening service is still positive but smaller than the value of this service for a typical investor who does focus on daily price changes. In fact, our model also holds for a risk-neutral investor—although in this case the investor's value for the specialist's service is solely derived from the present value of the round-trip cost savings. Also, the free rider problem is mitigated to the extent that the price information in the two markets may not be fully integrated and/or the specialist receives compensation for his/her volatility dampening service from other sources such as subsidies that are paid by the securities exchange operator or the firms that list on the exchange.

[33] The utility associated with the reduction in volatility captured by the first term on the right hand side of the above equation focuses on the difference in volatilities associated with the two market structures (intermediated vs. non-intermediated). Strictly speaking, the above specification assumes a stationary, non-varying set of bid and ask prices over the entire holding period. However, the model is generalizable to allow for time-varying bid and ask prices which are driven by both underlying asset fundamentals and market structure differences. In this case, the terms within the model become more complicated but the basic result remains intact: the value of the specialist's service is driven solely by the utility associated with reducing short-term, market structure-related price volatility and the cost savings associated with a tighter bid-ask spread.

First, recall that:

a_M = E(V| Buy, Z_M)

b_M = E(V| Sell, Z_M)

a_N = E(V| Buy, Z_N)

b_N = E(V| Sell, Z_N)

where, V denotes the value of the security and Z is the order history in the designated market (*M* or *N*).

In addition, note that the utility function we present below involves only risk-averse investor preferences towards risk and thus it is independent of the Bayesian learning mechanism described above (which is based solely on the flow of past and current orders). This approach allows us to combine the two elements of investor preferences and the market maker's Bayesian learning process in the manner shown below. Thus, we can calculate the certainty-equivalents, $\bar{x}$ and $\bar{y}$, as follows.

$$u(\bar{x}) = \alpha[\frac{1}{2}u(b_M) + \frac{1}{2}u(a_M)] \qquad (1)$$

$$u(\bar{y}) = \frac{1}{2}u(b_N) + \frac{1}{2}u(a_N) \qquad (2)$$

In Equations (1) and (2), we incorporate the possibility that there are differences in the likelihood of having an order filled at the intermediated and non-intermediated markets by including an additional parameter, α, which, as noted earlier, represents the ratio of the order execution probabilities in the two markets. For example, we can consider the possibility that there might be a lower probability of executing an order due to a slower response in the intermediated market caused by an error or an order processing delay (even if the specialist employs some automated market-making technology) and thus α would be less than 1. On the other hand, although the specialist may be slower at times, this individual might be able to use his/her intuition, experience, and knowledge of potential buyers and sellers in order to increase the likelihood of executing a large order (and on potentially more favorable terms than those available in a non-intermediated market). In this case, α would be greater than 1. Since investors formulate an expected value of $\overline{f}$ conditional on their perceived probability of executing an order in the specialist market, the relative probabilities of order execution in the two types of markets, as measured by α, will affect investors' maximum willingness to pay for the specialist's services.

Using the log utility function described previously as an example, we have

$$\log\overline{x} = \frac{\alpha}{2}(\log b_M + \log a_M) \Leftrightarrow \overline{x} = (a_M b_M)^{\frac{\alpha}{2}} \tag{1a}$$

$$\log\overline{y} = \frac{1}{2}(\log b_N + \log a_N) \Leftrightarrow \overline{y} = (a_N b_N)^{\frac{1}{2}} \tag{2a}$$

Also, we assume the cost advantage of the specialist's quote is symmetrical so that both the bid and ask prices are different than the non-intermediated market's quote by a uniform amount, *d*, which implies

$$a_N - a_M = b_M - b_N = d \tag{3}$$

Hence, $\overline{y} = (a_N b_N)^{\frac{1}{2}} = ((a_M + d)(b_M - d))^{\frac{1}{2}}$ (4)

Using (1a) and (2a) in conjunction with (3) and (4), we find the maximum value of a specialist's risk management service, $\overline{f}$, for trading one share (or unit) of the asset can be defined as

$$\overline{f} = \sum_{t=0}^{T} \rho_t (\overline{x} - \overline{y}) + (1+\rho_T)d = \sum_{t=0}^{T} \rho_t ((a_M b_M)^{\frac{\alpha}{2}} - ((a_M + d)(b_M - d))^{\frac{1}{2}}) + (1+\rho_T)d \quad (5)$$

where $\rho_t = \dfrac{1}{(1+ {R_F}/{N})^t}$, R_F is the annual risk-free discount rate, and N represents the number of compounding periods per year.[34]

II. d) Main Propositions and Key Implications of the Model

Based on Equation (5) and the previous discussion, the following proposition holds.

Proposition 1. When the relative probability of executing an order is the same in both markets, i.e., $\alpha = 1$, then $\overline{f}$ is positive if and only if the specialist's reduction in the half-spread, *d*, is positive; and it is zero when *d* = 0.

The reason supporting Proposition 1 is that $(a_M b_M)^{\frac{1}{2}} - ((a_M + d)(b_M - d))^{\frac{1}{2}} > 0 \Leftrightarrow d > b_M - a_M$, and $d > 0 > b_M - a_M$. So, if d is positive, then $(a_M b_M)^{\frac{1}{2}} - ((a_M + d)(b_M - d))^{\frac{1}{2}}$ is positive and $\overline{f}$ is also positive. Second, in the case that d is negative, $\overline{f}$ must be negative because $(a_M b_M)^{\frac{1}{2}} - ((a_M + d)(b_M - d))^{\frac{1}{2}}$ is negative as well. Note that when $d = 0$, then $\overline{f} = 0$.[35] Proposition 1 is consistent with casual observation of how the market share of ECNs has grown over time (at the expense of specialist markets such as the NYSE) as the spreads in the two types of markets have converged so that *d* is effectively zero or negative for many U.S. stocks. As noted in

[34] As noted earlier, the risk-free rate is the appropriate discount rate in our model because all of the values in the numerator of Equation (5) are certainty-equivalents (expressed in dollars).

[35] As mentioned earlier, one could also relax the assumption that *d* is a constant in our analysis. For example, if *d* is allowed to be stochastic, then investors might still route orders to the intermediated market as long as the *expected value* of *d* is positive. In this case, *d* could vary over time (e.g., at some times *d* is positive while at other times *d* is zero or even negative) and the intermediated market could still remain viable if the expected value of *d* is greater than zero. However, formally modeling a stochastic *d* environment is beyond the scope of this paper and thus we focus on the simpler assumption of a constant *d*.

Lucchetti (2007), this effect has also reduced the activity and profitability of NYSE specialists.

Furthermore, Equation (5) is an exact equilibrium solution when the specialist is a monopolist and all investors have identical utility functions, holding periods, and common initial endowments of wealth. And when the holding period, T, is infinite, then it converges to:

$$\overline{f} = \sum_{t=0}^{\infty} \rho_t (\overline{x} - \overline{y}) + (1 + \rho_T) d = \rho_\infty ((a_M b_M)^{\frac{\alpha}{2}} - ((a_M + d)(b_M - d))^{\frac{1}{2}}) + d \qquad (5a)$$

where, $\rho_\infty = 1 / (R_f / N)$, and, N = the number of compounding periods within a year.

As noted above, d can be negative (i.e., the spread is narrower in the non-intermediated market). Thus, if the probability of executing an order, α, is equal in both the intermediated and non-intermediated markets, then there is no economic value to using an intermediated market. In this case, one would expect investors to avoid sending their orders to this market (and, instead, they will route orders to a non-intermediated market).

As we show below, the relative probability of order execution (α) is quite important because it enables the specialist market to remain viable in either of two ways. First, the specialist can compete effectively by offering "volatility dampening" via potentially smaller spreads (i.e., $d > 0$) as noted earlier. In this case, the specialist can "afford" to offer inferior order execution probability (i.e., $\alpha < 1$) and still remain viable (assuming the specialist's revenue is greater than or equal to the costs of providing his/her service). Second, the specialist could remain viable even when $d < 0$ if the specialist offers better "execution risk management" by providing a sufficiently superior order execution probability (i.e., $\alpha > 1$). The intuition here is that there is a trade-off between: a) the costs and benefits pertaining to the specialist's ability to quote a narrower spread ($d > 0$), and b) the costs and benefits associated with the specialist's ability to provide a greater probability of order execution ($\alpha > 1$).[36]

Both Equations (5) and (5a) reveal that $\overline{f}$ is influenced by five key components: d (the cost savings of the intermediated market's tighter spread); the "relative spread" (i.e., the quoted spread, S_M, in relation to the overall level of the specialist's bid and ask prices—proxied by the quote midpoint, *QMP*); the relative probability of executing an order in the intermediated market, α; the investment holding period, T; and the risk-free rate variable, R_f. Note that both equations show that $\overline{f}$ is inversely related to the level of risk-free interest rates and positively related to the cost savings of the specialist's tighter spreads, d, the relative probability of order execution in the intermediated market, α, and the holding period, T. In addition, as we demonstrate in Section III below, numerical examples based on Equations (5) and (5a) indicate that the relative spread quoted by the specialist (defined as S_M / *QMP*) has a positive relation with $\overline{f}$, ceteris paribus.

The following proposition summarizes the main conclusion.

Proposition 2. The maximum willingness to pay for the specialist's service, $\overline{f}$, is positively related to *d* (the specialist's reduction of the half-spread).

To see this, we take the derivative of $\overline{f}$ with respect to d:

[36] Although the second scenario presented above does not represent the typical market conditions envisioned in our model, investors might still have an incentive to use the intermediated market because the disincentive caused by the specialist's wider spread (due to $d < 0$) can be offset by the benefit of an increased probability of execution in the specialist market (because $\alpha > 1.0$). This scenario might occur if the specialist market's ability to handle larger orders is superior to the non-intermediated market (and thus the probability of execution of these orders is higher in the specialist market). In addition, if these larger orders are more likely to be submitted by better-informed investors, then the specialist would respond by widening his/her spread which, in turn, can cause d to become negative (while α would remain greater than 1.0).

$$\frac{\partial \overline{f}}{\partial d} = \sum_{t=0}^{T} \rho_t \frac{1}{2} \frac{1}{\sqrt{(a_M + d)(b_M - d)}} [(a_M - b_M) + 2d] + 1 + \rho_T > 0 .$$

Note that since $a_M > b_M$, the first term is positive.

This result indicates that risk-averse investors are willing to pay more for an intermediated market's services because it can tighten the bid-ask spread, thus providing two economic benefits to investors: 1) reducing round-trip trading costs and 2) decreasing return volatility. In addition, Proposition 2 is consistent with Hendershott and Moulton's (2008) finding that a greater share of NYSE order flow is being handled electronically and less activity is being transacted via floor-based specialists. According to our model, this could be due to specialists finding it more difficult and less profitable to participate when *d* is near zero.

To see how the intermediated market's spread affects the value of the specialist's services, we rewrite Equation (5) to express the relationship between $\overline{f}$ and S_M. Recall that

$S_M = a_M - b_M$, thus

$$\overline{f} = \sum_{t=0}^{T} \rho_t (\sqrt{a_M b_M} - \sqrt{(a_M + d)(b_M - d)}) + (1 + \rho_T) d$$

$$= \sum_{t=0}^{T} \rho_t (\sqrt{(b_M + S_M) b_M} - \sqrt{(b_M + S_M + d)(b_M - d)}) + (1 + \rho_T) d \tag{5b}$$

This leads to another main conclusion of the paper:

Proposition 3. When the relative probability of executing an order is the same in both markets, i.e., $\alpha = 1$**,** $\overline{f}$ **is positively dependent on** S_M**, as long as** d, b_M, and S_M **are positive.**

To prove this, we take the derivative,

$$\frac{\partial \overline{f}}{\partial S_M} = \sum_{t=0}^{T} \rho_t \frac{1}{2} \left(\frac{b_M}{\sqrt{(b_M + S_M) b_M}} - \frac{b_M - d}{\sqrt{(b_M + S_M + d)(b_M - d)}} \right).$$

The above derivative is positive if and only if

$$\frac{b_M}{\sqrt{(b_M + S_M) b_M}} > \frac{b_M - d}{\sqrt{(b_M + S_M + d)(b_M - d)}} \Leftrightarrow$$

$$\begin{aligned}
&b_M^2 (b_M + S_M + d)(b_M - d) > (b_M - d)^2 (b_M + S_M) b_M \Leftrightarrow \\
&b_M (b_M + S_M + d) > (b_M - d)(b_M + S_M) \Leftrightarrow \\
&2 d b_M + d S_M > 0
\end{aligned}$$

Thus, as long as d, b_M, and S_M are positive, we have $\frac{\partial \overline{f}}{\partial S_M}$>0.

The above analysis confirms that the specific value of *d* is a critical component of $\overline{f}$ and that *d* is determined by the competitiveness of the specialist's bid-ask spread, S_M, in relation to the non-intermediated market's spread, S_N. Interestingly, Proposition 3 is consistent with the empirical evidence of Charitou and Panayides (2009) and others that document how specialists are becoming more involved in trading small- and mid-cap stocks (which typically are less-liquid and have larger spreads). The intuition underlying Proposition 3's positive relation between $\overline{f}$ and S_M can be seen by referring to Figure 2. Close inspection of this graph shows that a specialist's service is more valuable when investors are more risk averse (i.e., the curve is more concave) and when bids and offers are further apart because a wider spread implies greater volatility (due to a bigger bid-ask bounce). Thus, there is more opportunity for the specialist to quote a tighter bid-ask spread which, in turn, can be quite valuable to a very risk-averse investor that would otherwise have to endure higher volatility due to a potentially even wider spread in the non-intermediated market.

Also, it should be noted that if S_N is actually tighter than the specialist's spread (possibly due to lower overhead costs or greater liquidity in the non-intermediated market), then d and $\overline{f}$ are both negative (i.e., there is an economic disincentive to send an order to the specialist market in this case unless the probability of executing an order in the intermediated market is sufficiently higher than in the non-intermediated market). In addition, the specialist must cover his/her costs associated with making a market in the risky asset. Thus, there is one key requirement for an intermediated market to remain viable under typical market conditions: the value of $\overline{f}$ plus S_M should be large enough to cover the costs of market-making that are commonly included in market microstructure models.[37]

That is, $\overline{f}$ plus S_M represents the total specialist revenue from trading one unit (or share) of the risky asset. Via the assumption that d is a constant, our model suggests that the way specialists are compensated for their services should include a fixed component (the upper bound of which is $\overline{f}$) and a potentially variable component (S_M) which can adjust dynamically with market conditions related to the underlying asset.[38] Overall, for the specialist to stay viable, the sum of $\overline{f}$ and S_M must be greater than or equal to the specialist's order processing costs, inventory holding costs, and any costs associated with trading against more-informed traders. Therefore, our model is indirectly related to the existing literature of Kyle (1985), Glosten and Milgrom (1985), Glosten and Harris (1988), Glosten (1989), and others because these strategic trader-based "spread" models provide a floor on how much the specialist can charge investors and still remain viable. More formally, we can state this relationship as follows:

$$\overline{f} + S_M \geq \textit{Total Trading Costs (per share)} = AC = g(INV, AI, KL, Q) > 0 \qquad (6)$$

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[37] We define "typical market conditions" in our model as when: 1) $d > 0$ (or at least the expected value of d is greater than zero) and 2) the probability of order execution in the non-intermediated market is either greater than or equal to the probability of order execution in the specialist market (i.e., $\alpha < 1$).

[38] For example, even when $S_M = 0$, both d and $\overline{f}$ can still be positive; as can be seen by setting $S_M = 0$ within Equation (5b).

The total trading costs (per share) should equal the expected average cost, *AC*, associated with the following four key components:

INV, the cost of holding shares in the underlying security in inventory to assist in maintaining a fair and orderly market,

AI, the cost of trading with informed traders that know more than the market specialist (i.e., an adverse selection cost caused by information asymmetries between traders),

KL, the cost of physical capital and the specialist's labor associated with providing the market making service (e.g., the cost of computers, software, regulatory compliance, salaries / wages), and

Q, the quantity of shares traded by the specialist during the trading period.

From Equation (6), we can see that the viability of the intermediated market depends on the specialist's ability to charge enough to cover the above costs that have been identified by previous theoretical and empirical research. The first three variables on the right hand side of (6) are positively related to total trading costs (per share) while trading volume (*Q*) is inversely related to *AC*. Interestingly, if $\overline{f}$ plus S_M cannot cover these costs, then the specialist market might not be economically viable and we would expect only a non-intermediated market to exist. Equation (6) also illustrates how changes in trading volume as well as the costs of order processing, inventory management, and asymmetric information can be incorporated within our model. Our model thus shows that a specialist must generate sufficient value via its volatility dampening and trading cost reduction services in order to justify the intermediated market's viability. In contrast to the existing literature, the specialist can no longer assume he/she can set the bid-ask spread to recover the costs associated with asymmetric information, inventory management, and order processing. In a world with a non-intermediated market alternative, the specialist must ensure he/she adds sufficient value to cover these market making costs.

In the remainder of the theoretical analysis, we assume that $\overline{f}$ plus S_M is greater than or equal to this floor level, *AC*, and that *AC* is constant.[39] Lastly, we cannot examine the relationship between the maximum willingness to pay for the specialist service, $\overline{f}$, and the degree of investor risk aversion using the log utility function. However, we do examine this issue with the quadratic utility function in the Appendix.

Proposition 4. The maximum willingness to pay for the specialist's service, $\overline{f}$, is positively related to α, the relative probability of execution in the intermediated market.

To see this, we show that:

$$\frac{\partial \overline{f}}{\partial \alpha} = \sum_{t=0}^{T} \rho_t [(a_M b_M)^{\alpha/2} \log(a_M b_M)^{1/2}] = \sum_{t=0}^{T} \rho_t \frac{1}{2} (a_M b_M)^{\alpha/2} (\log a_M b_M) > 0 .$$

Note that the above is true if and only if $a_M b_M > 1$.[40]

As the relative probability of execution in the intermediated market increases (α rises), then the risk of non-execution in the intermediated market decreases and, in turn,

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[39] We hold *AC* constant in our analysis but this assumption can be relaxed if one wishes to explore the impact of *AC's* variables on $\overline{f}$. Since this would be beyond the scope of this paper, we leave this issue as a possible avenue for future research.

[40] This condition is easily met as long as the asset's bid and offer prices are above $1.00 (which is the case for all U.S. stocks except those referred to as "penny" stocks).

raises the trader's willingness to pay for the specialist's risk management service.[41] However, an investor wishing to trade a very large block of stock might perceive a very small probability of executing this large order in the intermediated market (e.g., due to specialist capital constraints, fears of information leakage, front-running, etc.). For this investor, α might be close to zero and thus, according to (5b), the trader might find that $\overline{f}$ is negative. In this case, there can be an economic disincentive to send the large order to the intermediated market and he/she might therefore choose to route the order to the non-intermediated market. Consistent with Proposition 4, the continued growth of non-intermediated ATS-type markets such as ITG's Posit, Liquidnet, and Pipeline in recent years suggests that institutional investors might perceive α to be relatively low in the traditional U.S. equity market centers for large orders (and thus these investors opt to route many of their 10,000+ share orders away from the intermediated markets).[42] In sum, the above analysis suggests that α can be an important determinant of $\overline{f}$ beyond the four variables already discussed above (i.e., d, T, S_M / QMP, and R_f).

III. Numerical Application of the Basic Model

To provide further insight into the model's implications, we report in Table 1 some numerical examples for three hypothetical securities with varying levels of: 1) quote midpoints (*QMP*), 2) half-spreads (i.e., half of the bid-ask spread), and 3) cost advantages over non-intermediated markets (*d*). The *% Spread* values in Table 1 denote the quoted spread in the intermediated market for each of the three securities as a

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[41] An increase in α might be due to increased automation and faster response time by the specialist via the introduction of specialist-specific proprietary, automated trading algorithms (such as those being developed by U.S. market centers such as the New York Stock Exchange).

[42] In addition, these institutional traders have increasingly "sliced and diced" their large orders into several smaller orders and submitted them sequentially to an intermediated market in order to minimize adverse market impact and lessen information "leakage" about these orders. In effect, this slicing and dicing activity could be viewed as another way for large traders to realize a higher α, collectively, for their set of smaller orders (whereas the expected α for one large order might be quite low). This behavior also suggests that α can be very different for various types of investors (and even different types of orders for the *same* investor might have differing α values). This possibility is left for future research.

percentage of the respective quote midpoints (i.e., *% Spread* = S_M / *QMP*). As can be seen from Table 1, the three securities' *QMPs* range from \$10 to \$100 per unit while the relative quoted spreads vary from 2 to 100 basis points. This range in *QMP* and relative spreads is meant to capture the typical cross-sectional variation in current U.S. equities markets caused by differences in liquidity. The value of *d* also varies from 1 cent to 10 cents in order to provide an economically meaningful difference in the costs of trading on the intermediated market vis-à-vis the non-intermediated market. All results are based on a fixed, annual risk-free discount rate of 5% (compounded daily) and α is constant at 1.

The values reported for the three columns under the *Holding Period* heading contain estimates based on 1-day, 1-year, and infinite investment holding periods. Panel A of Table 1 provides estimates of the maximum willingness to pay for the specialist's services, $\overline{f}$, while Panel B reports the proportion of these $\overline{f}$ estimates which are directly attributable to the economic value of the specialist's volatility dampening service.

As can be seen from the $\overline{f}$ estimates of Table 1, there is substantial variation in the value of the specialist's services due to differences in holding periods (*T* in our model), the intermediated market's relative spread (*% Spread*), and the value of *d*. Table 1 demonstrates that the value of $\overline{f}$ is driven almost entirely by the trading cost savings related to *d* when the time horizon is very short (i.e., when T = 1 day). In effect, $\overline{f}$ is only slightly above *2d* for all three securities when T = 1 day. Further, Panel B shows that the value of the specialist's risk reduction service is less than 1% of the overall value of $\overline{f}$ for all three assets when investors have a 1-day holding period.

So, when *T* is short, the risk management service is not very valuable for any combination of *QMP*, bid-ask spread, and *d*. This is not surprising because the value of the specialist's volatility dampening should not be very high if this risk management service is only "used" by the investor for a single day. That is, the value of risk management in this case is low because an investor's exposure to the asset's price volatility is also very low (because prices do not usually fluctuate dramatically over the course of one day). However, the results change dramatically when the holding period is extended to 1 year or an infinite time horizon. For a 1-year holding period, $\overline{f}$ varies from 2 to 23 cents and this range increases to 2.1 cents - $2.787 for the infinite horizon. As expected, the value of the specialist's risk reduction activity increases as a percentage of the $\overline{f}$ estimates when the time horizon is extended. For example, risk reduction now accounts for over half of the 1-year $\overline{f}$ estimate for the security with a *QMP* of $10 (i.e., 57.8%). In addition, the specialist's volatility dampening service represents the majority of the value associated with $\overline{f}$ when these estimates are computed over an infinite time horizon (ranging from 52.3% to 98.2% for the $100- and $10-*QMP* securities, respectively).

In terms of the intermediated market's spread, S_M, and the asset's *QMP*, we find that $\overline{f}$ is more valuable when the *% Spread* is higher. As Panel A of Table 1 shows, the asset with a $10 *QMP* has a higher *% Spread* of 100 basis points and also reports $\overline{f}$ estimates that are further above *2d* than the two other assets with lower *% Spread* values. In contrast, $\overline{f}$ does not vary much for the security with the lowest relative spread (i.e., $\overline{f}$ for the $100 QMP security is between 2.0 and 2.1 cents for all holding periods in Table 1). So, when d and S_M are held constant, lower levels of *QMP* result in larger $\overline{f}$ estimates, while higher levels of *QMP* lead to smaller $\overline{f}$ estimates. Thus, the overall level of an asset's price and its relation to the intermediated market's spread can also have a strong influence on $\overline{f}$, with less-liquid stocks (i.e., those with a high *% Spread*) having larger values for $\overline{f}$.

In sum, the numerical examples displayed in Table 1 confirm that tighter spreads in the intermediated market (as measured by d) can be a critical component in determining the value of the specialist's service, $\overline{f}$. In addition, the examples illustrate how the investor's holding period, T, affects the relative contribution of the specialist's two key services: 1) risk management activity and 2) the round-trip trading cost savings associated with a tighter spread. For very short holding periods such as one day, the specialist's value is determined mostly by the round-trip cost savings associated with tighter spreads while progressively longer holding periods shift the total value of the specialist's service more towards the volatility dampening service. The numerical examples suggest that both *d* and *T* are important determinants of investor's willingness to pay for the specialist's volatility dampening service.[43] As noted earlier, this risk management service also has some qualities of a public good. Therefore, even though the specialist's risk reduction activity can have a relatively small value for, say, a short-term individual investor, this service can have a large market-wide value when cumulated across all investors. Thus, even when the holding period of the average investor is short, the specialist's risk reduction activity can provide a substantial benefit to the overall market and society in general.

IV. Evidence from Simulations and Rule 605 Order Execution data

We provide further evidence about our model's implications via numerical simulations and some empirical tests based on SEC Rule 605's order execution information in Tables 2 and 3, respectively. For the numerical simulations, we are still in the process of finalizing and tabulating these results. Preliminary indications in this area are positive but more needs to be done before incorporating this analysis here. Clearly, the next draft of the paper will include these results.

Going beyond the simulation results noted above, we compare in Table 3 the SEC Rule 605 order execution statistics of the NYSE floor-based system to those of NYSE's ARCA ECN system. This comparison provides a useful test of our model's predictions

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[43] Two caveats should also be noted here. First, the numerical examples in Table 1 all assume the relative probability of execution in the intermediated market, α, is 100%. Clearly, if this assumption is relaxed, then this additional variable will play an important role in determining the value of $\overline{f}$. Second, our numerical examples also assume all investors have the same level of wealth, utility function, and time horizon. Thus, these assumptions need to be relaxed if one wanted to assess the value of $\overline{f}$ in a real-world setting. Since the numerical examples are meant solely to demonstrate the sensitivity of our estimates to various levels of *d*, *T*, and *QMP*, we do not pursue the relaxation of the "representative investor" assumption.

because both trading venues can trade NYSE-listed stocks and the main difference between the two venues is the structure of the markets (as noted in the Introduction, NYSE's floor is an intermediated market while ARCA's ECN is an electronic non-intermediated market). To conserve space, we focus on the order execution statistics for small market orders (100-499 shares) during two periods: June 2006 and June 2009.[44] By using the same month for both years, we control for any potential seasonality in trading behavior while the two specific years chosen (2006 and 2009) avoid any unusually volatile trading activity. This approach also enables us to examine these statistics both before and after the advent of the SEC's Reg NMS rule changes (which were implemented in 2007).

As Table 3 shows, the two markets' averages for effective spreads, order execution probabilities, execution speed, and relative market shares have changed dramatically during June 2006 – June 2009. In addition, the table reports estimates of our model's $2d$ and α variables (measured by the difference in effective spreads between the two markets and the ratio of execution rates, respectively). Panel A focuses on the 28 NYSE-listed stocks that comprise the Dow Jones Industrial Average while Panel B reports data for all 3,152 NYSE-listed stocks. The two panels show that effective spreads have declined and execution speed has accelerated over the 3-year period (although the ARCA system is still faster than the NYSE floor system at 0.04 vs. 0.43 seconds for all NYSE-listed stocks).

Spreads are also typically lower on the ARCA ECN and thus $2d$ has become increasingly negative. At the same time, the order execution rate of the ECN has improved substantially over the 3 years and thus the advantage that NYSE's floor once enjoyed in this area has now virtually disappeared. This can be seen by α dropping from

[44] We also perform this empirical analysis with both small and large marketable limit orders (100-499 and 5,000-9,999 shares) and we find qualitatively similar results as those reported here for small market orders. Thus, for brevity, we focus our analysis and discussion on the results for small market orders displayed in Table 3.

2.90 to 1.01 for all NYSE stocks (Dow stocks show a similar pattern with α falling from 2.27 to 1.02). Thus, while the NYSE floor system enjoyed an advantage in order executions in June 2006, the order execution rates for the venues are statistically indistinguishable as of June 2009.

Given that *2d* and α are positively related to an investor's willingness to pay for the intermediated market's services, our model predicts that the declines in *2d* and α should lead to a decrease in market share for the NYSE's intermediated, floor-based system. As can be seen by the data reported in the fourth row of both panels in Table 3, the relative market share of the floor-based system has indeed declined dramatically. For all 3,152 NYSE-listed stocks, the ratio of NYSE floor trading volume relative to ARCA trading volume (measured in shares) has declined significantly from 143.5 times to 8.7 times ARCA's daily volume (a similar pattern also holds for the much-larger Dow stocks). Although the results of Table 3 are based on simple difference-in-mean *t*-tests, they provide encouraging initial support for our model's main predictions and thus suggest that additional statistical analysis of order execution and market share statistics across numerous trading venues can be a fruitful avenue for future research.

V. Conclusion

We develop a model that analyzes the type of competition which exists between a non-intermediated market and an intermediated market when both markets are allowed to trade the same securities. Specialists are viewed as providers of a unique "volatility dampening" service as well as a mechanism for reducing round-trip trading costs. In addition, the specialist can compete by providing greater certainty that orders routed to the specialist market will be executed. We refer to this additional specialist function as an "order execution risk management" service. In contrast to existing spread-based models of specialist behavior, we find that specialists cannot remain viable by simply assuming they can recover the typical costs associated with asymmetric information, inventory management, and order processing.

Instead, when competing with a non-intermediated market, a specialist must generate sufficient value from risk-averse investors via volatility dampening, trading cost reduction, and / or order execution risk management services in order to cover these traditional market making costs. The economic value of these three specialist services is determined by five key factors (the difference in spreads between the two financial market types, investors' holding periods, the specialist's quoted spread in relation to the asset's price, the relative probability of executing an order in the intermediated market, and the short-term risk-free rate). Our model also suggests an alternative way to compensate a specialist, with one component comprised of a fixed fee and a second component paid as a variable charge that is adjusted dynamically in response to changes in the current market conditions for the underlying security.

Numerical illustrations quantify the magnitude of the model's predictions and confirm the importance of the factors noted above. Our model suggests some "high frequency" traders might not find much value in the specialist's risk-reduction service but a number of "buy and hold" investors could derive significant value from this risk management activity. The intuition for this result is that risk management is not as valuable for a short-term investor because an asset's price does not usually exhibit large fluctuations over a very short time horizon such as one day. In contrast, longer-term buy and hold institutional investors might be more willing to pay for the intermediated market's services if these investors face short-term frictions such as daily margin calls, sudden redemptions / new investments, and daily performance reporting requirements.

A specialist's risk management service has some attributes of a public good and thus the value of this service might be relatively small for any individual investor but the market-wide value of this service still can be quite large when aggregated across all investors. If specialists cannot recoup the full value of this service directly from their market making activities, then the model suggests that all market participants might benefit if some form of institutional support was provided to these specialists (e.g., via subsidies paid by the securities exchange operator and / or the corporate issuers that list their securities on the exchange). We find that our model is consistent with current empirical evidence related to order execution information for NYSE-listed stocks as well as recent changes in the compensation schemes for designated market makers at the NYSE, Borsa Italiana, and other exchanges.

The model can also provide guidance to market participants and policy makers not only in equity markets but also other financial markets such as the U.S. Treasury debt market. For example, constituents of these markets can use the model to better understand how variations in the costs and benefits of the two types of markets lead to changes in the way investors choose to route their orders.

Avenues for future research include relaxing some of the model's assumptions and examining the results of these changes. One could explore the impact of having multiple, competing market makers rather than one monopolistic specialist. This alternative assumption most closely characterizes the market structure of OTC markets such as the Nasdaq Stock Market and the primary dealer network of the U.S. Treasury debt market. One can also attempt to estimate "equilibrium" solutions for a specialist market by relaxing the assumption of a common (or representative) investor so that the actual demographics of the market's heterogeneous investors can be used to gauge potential changes in the relative market shares of the intermediated and non-intermediated markets.

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APPENDIX

As noted in Section II.b., we consider a commonly used concave utility function: the quadratic utility function.

$$u_i(z) = z - \frac{\gamma_i}{2} z^2, \ \ \gamma_i > 0,$$

where z is the dollar value of the amount invested in the risky asset. That is, we assume investors are risk-averse. In contrast to the logarithmic utility function, the quadratic utility function allows us to observe directly the relationship between the investor's willingness to pay for the service provided by the market specialist, namely $\overline{f}_i$, and the degree of risk aversion.

Note that in Figure 2, the arrows depict the derivation of the price equivalents of the two markets, with $\overline{x}_i$ representing the price equivalent of the utility obtained from using the intermediated market and $\overline{y}_i$ representing the non-intermediated market's price equivalent. The individual investor's maximum willingness to pay for the service provided by the market specialist can be obtained as $\overline{f}_i = \sum_{t=0}^{T} \rho_t (\overline{x_i} - \overline{y_i}) + (1 + \rho_T) d$.

Recall the equations which calculate the price equivalents $\overline{x}$ and $\overline{y}$.

$$u(\overline{x}) = \alpha[\frac{1}{2}u(b_M) + \frac{1}{2}u(a_M)], \text{ where } 0 < \alpha \leq 1. \quad (1)$$

$$u_i(\overline{y}_i) = \frac{1}{2}u_i(b_N) + \frac{1}{2}u_i(a_N) \quad (2)$$

Using the quadratic utility function described earlier as an example, we now have

$$\frac{\gamma_i}{2}\overline{x}_i^2 - \overline{x}_i + \frac{\alpha}{2}[b_M - \frac{\gamma_i}{2}b_M^2 + a_M - \frac{\gamma_i}{2}a_M^2] = 0 \Leftrightarrow$$

$$\overline{x}_i = \frac{1 - \sqrt{1 - \alpha\gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2)]}}{\gamma_i} \quad (1c)$$

And $\frac{\gamma_i}{2}\bar{y}_i^{\,2} - \bar{y}_i + \frac{1}{2}[b_N - \frac{\gamma_i}{2}b_N^2 + a_N - \frac{\gamma_i}{2}a_N^2] = 0 \Leftrightarrow$

$$\bar{y}_i = \frac{1 - \sqrt{1 - \gamma_i[(a_N + b_N) - \frac{\gamma_i}{2}(b_N^2 + a_N^2)]}}{\gamma_i} \qquad (2c)$$

Recall Equation (3), a_N - a_M = b_M - b_N = d; and also, recall that we assume QMP_M = QMP_N, which implies:

$$a_M + b_M = a_N + b_N \qquad (7)$$

Using (1c) and (2c) in conjunction with (3) and (7), we find the value of a specialist's "risk management" service $\bar{f}_i$ can be defined as

$$\bar{f}_i = \sum_{t=0}^{T} \rho_t(\bar{x}_i - \bar{y}_i) + (1 + \rho_T)d$$

$$= \sum_{t=0}^{T} \rho_t\left(\frac{1 - \sqrt{1 - \alpha\gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2)]}}{\gamma_i} - \frac{1 - \sqrt{1 - \gamma_i[(a_N + b_N) - \frac{\gamma_i}{2}(b_N^2 + a_N^2)]}}{\gamma_i}\right) + (1 + \rho_T)d$$

$$= \sum_{t=0}^{T} \rho_t \frac{\sqrt{1 - \gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2) + \frac{\gamma_i^2}{2}[2d(a_M - b_M) + d^2]} - \sqrt{1 - \alpha\gamma_i[(a_M + b_M) - \frac{\alpha\gamma_i}{2}(b_M^2 + a_M^2)}}{\gamma_i}$$

$$+ (1 + \rho_T)d \qquad (5c)$$

Next, we use a numerical example to illustrate the demand and the specialist's profit maximizing price of f^*, where we set $a_M = 40.025; b_M = 39.975; d = 0.025; \alpha = 1.$,

γ_i	$\bar{f}_i$
0.005	0.0502154

0.010	0.0526063
0.015	0.0573801
0.020	0.0717334
0.025	0.0908598

Figure 1 shows the demand curve based on the above example.

Similar to the log utility function, $\overline{f}_i$ is positive if d is positive; and in the case that d is negative, $\overline{f}_i$ is also negative; and when $d = 0$, $\overline{f}_i = 0$.

The main results are as follows:

(i) $\overline{f}_i$ is positively related to d, the reduction in the half spread offered by the market specialist. Since $a_M - b_M > 0$, this can be easily verified. This result indicates that risk-averse investors are willing to pay more for an intermediated market's services because it can tighten the bid-ask spread, thus providing two economic benefits to investors: 1) reduce "round-trip" trading costs and 2) decreased return volatility.[45]

(ii) $\overline{f}_i$ is positively related to α, the probability of execution in the intermediated market. To see that, we need to show that

$$(a_M + b_M) > \frac{\gamma_i}{2}(b_M^2 + a_M^2) \Leftrightarrow b_M(1 - \frac{\gamma_i}{2}b_M) + a_M(1 - \frac{\gamma_i}{2}a_M) > 0 .$$

Since $a_M, b_M < \dfrac{1}{\gamma_i}$, we have $a_M, b_M < \dfrac{2}{\gamma_i} \Rightarrow 1 - \dfrac{\gamma_i}{2}b_M > 0$ and $a_M(1 - \dfrac{\gamma_i}{2}a_M) > 0$. Thus $\overline{f}_i$ is positively related to α.

[45] As discussed in Sections II of the paper, d can be negative (i.e., the spread is narrower in the non-intermediated market). In this case, the same caveats noted in this section also apply here.

(iii) When $\alpha = 1$, $\overline{f}_i$ is positively related to γ_i, the degree of risk aversion. To see this, we need to take the partial derivative w.r.t. γ_i. First, we rewrite equation (5c) as

$$\overline{f_i} = \sum_{t=0}^{T} \rho_t \{ \sqrt{\frac{1-\gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2)]}{\gamma_i^{\ 2}} + [d(a_M - b_M) + \tfrac{1}{2} d^2]}$$
$$- \sqrt{\frac{1-\gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2)]}{\gamma_i^{\ 2}}} \} + (1+\rho_T)d$$

Next, we set

$$g(\gamma_i) = \frac{1-\gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2)]}{\gamma_i^{\ 2}}, \text{ and}$$

$$w = d(a_M - b_M) + \tfrac{1}{2} d^2$$

And we rewrite equation (5c) as

$$\overline{f}_i = \sum_{t=0}^{T} \rho_t [\sqrt{g(\gamma_i) + w} - \sqrt{g(\gamma_i)}] + (1+\rho_T)d \qquad (5d)$$

Then

$$\frac{\partial \overline{f_i}}{\partial \gamma_i} = \sum_{t=0}^{T} \rho_t [\frac{1}{2\sqrt{g(\gamma_i) + w}} g'(\gamma_i) - \frac{1}{2\sqrt{g(\gamma_i)}} g'(\gamma_i)] = \sum_{t=0}^{T} \rho_t \frac{1}{2} g'(\gamma_i) [\frac{1}{\sqrt{g(\gamma_i) + z}} - \frac{1}{\sqrt{g(\gamma_i)}}]$$

.

Since $\frac{1}{\sqrt{g(\gamma_i) + z}} - \frac{1}{\sqrt{g(\gamma_i)}} < 0$, to prove that $\frac{\partial \overline{f_i}}{\partial \gamma_i} > 0$, we need to show that $g'(\gamma_i) < 0$.

Recall that $g(\gamma_i) = \frac{1-\gamma_i[(a_M + b_M) - \frac{\gamma_i}{2}(b_M^2 + a_M^2)]}{\gamma_i^{\ 2}} = \frac{1}{\gamma_i^{\ 2}} - \frac{a_M + b_M}{\gamma_i} + \frac{b_M^2 + a_M^2}{2}$, Thus $g'(\gamma_i) = -\frac{2}{\gamma_i^{\ 3}} + \frac{a_M + b_M}{\gamma_i^{\ 2}}$. And it is negative if and only if $\frac{2}{\gamma_i^{\ 3}} > \frac{a_M + b_M}{\gamma_i^{\ 2}}$ $\Leftrightarrow$ $a_M + b_M < \frac{2}{\gamma_i}$. Since $\frac{1}{\gamma_i}$ is the satiation point, $a_M, b_M < \frac{1}{\gamma_i}$, thus $a_M + b_M < \frac{2}{\gamma_i} \Rightarrow$ $g'(\gamma_i) < 0 \Rightarrow \frac{\partial \overline{f_i}}{\partial \gamma_i} > 0$.

Risk-averse investors prefer lower return volatility and therefore are more willing to pay for an intermediated market's risk management service when they are more risk-averse (i.e., as γ rises).

Figure 1. Derivation of Demand and Marginal Revenue Functions – Quadratic Utility

The graph plots the *Demand* curve and equilibrium level price, f^*, of the specialist's risk management service when the marginal revenue (MR) exceeds the marginal cost (MC) of providing this service (in this graph, we assume for simplicity that MC = 0). In this case, the equilibrium price equals the maximum willingness to pay for this service based on the least risk-averse investor's demand (i.e., $f^* = \overline{f}_i$ where i = the 5th unit of the risky asset).

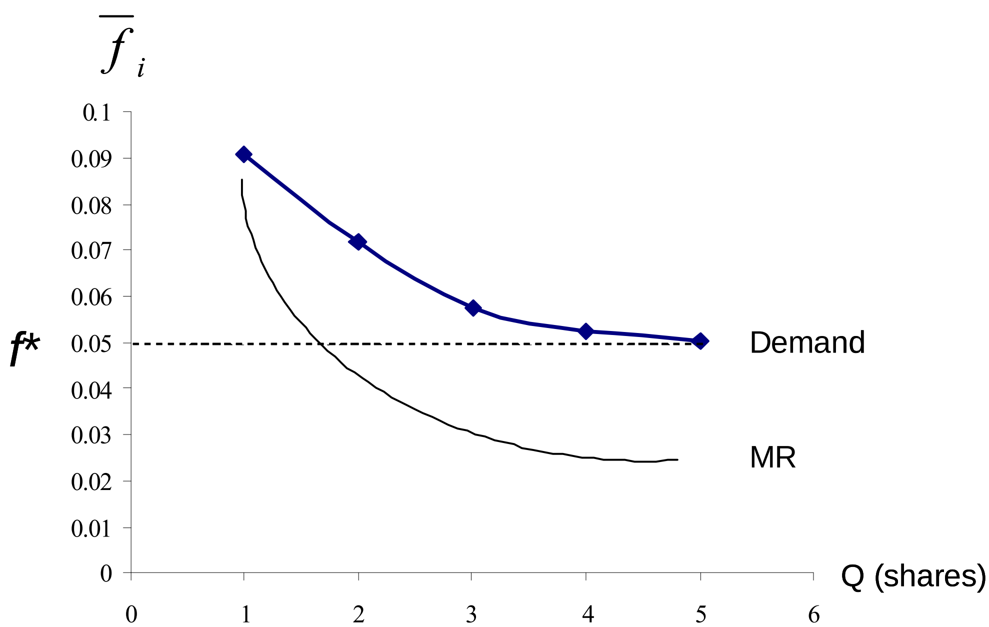

Figure 2. Comparison of Utility obtained from Quote Setting Behavior in Intermediated (M) and Non-Intermediated (N) Markets

The graph plots the expected utility, U(*z*), as a concave function of the investor's wealth invested in the risky asset (*z*). The quote midpoint (*QMP*) is the simple average of the bids and offers in the both the intermediated and non-intermediated markets. We assume the *QMPs* are the same for the two markets, based on the bid and ask prices for the intermediated (b_M, a_M) and non-intermediated markets (b_N, a_N). The differences between the two markets' bids and the two markets' offers are both assumed to be equal to *d*. The certainty-equivalent value of trading in the intermediated market is denoted as $\bar{x}$ in the graph while the certainty-equivalent value of trading in the non-intermediated market is denoted by $\bar{y}$.

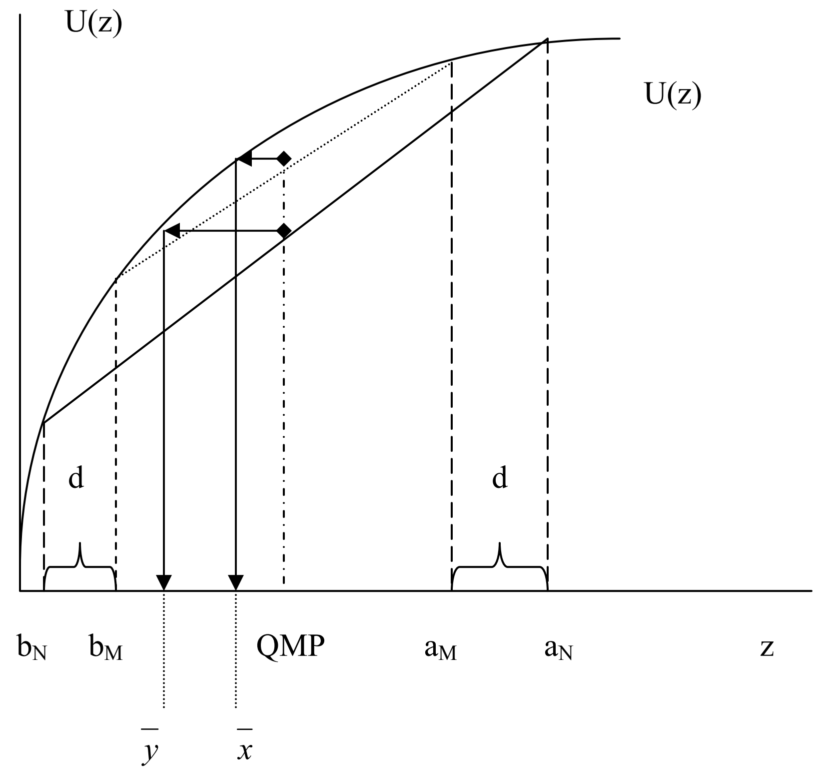

Table 1. Maximum Willingness to Pay for the Specialist's Services

The table provides some numerical examples for three hypothetical securities with varying levels of quote midpoints (*QMP*), *Half-Spreads* (half of the bid-ask spread), and cost advantages over a non-intermediated market (*d*). The *% Spread* values denote the *Quoted Spread* (i.e., twice the *Half-Spread*) as a percentage of the quote midpoints. The values reported for the three columns under the *Holding Period* heading provide estimates based on 1-day, 1-year, and infinite investment holding periods. Panel A provides estimates of the maximum willingness to pay for the specialist's services ($\overline{f}$) while Panel B reports the percentage of these $\overline{f}$ estimates which are associated with the specialist's volatility dampening activities. All results are based on a fixed, annual risk-free discount rate of 5% (compounded daily) and α is constant at 1.

A. Estimates of $\overline{f}$

				Holding Period		
QMP	*Half-Spread*	*d*	*% Spread*	1 day	1 year	∞
$ 10	$ 0.05	$ 0.05	1.000%	$ 0.1003681	$ 0.2310663	$ 2.7875856
$ 40	0.025	0.025	0.125%	0.0500200	0.0571246	0.1960938
$ 100	0.01	0.01	0.020%	0.0200001	0.0200463	0.0209500

B. Risk reduction's value (as % of $\overline{f}$)

QMP	*Half-Spread*	*d*	1 day	1 year	∞
$ 10	$ 0.05	$ 0.05	0.37%	57.78%	98.21%
$ 40	0.025	0.025	0.05%	14.61%	87.25%
$ 100	0.01	0.01	0.01%	2.66%	52.27%

Table 2. Results of Numerical Simulation based on Equation (5)

The table presents average values of the key measures variables in Equation (5) assuming a uniform distribution of investors in terms of both risk aversion (γ_i) and time horizon (T).

As noted in the text, the simulation results are not yet ready for inclusion at this point.

Table 3. Comparison of Performance Metrics between NYSE and the ARCA ECN

The table presents average values of key measures of market performance during June 2006 and June 2009 for both the NYSE floor-based system and an ECN which trades NYSE-listed securities, NYSE's ARCA system. Panel A presents evidence for the 28 NYSE-listed stocks that comprise the Dow Jones Industrial Average while Panel B displays results for all NYSE-listed stocks during the sample period. Average data are computed across all days and all relevant stocks based on Rule 605 data for small market orders (100-499 shares) reported by the NYSE and ARCA to the SEC. *Effective spread* represents the average difference between the transaction price and the quote midpoint (multiplied by 2). *Execution rate* is computed by dividing the number of shares executed at the trading venue by the total number of shares submitted to the venue (including canceled and routed-away orders). *Speed @ NBBO* displays the execution speed of orders (in seconds) that were placed at the national best bid or offer (NBBO). *Relative Mkt. Sh.* is an average of the relative share trading volumes in the two trading venues (computed by dividing the number of shares traded on the NYSE by the number of shares traded on ARCA's system). *NYSE's 2d* shows the average difference in the two venues' Effectived spreads (referred to as *2d* in our model). *NYSE's α* reports the average ratio of the two venues' Execution rates (with NYSE's Execution rate in the numerator). ***** = significantly different between NYSE and ARCA for a specific time period at the .01 level. **†** = significantly different between June 2006 and June 2009 at the .01 level.

A. Dow-30 Stocks listed on the NYSE (n = 28 stocks)

	NYSE			**ARCA**		
	June 2006	*June 2009*	*% Chg.*	*June 2006*	*June 2009*	*% Chg.*
Effective Spread	$ 0.021	$ 0.010	-52.8%	$0.020	**$0.008***	-61.3%
Execution Rate (%)	98.6	75.2	-23.7%	**43.5***	73.9	+69.9%
Speed @ NBBO	5.36 sec.	0.18 sec.	-96.8%	**1.69*** sec.	0.05 sec.	-97.1%
Relative Mkt. Sh. (x)	-	-	-	222.4	**9.4**†	-95.8%
NYSE's *2d*	-	-	-	-$0.0017	-$0.0025	-43.5%
NYSE's α (x)	-	-	-	2.27	**1.02**†	-55.1%

B. All Stocks listed on the NYSE (n = 3,152 stocks)

	NYSE			**ARCA**		
	June 2006	*June 2009*	*% Chg.*	*June 2006*	*June 2009*	*% Chg.*
Effective Spread	$ 0.055	$ 0.046	-16.3%	**$0.045***	**$0.030***	-32.7%
Execution Rate (%)	97.7	65.8	-32.6%	**33.7***	65.5	+94.3%
Speed @ NBBO	10.4 sec.	0.43 sec.	-95.9%	**3.86*** sec.	**0.04*** sec.	-98.9%
Relative Mkt. Sh. (x)	-	-	-	143.5	**8.7**†	-94.0%
NYSE's *2d*	-	-	-	-$0.0103	**-$0.0160**†	-54.8%
NYSE's α (x)	-	-	-	2.90	**1.01**†	-65.3%