The Effect of Maker-Taker Fees on Investor Order Choice and Execution Quality in U.S. Stock Markets*

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January 23, 2015

Abstract

Equity exchanges competing for orders are using new pricing strategies. Typically, liquidity suppliers are compensated and liquidity demanders are charged. This pricing structure is controversial because of its potential effects on investor order choice, market quality, trader welfare, and economic efficiency. I develop a theoretical model of maker-taker fees in the presence of a broker and equity exchanges and test the model empirically using order level data from SEC Rule 605. The broker charges investors a commission and endogenously chooses to route orders to a dealer or equity exchange. The exchanges keep a portion of the taker fee as profit and pass the remaining amount to the broker as a maker rebate when its order providing liquidity executes. The theoretical model predicts that as the taker fee and maker rebate increase, holding constant the amount kept as profit by the exchange: (1) the bid-ask spread declines, (2) the total trading cost increases, (3) the trader participation falls, (4) the proportion of marketable order shares rises, and (5) the non-marketable limit order fill rate increases. These implications are different from those of the model by Colliard and Foucault (2012), because my model implies that changes in the split of trading fees between liquidity suppliers and demanders affect order choice and thereby execution quality. I find empirical evidence consistent with my model's predictions. In particular, as the taker fee and maker rebate increase, holding constant the amount kept as profit by the exchange: (1) the bid-ask spread declines, (2) the trader participation falls, (3) the proportion of marketable order shares rises, and (4) the non-marketable limit order fill rate increases.

JEL Classification: G00, G18, G20, L10.

Keywords: Limit order book, maker or taker fees, bid-ask spread, liquidity rebates.

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*I thank my committee members, Robert H. Jennings, Craig W. Holden, Zhenyu Wang, Ryan D. Israelsen, Juan Carlos Escanciano, Rick Harbaugh, and Jason Brown for their very helpful comments and support. I also thank Jeff Prince, Jeffrey W. Smith, Jean-Edouard Colliard, Thierry Foucault, and Rick deFriesse for their assistance. The author gratefully acknowledges The NASDAQ OMX Group Educational Foundation for providing financial support through the Ph.D. Dissertation Fellowship.

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Regulatory changes in the form of the SEC's Regulation National Market System (Reg NMS), and especially the Trade-Through Rule (Rule 611), in combination with high-speed networks and powerful computers have allowed upstart electronic limit order markets to compete successfully against traditional equity exchanges in the United States and Europe. This has led to intense competition between exchanges. The NYSE and NASDAQ no longer have a near monopoly on equity trading in the United States. According to the Fidessa[1], which tracks market fragmentation, as of the week ending on May 23, 2014, NASDAQ, NYSE, and NYSE ARCA have turnover shares of 27.23%, 18.04%, and 16.17%, compared to BATS X, EDGX and other exchanges that have turnover shares of 11.61%, 11.08%, and 15.88%, respectively. The equity exchanges vigorously compete for volume shares, because the amount of trading fees generated, demand for co-location services[2], and value of the market data fees are positively related to the proportion of overall trading that the exchange executes.

The competition between equity trading platforms has virtually eliminated human intermediated trades and led to electronic limit order books that vie for order flow through a maker-taker pricing structure. This pricing strategy charges a different fee for filled orders that take liquidity than those that add liquidity. Typically, a rebate is paid to investors posting liquidity (makers), and a transaction fee is charged to traders who remove liquidity from the exchange (takers). The SEC limits the maximum taker fee to be \$0.0030 per share and the maker rebates are usually smaller in absolute size to allow exchanges a positive profit margin.

At first glance, these small fees might appear to be trivial. According to NASDAQ's 2012 Annual Report, the firm received \$976 million in fees and paid out \$854 million in rebates, netting \$122 million in revenue for itself. This amount totals 34.7% of NASDAQ's net income for 2012. According to a June 2014 press release, TD Ameritrade, a large online brokerage, earned order routing revenue from maker rebates and payment for order flow of \$236 million, \$184 million and \$185 million for fiscal years 2013, 2012 and 2011, respectively (2014). According to Angel, Harris, and Spatt (2011), the median quoted bid-ask spread for S&P 500 stocks has been declining over the last decade and is \$0.0125 as of August 2009. Since the effective spread is only slightly larger than the \$0.01 tick size, the maker rebates represent a progressively larger proportion of the payoff to non-marketable limit orders[3] and the taker fees are an increasingly greater fraction of the costs to investors using marketable orders[4].

The effect of these maker-taker fees on order flow and execution quality across trading platforms is poorly understood and very controversial. Angel, Harris, and Spatt (2011) cite three problems associated

[1] For the latest data see: http://fragmentation.fidessa.com/usa. For an academic perspective see O'Hara and Ye (2011).

[2] High-frequency trading firms pay to place their servers in close proximity to the stock exchange matching engine in order to reduce latency.

[3] A non-marketable buy (sell) limit order has a limit price that is below (above) the current ask (bid). Non-marketable orders add liquidity to the exchange.

[4] Marketable orders are market orders or buy (sell) limit orders whose limit price is at or above (at or below) the current ask (bid) price. Marketable orders remove liquidity from the exchange.

with maker-taker pricing. First, it has produced quoted spreads that do not represent actual trading costs. Brokers must route marketable orders to the exchange with the best quoted price per Rule 611, but not necessarily to the exchange offering the true net lowest cost per trade. Second, it has distorted the routing decisions of brokers and investors with direct market access[5]. Brokers have a financial incentive to execute marketable orders away from the equity exchanges to avoid the taker fee and are rewarded with rebates for executing non-marketable limit orders to the exchanges.

Third, maker-taker pricing has aggravated agency issues between brokers and their clients. Brokers are incentivized to direct non-marketable limit orders to the venue offering the highest rebate. However, this destination may not necessarily be the best for clients, if it offers a relatively slow execution speed, high non-execution probability, or a high probability of execution outside-the-quote. Maker-taker pricing has increased the cost to brokers of executing marketable orders in the exchanges; consequently, brokers will internalize uninformed marketable orders whenever possible. As a result, non-marketable limit orders that are sent to the exchange are more likely to execute when the price moves against them since the orders submitted there are disproportionately informed. Battalio, Corwin, and Jennings (2014) find empirical evidence that non-marketable limit orders directed to venues with relatively high taker fees experience lower fill rates and suffer greater adverse selection.

Angel, Harris, and Spatt (2011) were the first to hypothesize that allocating a maker rebate that is subsidized by a taker fee should have no effect on the market equilibrium, as bid-ask spreads adjust and precisely offset the change in the maker fee, as long as fees and rebates are passed onto clients. Colliard and Foucault (2012) test this intuition and mathematically prove that only changes in the net fee[6], booked as profit by the exchange, affect trading volume and market liquidity. Thus, changes in the magnitude of the maker-taker fees will not influence real net-of-fees spread or the order choice of investors.

In reality, many traders, especially long term investors, do not have direct market access. Thus, they are unable to directly interact with the limit order book of an exchange. Typically, these investors pay a flat-rate commission per trade to a broker, and the broker, in turn, fills the order. Customers do not typically know where the order executes. The investor's broker, chooses which trading venue receives the order, and pays maker-taker fees for any filled orders.

Using the model of Colliard and Foucault (2012) as a base platform, I introduce three changes. First, in the established model all traders are assumed to have direct market access, and pay taker fees and receive maker rebates. In my model, there are two trader types: those who have direct market access and others who access the exchange through a broker and pay an endogenous flat-rate commission. Second, in Colliard

[5]Traders who interact directly with an equity exchange's limit order book through electronic trading facilities.
[6]The net fee is defined as the taker fee less the maker rebate.

and Foucault (2012) all liquidity in the exchange is provided by the investors. Consequently, marketable orders cannot always be executed at this destination due to a lack of liquidity on one or both sides of the limit order book. The new model features electronic market makers, who are willing to provide liquidity at any time in order to earn maker rebates.

Third, all investors choose their respective order type, limit price quotation strategy if relevant, and routing destination in Colliard and Foucault (2012). In my model, the investor chooses between a marketable order or non-marketable limit order, and if relevant, a limit price quotation strategy, but the broker decides whether the order is routed to one or more equity exchanges or an OTC dealer. It is important to highlight what drives the differential predictions of my model. Surprisingly, it is not the level of competition between brokers, but the fact that investors are insulated from the impact of each and every maker rebate and taker fee when an order is filled. The brokerage flat-rate commission serves as an anesthetic, whereby the trader does not completely sense the consequences of her order choice.

In this paper, I examine whether the maker rebate and taker fee affect order choice and execution when an investor pays a flat-rate commission. My model has six implications. First, the bid-ask spread decreases when the taker fee and maker rebate increase, holding the amount booked as profit by the exchange constant. This outcome is also predicted by Colliard and Foucault (2012) as well. Second, I find that total trading cost[7] to investors increases, when the taker fee and maker rebate increase, even if the net fee is held fixed. The total trading cost represents the net-of-fees bid-ask spread and the brokerage commission to an investor wanting to buy and then sell the same stock. Intuitively, this prediction is different from that of Colliard and Foucault (2012), because the commission adjusts to recover the broker's costs, which causes the relative level of the taker fee and maker rebate, holding fixed the profit retained by the exchange, to affect the total trading cost.

Third, when faced with this increased cost, investors submit both fewer non-marketable limit and marketable order shares. Thus, investor participation in the exchange is decreasing in the taker fee and maker rebate. Fourth, the proportion of marketable order shares increases and non-marketable limit orders decreases. This will occur because some investors, who still desire to trade even after the taker fee and maker rebate increase, and would have preferred a non-marketable limit order before the pricing change, now choose a marketable order instead. This change in the investors endogenous choice occurs because the level of the maker-taker fees, and not just the fee pocketed by the exchange, impacts the total trading cost. Since both the buy and sell sides of the limit order book in my model always contain liquidity, a trade executes whenever an investor submits a marketable order. The limit order book never has an empty side in my model, because

[7] Defined as the difference between the price paid on a buy market order and received on sell market order, after paying the brokerage commission.

electronic market makers, who have direct market access, are always willing to supply liquidity, especially when the maker rebate increases. This means that changes in the taker fee and maker rebate impact the trading rate, and, consequently, the exchange equilibrium.

Fifth, the probability that a non-marketable limit order executes (or fill rate) increases as the taker fee and maker rebate increase. As investors increasingly choose a marketable order instead of non-marketable limit order, the remaining non-marketable limit orders that are submitted experience a smaller risk of non-execution. Sixth, the model predicts that an increase in the taker fee has a larger impact than a commensurate decrease in the maker rebate, then the bid-ask spread and both the number of marketable or non-marketable order shares decreases relatively more, percentage of marketable order shares changes relatively more, and execution probability of non-marketable limit orders increases relatively more for a change in the taker fee than maker rebate.

To examine market quality, I use SEC Rule 605 data, which report execution metrics each month per stock by trading venue. All stock exchanges, dealers, and any other market centers executing trades are required to report on their own websites according to standardized definitions on select order types. The reports allow me to examine execution quality as measured by quoted spreads, effective spreads, realized spreads, price impact, fill rates, and order type submissions across trading venues. I use taker fees and maker rebates from U.S. stock trading venues from March 2009 through December 2011 in combination with CRSP and SEC Rule 605 data to empirically test my model predictions. The fees are available for NYSE- or NASDAQ-listed stocks at a monthly frequency for each trading venue and are collected from the US Securities and Exchange Commission[8], Federal Register[9], exchange websites, *Traders Magazine*[10], and Factiva.

First, consistent with my model, I find that the quoted and effective spread fall whenever the taker fee and maker rebate increase, holding constant the profit booked by the exchange. This result is consistent with the empirical findings in Malinova and Park (2014). Second, I am unable to directly test whether the total trading cost increases, when the taker fee and maker rebate rises, because a time series of brokerage commissions is unavailable. Third, I also find that not only an increase in the net fee, but also an increase in the taker fee and maker rebate is associated with a decline in the both the number of shares of marketable and non-marketable limit orders. This empirical result is unique to this paper and suggests that the level of taker fee and maker rebates can affect the order choice of investors paying a flat-rate brokerage commission. Fourth, the proportion of marketable (non-marketable limit) order shares increases (decreases) whenever the taker fee and maker rebate increase, because a subset of investors switch from using non-marketable limit

[8]http://www.sec.gov/rules/sro.shtml
[9]https://www.federalregister.gov
[10]http://www.tradersmagazine.com

orders to marketable orders. The fact that investor order choice changes suggests that the total trading cost for investors using a broker is being affected by the maker-taker pricing. Fifth, if the taker fee and maker rebate increase, then the execution probability of non-marketable limit orders increases. This is empirical evidence that the exchange fees are influencing the market equilibrium, and is consistent with the idea found in my model and that of Foucault, Kadan, and Kandel (2013) that an exchange can increase its volume share of the equities by fine tuning the fee it charges to each side of the market.

Sixth, I do find evidence consistent with the prediction of my model, that a rise in the taker fee increases the fill rate of non-marketable limit orders more than the same size fall in the maker rebate. However, in contrast to my model's predictions I find that the number of marketable, non-marketable limit, or total order shares declines more for a decrease in the maker rebate than an increase in the taker fee. Thus, my empirical results are not consistent with those of Cardella, Hao, and Kalcheva (2013), who find that an increase in the taker fee has a stronger effect than a decrease in the maker rebate on trading volume.

On examining the data further, I discover some evidence that the price impact of marketable order shares decreases as the taker fee and maker rebate increase. This finding is consistent with the intuition in my model that investors paying a flat-rate commission switch from non-marketable limit to marketable orders and is formalized in Brolley and Malinova (2013). However, I do not find that electronic market makers, who earn maker rebates by submitting limit orders directly to exchanges are able to profit from reduced adverse selection as the realized spread plus twice the maker rebate[11] falls when the taker fee and maker rebate increase holding the net fee constant. In fact, regression evidence suggests that if price impact is falling that liquidity providers are unable to benefit from the fall in adverse selection.

These results suggests that the taker fee and maker rebate affect the total trading cost even after controlling for the amount of the fee booked by exchanges as profit. In effect, this evidence supports the prediction from my model that the change in the bid-ask spread does not adjust to perfectly offset the change in the taker fee and maker rebate. This is the essential message derived out of my model and is in contrast to that of Colliard and Foucault (2012). To state it differently, the level of the taker fee and maker rebate for an exchange changes the equilibrium. In addition, this empirical analysis is the only one that finds evidence of an association between changes in investor order choice, trading rate, and execution probability of non-marketable limit orders and adjustments in the exchange fees.

There are two theoretical models related to mine that introduce market frictions when examining the effect of maker-taker pricing. The major difference between my model and that of Foucault, Kadan, and Kandel (2013) is that their model does not contain a brokerage commission. In their model trading volume may

[11] The amount earned by providing liquidity to a marketable sell order and then a marketable buy order, including maker rebates, but net of loses to informed traders.

increase or decrease, because a fixed tick size prevents prices from neutralizing the effect of the maker rebate. In addition, my model focuses on the role of maker-taker pricing in competition between exchanges and between exchanges and OTC dealers. It highlights the function that brokers play as a financial intermediary routing orders from investors to various execution venues. My model generalizes beyond the retail example, to any trading environment where an institution pays a flat-rate commission for brokerage services. Unlike the model by Brolley and Malinova (2013) where privately informed investors trade in a market closely monitored by low-latency liquidity traders, my model does not highlight the order choice of asymmetrically informed investors and their corresponding effect on the price impact. This difference permits my model to offer simple analytical solutions and distinct predictions; namely, (1) the falling bid-ask spread may not offset commission increases driven by higher taker fees and (2) the number of shares of all order types decreases when the taker fee and maker rebate increases.

This empirical analysis differs from that of two earlier papers. First, I focus on the effect of the level of the taker fee and maker rebate on execution quality measures, while holding the amount of profit booked by the exchange fixed, whereas Cardella, Hao, and Kalcheva (2013) do not hold the net fee constant. Since changes in the taker fee or maker rebate levels are typically accompanied by changes in the fee kept by the exchange, it is difficult to ascertain the differential impact of different changes. Second, the advantage of using SEC Rule 605 data to test my model is that I can observe a decline in the number of shares submitted to each exchange and in aggregate. Third, SEC Rule 605 data contain actual spread measures that do not require trade direction inference (Lee and Ready, 1991), as the data are order level not trade and quote data (TAQ) as in Cardella, Hao, and Kalcheva (2013). This is significant with respective to testing my model, because brokers route orders, not individual trades, to exchanges. Fourth, my analysis is based on a broad sample of 4,236 NYSE- and NASDAQ-listed stocks across nine U.S. equity exchanges for thirty-four months. Malinova and Park (2014) examine the introduction of maker rebates (but not taker fees) on the Toronto Stock Exchange (TSX) for sixty-five AMEX- and NASDAQ-cross-listed stocks. Their empirical findings are relatively less generalizable because they are based on a smaller sample of stocks, exclude NYSE-listed securities, and examine execution quality measures from the TSX only.

This paper is organized as follows. Section 1 summarizes the model setup, characterizes the equilibrium, and outlines the empirical implications. Section 2 describes the datasets, explains the sample selection, and sketches out the empirical methodology. Section 3 discusses results from the empirical analysis. Section 4 concludes.

1 Theoretical Model

1.1 Model Setup

Much of the structure of my model is adopted from Colliard and Foucault (2012). Figure 1 outlines the choices available to the investor and timing of an order execution. First, an investor at date τ must decide whether or not to trade. If the gains of trade to the individual investor, L, are equal to or greater than the brokerage commission, c, then she will trade. Otherwise, she will not trade because the surplus earned by all marketable orders would be negative. Assuming the investor wants to trade, she will choose a non-marketable limit or marketable order depending on the relative payoff of the two order types. If she opts for a marketable order, she will submit it to a broker, who will route it to an equity exchange or dealer market. A market sell (buy) will hit the best available bid (ask) price at its destination, and will execute immediately with certainty. If she instead selects a non-marketable limit order, she must determine the ask (bid) price for a limit sell (buy) to post, and submit it to the broker. Assuming that the broker sends the limit sell (buy) to the exchange, it will execute only if a market buy (sell) hits its ask (bid) price. This only occurs when the next investor arriving at date $\tau + 1$ choses a market buy (sell). Otherwise, the limit sell (buy) from date τ is unfilled, and the order trades in the dealer market with a less than one interval delay. If the broker initially routes the limit sell (buy) from date τ to the dealer market, then it will be executed by dealer at date $\tau + 1$. The investor who posts quotes is defined as a "maker" and trader who hits these quotes is a "taker".

The security pays a single cash flow, v. At each date $\tau = 1, 2, \ldots$, the security pays its cash flow with probability $(1 - \rho)$. If the security does not pay out, then an investor appears to trade one share. One investor arrives sequentially at each date. If the investor does not trade, she is not permitted to do so later. Each investor is a buyer or seller with an independent probability of one-half. If she infers a high stock valuation, $V_H = v + L$, she buys, and if she infers a low valuation, $V_L = v - L$, she sells [12]. When a transaction occurs on the exchange between two investors submitting orders through a broker, the gains from trade to be split between buyers and sellers is $G^l = 2L - 2c$.

Investors also have different levels of impatience. The known proportion of patient investors in the population is π. The discount factor for patient investors is $\widehat{\delta_H}$ and the impatient investors discount factor is $\widehat{\delta_L}$, where $0 < \widehat{\delta_L} < \widehat{\delta_H}$. The discount factor represents the investor's relative valuation of having an

[12] Several other models generate gains from trade based on private values, such as Hollifield, Miller, and Sandås (2004) and Goettler, Parlour, and Rajan (2005; 2009). Duffie, Gârleanu, and Pedersen (2005) provides the economic intuition for the private values. The following is an example of private value trading: Suppose two children each purchase chewing gum packages containing baseball cards. One child may have a low private value, and the other may have high private value for a particular player's card based on the team or franchise's geographical location that is independent of the gum's retail price.

order execute immediately versus with a possible delay. The cost of a given delay is relatively high for an impatient versus patient investor.

More than one exchange exists and they are assumed to be perfectly competitive profit maximizers. The exchange earns the net fee, that is, the gross profit, f^N, and incurs a processing cost, ω, per execution. Thus, the net profit per trade is $f^N - \omega$, where $f^N \geq \omega > 0$. The net fee is split between the two sides of the market. The exchange charges liquidity demanders a taker fee, f^{ta}, and liquidity providers a maker fee, f^{ma}, whenever a transaction occurs. The net fee, f^N, is the sum of the maker and taker fees and is the gross profit to the exchange.

The predominant pricing structure is maker-taker ("non-inverted"), where the taker pays a fee and the maker receives a rebate. The taker fee and maker rebate are a function not only of the net fee but also the fee level, f^L. For a given net fee, a rise (fall) in the fee level will increase (decrease) the taker fee and maker rebate. In essence, the fee level determines the degree to which the takers subsidize the maker rebates. Table 1 is an example of fees and pricing structures across exchanges used in my empirical analysis. The domain of the fee level is $\left(\mathbb{R} \,\middle|\, f^L \notin [0,1]\right)$.

The limit order book is filled by non-marketable limit orders submitted by investors via a broker and high frequency traders behaving as electronic market makers. These electronic market makers are not necessarily designated market makers, as they may not have an affirmative obligation to provide liquidity. Empirical evidence of their existence has been documented by Menkveld (2013). Angel, Harris, and Spatt (2011) describe how exchanges use flash orders to locate liquidity from electronic market makers willing to match or improve posted quotes.

These liquidity providers constantly monitor the order flow entered into the limit order book. Their objective is to earn the maker rebate and half-spread by submitting limit buys or sells whenever a side of the book is empty. They value the security at the unconditional mean price (that is, at the midpoint of the bid-ask spread), v, and do not have a private value or information regarding the stock. For simplification, the cost of monitoring the market and server co-location services is set to zero. In addition, they do not have liquidity needs and face perfect competition from other electronic market makers. Consequently, the electronic market makers post an ask price equal to the unconditional security value, v, plus one-half the bid-ask spread, and a bid price equal to the security value, v, less one-half the bid-ask spread.

The bid-ask spread is an equilibrium outcome and is a function of the fees charge by the exchange and dealer market. A non-marketable limit order submitted by an investor is assumed to have order execution priority, and its bid or ask price is never improved upon by electronic market makers. Hence, the gain from trade of a market sell (buy) hitting the quote of a limit buy (sell) is the same, regardless of whether the limit order was submitted by an investor or electronic market maker. If the electronic market maker's order is not filled on the same date τ it is submitted, then it expires automatically.

Dealers provide competition to the exchanges by continuously posting ask and bid prices, A^d and B^d, respectively. They do not have information or private values for the stock, and, consequently, value it at v. The dealer does incur an exogenous order processing cost of λ per share. A broker who chooses to trade in the dealer market, obtains quotes from several dealers, and executes the order against the most favorable quotes. If the best bid (ask) is quoted by two dealers simultaneously, then the broker randomly chooses one. Because of perfect competition the dealer quotes are $A^d = v + \lambda$ and $B^d = v - \lambda$, respectively. When a trade executes in the dealer market, the gains of trade to an investor using a broker is $G^d = L - c$, where c is a brokerage commission. The dealer market serves two purposes in the model (Pagnotta, 2010; Colliard and Foucault, 2012). First, it serves as an additional destination to which brokers may route orders. Second, it serves as a mechanism to clear unfilled limit orders.

Brokers play an integral role in this model. They value the security at v, and do not have a private value or any information regarding the stock. The investor (not electronic market makers) does not have direct market access, but the broker does. As a result, she pays the broker a commission to execute the order. The broker chooses the venue, an exchange or dealer, who in turn, fills the order. More than one broker exists and they engage in perfect competition. If several brokers have the same commission, the investor will randomly pick one of them to receive the order.

Suppose the broker routes an order to the exchange at date $\tau + 1$. Then the broker will pay a taker fee, f^{ta}, when a client's marketable sell or buy executes, and, if relevant, will collect a maker rebate, f^{ma}, if the marketable order hits a quote posted by a non-marketable limit order investor from date τ. If the non-marketable limit order from date τ is not filled, then it will be executed in the dealer market where the broker will incur the order processing cost, λ. Should the broker choose to route all orders to the dealer market instead, he will pay the order processing cost, λ, for each marketable order that hits the dealer's quotes. Brokers charge a flat-rate commission, c, per executed order for each investor. Due to perfect competition, the broker will earn zero profit and the commission will be a weighted average of the taker fee, maker rebate, and dealer order processing cost, where the weights are the probabilities of different order types executing. These probabilities are a function of the brokerage commission and the investor's order type choice and quotation strategy.

1.2 Equilibrium Characterization

When an investor arrives at date $\tau+1$, she choses to buy if $V_H = v + L$ or sell if $V_L = v - L$ with probability one-half, where L is greater than the commission. Assuming that she decides to trade, she must pick between a marketable order or non-marketable limit order. In particular, the investor submits a marketable order and hits the price quoted by the investor from date τ or the electronic market maker arriving at date $\tau+1$, or posts her own quote in the limit order book at the cost of a delay and risk of non-execution. I assume that δ_i is investor i's discount factor where $\delta_i \equiv \rho \cdot \widehat{\delta_i}$ for $i \in \{H, L\}$.

Non-marketable limit orders have a life span of only one period, but in contrast to Colliard and Foucault (2012), one side of the limit order book is never empty. It contains a non-marketable limit sell (buy) at date $\tau+1$ from an investor, if an investor submitted a sell (buy) at date τ. The buy (sell) side of the book contains a limit order submitted at date $\tau+1$ by the electronic market maker. If at date τ, the investor submitted a marketable order or chose not to trade, then the buy and sell sides of the book are populated by corresponding non-marketable limit orders entered by the electronic market maker at date $\tau+1$. The ask and bid prices at date $\tau+1$, are A_τ and B_τ, respectively.

Suppose an investor arrives at date $\tau+1$, with a discount factor, δ_i. Assume that $V_\tau(\delta_i)$ is the biggest expected payoff that a limit order can receive. The payoff for a non-marketable limit buy or sell is exactly the same, since the probability of a buy or sell is one-half. The investor will pick a market order, if the payoff of this order type is greater than the payoff of the limit order, $V_\tau(\delta_i)$, or not trading. Given this setup, I solve for the ask and bid prices posted by non-marketable limit order investors in order to define the value of a limit order.

Suppose an investor of type δ_i arrives at date τ. She submits a marketable order if and only if $A_\tau \leq \widehat{A_\tau(\delta_i)}$ when she is a buyer and if and only if $B_\tau \geq \widehat{B_\tau(\delta_i)}$ when she is a seller, where

$$\widehat{A_\tau(\delta_i)} = V_H - c\left(f^{ta}, f^{ma}, \lambda, \pi\right) - V_\tau\left(\delta_i\right), \tag{1}$$

$$\widehat{B_\tau\left(\delta_i\right)} = V_L + c\left(f^{ta}, f^{ma}, \lambda, \pi\right) + V_\tau\left(\delta_i\right). \tag{2}$$

Additionally, the high and low fill rates are ϕ_H and ϕ_L, respectively, where $\phi_H > \phi_L$, so that the value of a limit order is

$$V_\tau\left(\delta_i\right) = \delta_i \cdot \max_{k \in \{H,L\}} \left\{\phi_k\left(G^l - V_{\tau+1}\left(\delta_i\right)\right) + \left(1-\phi_k\right) G^d\right\}, \text{ for } i \in \{H, L\}. \tag{3}$$

I will explain Equations 1 - 3 by example. Suppose a non-marketable limit sell order arrives at date τ and submits an ask price at A_τ. This can only happen if the following conditions are met: (1) the difference between the private value and the mean value of the security is greater than the commission ($L > c$) and (2) the value of a limit sell is greater than a market sell. The investor arriving at date $\tau + 1$, will accept this ask price if she is a buyer with cut-off price $\widehat{A_\tau(\delta_i)}$ greater than A_τ. A_τ is the ask being quoted in the exchange, and the investor with δ_i infers that the ask is $\widehat{A_\tau(\delta_i)}$. She is happy to buy the stock with a marketable order at a perceived low price, A_τ, because she believes she can sell it at $\widehat{A_\tau(\delta_i)}$. Assuming the trading game continues at date $\tau+1$, the probability of a non-marketable limit sell execution from date τ is ϕ_H if $A_\tau \leq \widehat{A_{\tau+1}(\delta_H)}$, ϕ_L if $\widehat{A_{\tau+1}(\delta_H)} < A_\tau \leq \widehat{A_{\tau+1}(\delta_L)}$, and zero if $\widehat{A_{\tau+1}(\delta_L)} < A_\tau$. This means that the limit seller can post the ask at two different prices[13]: (1) a relatively low ask, $\widehat{A_{\tau+1}(\delta_H)}$, that is attractive to both patient and impatient buyers or (2) a relatively high ask, $\widehat{A_{\tau+1}(\delta_L)}$, that appeals to impatient buyers, but not to patient ones. The ask, $\widehat{A_{\tau+1}(\delta_H)}$, has a higher fill rate, ϕ_H, because it appeals to both patient and impatient traders, but at the cost of a smaller surplus when it is hit. Equation 3 is the value of a limit buy or sell for the patient or impatient investor given the fill rate ϕ_k, where $G^l - V_\tau(\delta_i)$ is the surplus when the limit order is executed at the exchange and G^d is the surplus when the order is cleared in the dealer market (because it failed to fill in the execution).

The buyer who arrives at date $\tau+1$, has two choices: (1) post a bid price or (2) enter a market buy to hit the ask posted by the date τ investor. The decision rule for a marketable buy versus non-marketable limit buy is hidden in Equation 1. A buyer with type δ_i arriving at date $\tau+1$ will submit a marketable buy, if the security's private value less the commission and ask price is equal to or greater than the limit buy, $V_\tau(\delta_i)$.

In order to solve for the equilibrium, I concentrate on an investor's order choice and quotation strategies that only rely on the current state of the limit order market and not on history or date of arrival (Goettler, Parlour, and Rajan, 2005; Colliard and Foucault, 2012). As a consequence of stationarity, $V_\tau(\delta_i) = V^*(\delta_i)$ for all dates τ. The maximal expected payoff of a non-marketable limit sell or buy in equilibrium for an investor using a broker is

$$V^*(\delta_i) = \delta_i \cdot \underset{k\in\{H,L\}}{max} \left\{\phi_k \left(G^l - V^*(\delta_i)\right) + (1-\phi_k) G^d\right\}, \text{ for } i \in \{H, L\}. \tag{4}$$

For each set of exogenous parameters, I can solve for an investor's optimal choice by solving Equation 4. The solution will indicate if the investor picks a high or low fill rate, and the corresponding ask or bid price. The ask or bid price in equilibrium is given by the cut-off as defined in Equation 1 or 2. Even though a

[13] An impatient buyer is always willing to accept a higher ask price than a patient one. That is, $\widehat{A_{\tau+1}(\delta_H)} < \widehat{A_{\tau+1}(\delta_L)}$ for all dates τ.

patient investor will receive a higher expected payoff than an impatient one, $V^*(\delta_H) > V^*(\delta_L)$, due to the smaller discount factor, both investor types post the same price and receive the same non-marketable limit order fill rate.

Assuming that the broker routes all orders to the exchange, only one equilibrium is possible. This equilibrium can take on one of any five states at a given date τ as show in Table 2. The states differ according to the order choice of the patient and impatient investors. In state type 1, both patient and impatient investors choose to be makers or takers. The fill rate, the probability that a non-marketable limit order submitted by an investor (not an electronic market maker) executes, is high, because the non-marketable limit price posted is attractive to both patient and impatient investor types. State type 2, also has a high fill rate since both patient and impatient investors submit marketable orders, but only patient investors are posting quotes. Now the probability of non-marketable limit orders executing is relatively low in states 3 and 4. In state 3, only impatient investors are takers as long as both patient and impatient investors are posting quotes at a relatively high ask or relatively low bid price. State 4 is different in that patient investors only submit non-marketable limit orders and impatient investors only submit marketable orders. The last state, 5, can exist because both investor types can choose to only submit marketable orders. This is possible due to the activity of electronic market makers, who serve in this state as the only source of liquidity.

Since I have a Markov perfect equilibrium, I can obtain the probabilities for marketable and non-marketable limit order submissions and the fill rate for these non-marketable limit orders. Using these probabilities along with the fees from the exchange, f^{ta} and f^{ma}, and the dealer market, λ, I can solve for the brokerage expected equilibrium commission per trade. Since the broker is assumed to earn zero profit in expectation, he routes all orders to the lowest cost execution venue. He will send all orders to the exchange as long as the brokerage commission is smaller than or equal to the commission that would be charged for routing all flow to the dealer.

1.3 Differences Between Theoretical Models

To date there are three other theoretical papers that focus on the impact of maker-taker fees. Colliard and Foucault (2012), which is the base platform for my model, does not include any market frictions. In contrast, Foucault, Kadan, and Kandel (2013), Brolley and Malinova (2013) and my model feature market frictions.

Foucault, Kadan, and Kandel (2013) use a positive tick size as a friction, which prevents the effect of the maker and taker fees from being completely neutralized. This occurs because the tick size prevents the bid and ask prices from adjusting perfectly. As a result, the exchange can affect the trading rate by balancing the demand and supply of liquidity through changes in the fee level.

There are two differences between my model and that of Colliard and Foucault (2012). The first difference is that my model has electronic market makers, who ensure that no side of the limit book is ever empty. This agent's sole objective is to earn the half spread and maker rebate in exchange for providing liquidity. The model from Colliard and Foucault (2012) is very different because at least one side of the limit order book is always empty. If a limit buy (sell) order was submitted at date τ, then the limit sell (buy) side of the book is empty at date τ. If instead a market buy (sell) is executed at date τ, then both sides of the book are empty next period. In two equilibriums of their model (equilibrium types 3 and 4), the investors may choose a marketable sell (buy) order and direct it to the dealer market, whenever the buy (sell) side of the exchange's limit order book is empty.

The most important change I introduced into the model is the existence of a broker. Unlike Foucault and Colliard (2012), the investors are unable to interact directly with the limit order book or contact the dealer market. The broker serves as a financial intermediary, and he, not the investor, chooses the routing destination and endogenously sets the flat-rate commission. The investor now chooses the order type and, if relevant, selects the non-marketable limit order quotation strategy. The implications from my model differ from those of Colliard and Foucault (2012), because the flat-rate commission ensures that a subset of investors pay the taker fee and receive the maker rebate on average and not directly. The existence of the electronic market makers ensures that sufficient liquidity is always present in the limit order book, so that marketable orders can execute at anytime. Thus, the probability that a marketable limit order executes is greater than the fill rate of a non-marketable limit order for investors. As long as these two probabilities are different, the flat-rate brokerage commission will be a function of the fee level, which determines the size of the taker fee and maker rebate. Since the surpluses earned by the maker and taker are affected by the brokerage commission, a change in the fee level will alter an investor order choice type. This result is obtained even with perfect competition in the brokerage market.

There are two differences between my model and the work of Brolley and Malinova (2013). First, the motivation for trading in my model is the difference in private values accorded to the security by a buyer and seller. In Brolley and Malinova (2013), informed investors trade because of an informational advantage and uninformed investors trade for liquidity reasons. An equilibrium outcome of their model is that investors with more information use marketable orders and the relatively uninformed use non-marketable limit orders (Kaniel and Liu, 2006). Second, in my model the brokerage serves as a financial intermediary, who chooses to route the order flow from clients to equity exchanges or OTC dealers. It is my intention to extend this model so that it captures the effect of competition between exchange maker-taker fees, payment for order flow from third market dealers, and internalization.

1.4 Empirical Implications

The main result from my model is that the maker-taker fee level, f^L, which determines how large the taker fee and maker rebate are for a given net fee, affects which state exists in equilibrium. This occurs, because unlike Colliard and Foucault (2012), the change in the taker fee is not perfectly offset by an adjustment in the bid-ask spread. Thus, the surplus earned by a non-marketable limit or marketable order will no longer be the same. This will in turn affect the investor's decision to be a maker or taker as she will select the order type with the largest payoff.

Suppose the market is in equilibrium where the ask and bid are A^* and B^*, respectively. Since the probability of buying or selling is one-half, the quotes are centered about the expected mean value of the security, v. As a result, the ask is $A^* = v + S^*(c^*(f^{ta}, f^{ma}, \lambda, \pi))$, the bid is $B^* = v - S^*(c^*(f^{ta}, f^{ma}, \lambda, \pi))$, and the bid-ask spread is $S^*(c^*(f^{ta}, f^{ma}, \lambda, \pi)) = A^* - B^*$. If the taker fee and maker rebate increase, holding the net fee constant, then the electronic market makers will compete to earn the higher maker rebate by posting more attractive prices. Since the ask is posted at a relatively lower price and the bid is posted at a relatively higher price, the bid-ask spread falls. Thus I have the following testable null hypothesis:

Prediction 1: Costs and Spread.

1. *Holding the net fee or fee level constant, if the taker fee and maker rebate increase, then the*
   (a) *bid-ask spread decreases.*

Investors using a broker will pay a higher commission whenever the taker fee and maker rebate increase, since the probability of a marketable order executing is always greater than a non-marketable limit order filling. The total trading cost represents the difference between the price paid by a buyer using a marketable order and the price received by a seller for a marketable order after accounting for the round trip brokerage commission. Thus, it is defined as $T^*(c(\cdot)) = S^*(c^*(\cdot)) + 2c^*(\cdot)$, where $S^*(c(\cdot))$ is the bid-ask spread and $c^*(\cdot)$ represents the commission, $c^*(f^{ta}, f^{ma}, \lambda, \pi)$. Since the fall in the bid-ask spread is not sufficient to offset the increase in the twice the commission in my model, the total trading cost increases whenever the taker fee and maker rebate increases. As a reminder, the half spread is paid by a marketable order seller (buyer) to a non-marketable limit order buyer (seller) as compensation for offering liquidity. As a result, the surpluses earned by a maker or taker in equilibrium when a trade occurs are:

$$L - c^*(\cdot) - \frac{S^*\left(c^*(\cdot)\right)}{2} = L - \frac{T(c^*(\cdot))}{2}\, for\, a\, marketable\, order\, and \tag{5}$$

$$L - c^*\left(\cdot\right) + \frac{S^*\left(c^*\left(\cdot\right)\right)}{2} = L - 2c^*\left(\cdot\right) + \frac{T(c^*\left(\cdot\right))}{2}, for\, a\, non-marketable\, limit\, order. \tag{6}$$

Equation 5 (6) represents the surplus earned by a marketable (non-marketable limit) order buyer or seller. It is clear by examination that the surplus owed to a marketable order decreases and the surplus secured by an executed non-marketable limit order increases as the total trading cost increases. In addition, the term, -2$c^*\left(\cdot\right)$, appears in the surplus for the non-marketable limit order. Since the commission is a function of the fee level, by virtue of the taker fee and maker rebate, and the non-marketable limit and marketable order surpluses are a function of the commission, then the surplus earned by each order type is affected by how high the taker fee and maker rebate are set. This is a different implication than the one found in Colliard and Foucault (2012), since they argue that the net fee (not the fee level) is influential.

If the market is in equilibrium, then the payoff of a marketable sell (buy) precisely equals a non-marketable limit sell (buy) and must account for the non-zero probability of non-execution of limit sells (buys). When the taker fee, holding the net fee constant, increases, the commission[14] will increase and will reduce the surplus of both order types by the same amount in Equations 5 and 6. In addition, the bid-ask spread will fall and this will benefit the takers at the expense of the makers. Thus, the surpluses for each order type will fall, but the surplus for a marketable order will be relatively higher than that for a non-marketable limit order.

Thus, I have two expectations. First, an investor with a sufficiently low value for L will choose not to trade in order to avoid earning a negative surplus. Second, an investor, who would have formerly chosen a non-marketable limit sell (buy), now prefers a marketable sell (buy) instead. As the number of marketable orders increases relative to that of non-marketable limit orders, the proportion of marketable (non-marketable limit) orders to all orders will increase (decrease). Assuming that the equilibrium is in a low fill rate state, it may shift to a high fill rate state when both the patient and impatient investors are takers. To state this differently, since the probability of a marketable sell (buy) increases, limit buy (sell) quotes are hit more often. Thus, the non-execution risk of a limit order falls.

Prediction 2: Volume.

2. *Holding the net fee or fee level constant, if the taker fee and maker rebate increase, then the investor*

[14]In reality, brokerage commissions do not change as often as taker fees and maker rebates do. This commission is likely to be sticky due to costs of updating prices, imperfect information, or competition between brokerages, which constrains commissions at the expense of revenues.

(a) *refrains from trading more often (submits neither a marketable order nor non-marketable limit order);*

(b) *changes from a non-marketable limit to marketable order; and*

(c) *proportion of marketable order shares (trading rate) increases and proportion of non-marketable limit order shares decreases.*

The fill rate of a non-marketable limit order is affected by an increase in the fee level. However, it is not obvious from my model whether the fill rate will increase or decrease. Here is the intuition. Whenever a trade occurs on the exchange, the maker and taker share the gains of trade. Suppose the maker acquires the entire surplus. Then a non-marketable limit order with a high fill rate, ϕ_H, instead of a low fill rate, ϕ_L, increases the maker's expected profit by the difference in the gains of trade between a high and low fill rate, $(\phi_H - \phi_L) \cdot G^l$. So this suggests that the maker chooses quotes corresponding to a high fill rate. These quotes attract both patient and impatient traders. But an increase in the taker fee and maker rebate, increases the commission, which in turn, reduces the gains from trading. This on the other hand, suggests that the maker should choose a low fill rate, with a relatively high ask and low bid price, since the gains of trade is smaller. To ensure the investor at date, $\tau + 1$, chooses a marketable order instead of a non-marketable limit order, the maker must entice a patient maker with the amount that the patient investor forgoes by choosing a marketable order instead. This amount of money is $\phi_H \cdot V^* (\delta_H) - \phi_L \cdot V^* (\delta_L)$. This amount too is decreasing in the commission. An investor submits a non-marketable limit order with a high fill rate if and only if her gain from trading increases more than the increased amount needed to ensure the patient trader chooses a marketable order. Stated differently, a non-marketable limit order with a high fill rate is only chosen when $(\phi_H - \phi_L) \cdot G^l - (\phi_H \cdot V^* (\delta_H) - \phi_L \cdot V^* (\delta_L)) \geq 0$. Since both terms decrease with an increase in the commission, the net effect of an increase in the taker fee and maker rebate is uncertain.

Prediction 3. Fill Rate.

3. *Holding the net fee or fee level constant, if the taker fee and maker rebate increase, then the*

   (a) *fill rate (execution probability) of non-marketable limit order shares increase.*

Cardella, Hao, and Kalcheva (2013) empirically find that an increase in the taker fee decreases the trading volume more than the same size increase in the maker fee. A theoretical explanation for this finding exists in my model. But before describing this, I want to establish the direction of the changes. When the taker fee increases (maker rebate falls), holding the maker rebate (taker fee) constant, the brokerage commission will increase, and consequently, the bid-ask spread will fall. Since the fall in the half-spread is less than the increase in the commission, the total trading cost will increase. An investor with a sufficiently low value for L will choose not to trade in order to avoid earning a negative surplus, and the investor, who is still willing to trade, will choose a marketable order instead of a non-marketable limit order. As a result, the proportion of marketable orders will increase. This intuition motivates Prediction 4d of my model.

The commission is a weighted average of the exchange and dealer fees, where the weights are the relative probabilities of the investors' order choices. Since a non-marketable limit order always faces a risk of non-execution, and a marketable order always executes, a one unit increase in the taker fee will increase the commission more than a one unit decrease in the maker rebate. Thus, the knock-on effect delivered to the bid-ask spread, total trading cost, relative number of marketable and non-marketable limit order shares, and the fill rate will be larger when a change of fee occurs on the taker rather than the maker side of the market.

Prediction 4: Direction of Impact From Change in Taker Fee Versus Maker Rebate.

4. *Holding the maker rebate (taker fee) constant, if the taker fee increases (maker rebate decreases) then the*
   (a) *bid-ask spread decreases;*
   (b) *investor refrains from trading more often (submits neither a marketable order nor non-marketable limit order);*
   (c) *order type changes from a non-marketable limit to marketable order;*
   (d) *proportion of marketable order shares (trading rate) increases and proportion of non-marketable limit order shares decreases; and*
   (e) *fill rate (execution probability) of non-marketable limit order shares increase.*

Prediction 5: Size of Impact From Change in Taker Fee Versus Maker Rebate

5. *If an increase in the taker fee has a larger impact than a commensurate decrease in the maker rebate, then the*
   (a) *bid-ask spread decreases relatively more for taker fee;*
   (b) *trade participation decreases in probability relatively more for taker fee (submits neither a marketable order nor non-marketable limit order);*
   (c) *changes from a non-marketable limit to marketable order occur with a relatively higher probability with taker fee;*
   (d) *proportion of marketable order shares (trading rate) and proportion of non-marketable limit order shares changes relatively more for taker fee; and*
   (e) *fill rate (execution probability) of non-marketable limit order shares increases relatively more for taker fee.*

The model of Colliard and Foucault (2012) does not include a broker. Consequently, an increased maker rebate that is subsidized by the taker fee, causes investors to switch from a marketable sell (buy) to a non-marketable limit sell (buy). As investors post more aggressively priced quotes to increase the probability that the non-marketable limit order executes, they narrow the bid-ask spread until the point where the increase in the taker fee is perfectly offset by a fall in the bid-ask spread. At this point, the proportion of marketable orders or non-marketable limit orders is the same as it was at the moment before the taker fee increased. Since my model features a brokerage commission, the increase in the taker fee is not equal to the absolute value of the decrease in the bid-ask spread; consequently, the fee level affects volume, the proportion of marketable order shares, and the fill rate. The implications from their model, which are different from those of my model are:

Differential Predictions from Colliard and Foucault (2012).

1. *Holding the net fee constant, if the taker fee and maker rebate increase, then the*
   (a) *total trading cost does not change (bid-ask spread plus twice the taker fee);*
   (b) *number of marketable or non-marketable limit order shares does not change;*
   (c) *proportion of non-marketable limit or marketable order shares (trading rate) does not change; and*
   (d) *fill rate does not change.*

In contrast to my model, Brolley and Malinova (2013) feature informed and uninformed investors. Since investors with a relatively large informational advantage will use marketable orders and those with weaker information will use non-marketable limit orders (Kaniel and Liu, 2006; Rosu, 2014), the investors who switch from non-marketable limit to marketable orders when the taker fee and maker rebate increase will be disproportionately uninformed. This implies that the overall price impact of market orders will fall, as the proportion of informed marketable orders declines. Unlike my model, the total trading cost, the bid-ask spread plus twice the commission, decreases when maker rebate increases (holding the net fee constant), because executed non-marketable limit orders face relatively less adverse selection. Since my model does not examine asymmetrically informed investors, the model of Brolley and Malinova (2013) offers two distinctive implications:

Differential Predictions from Brolley and Malinova (2013).

1. *Holding the net fee constant, if the taker fee and maker rebate increase, then the*
   (a) *total trading cost decreases (bid-ask spread plus twice the commission); and*
   (b) *price impact of trades falls.*

1.5 Equilibrium With Multiple Exchanges

Consider the case where the broker can route the order to execute on two different exchanges, 1 and 2. Exchange *j's* net fee is denoted by f_j^N and its fee level is represented by f_J^L. If the broker is indifferent between the two exchanges, it is assumed that the orders are routed to each exchange with equal probabilities.

The investor chooses between a market and limit order, and if relevant, the bid and ask prices to be posted in the limit order book. Once the decision is made by the investor, the order is submitted to the broker.

Suppose exchange 1 has a higher net fee, $f_1^N > f_2^N \geq \omega > 0$. In addition, assume that both exchanges are non-inverted and have the same fee level, $f_1^L = f_2^L > 1$. Consequently, the taker fee is higher on exchange 1 than 2, $f_1^{ta} > f_2^{ta}$. If the broker executes a limit sell (buy) from date $\tau - 1$ against a market buy (sell) submitted at date τ, he pays $f_1^N - f_2^N$ more when the trade occurs on exchange 1 than 2. Moreover, if a market buy (sell) executes against a limit sell (buy) posted by an electronic market maker, the broker pays $f_1^{ta} - f_2^{ta}$ more for a trade cleared on exchange 1 than 2. Since the broker faces perfect competition, all trading will concentrate on exchange 2 with the lowest net fee.

Now suppose that exchange 1 chooses to compete along the fee level dimension. It can decreases its fee level until the point where the platform is inverted and has the same fill rate as exchange 2. Thus, the taker is paid a rebate on exchange 1 in the amount of $|f_1^{ta}|$ (as the taker fee is negative, $f_1^{ta} < 0$), but charged a fee, $f_1^{ta} > 0$, on exchange 2. The broker will minimize its commission by only routing market sells (buys) that execute against quotes posted by electronic market makers to exchange 1. In effect, exchange 1 has increased its profit at the expense of exchange 2, by drawing in select market order flow. At this point, exchange 2 can in turn increase the probability of a market order arriving, and its profit, by reducing its fee level until its taker rebate equals that of exchange 1, $f_1^L = f_2^L < 0$.

This process will continue until the maker fee increases towards the \$0.0030[15] per share boundary and the net fee is reduced to exchange's order processing cost, ω. The maker fee is a binding constraint, because it is used to subsidize the taker rebate. At this point, the broker will route half of the market and limit orders to each exchange. The total trading cost, which represents the cost of trading to takers, is the same on both exchanges. This occurs because exchange 1 and 2 share the same net fee and fee level, and the broker charges the same flat-rate commission to all investors. As a result, in equilibrium the makers will submit limit orders with a high fill rate to exchange 1 and 2. Subsection 1.2 describes the equilibrium states, which happens to be Nash, for exchange 1 and 2. The profit for each exchange is one-half the trading rate multiplied by the difference between the net fee and exchange's order processing cost. That is,

$$\max_{f_j^N,\, f_j^L} \Pi_j \left(f_j^N,\, f_j^L,\, f_{-j}^N,\, f_{-j}^L\, \omega,\, \lambda\right) \equiv \frac{1}{2} \cdot TR\left(f_j^N,\, f_j^L,\, f_{-j}^N,\, f_{-j}^L,\, \omega,\, \lambda\right) \cdot \left(f_j^N - \omega\right). \tag{7}$$

To conclude, it is apparent that the profit an exchange is determined not only by its net fee relative to its competitor but also by its relative fee level.

[15] Largest fee permitted by the Securities and Exchange Commission.

1.6 Welfare Analysis

I examine the effect of the fee level, f^L, and net fee, f^N, on the investors' welfare. Let $W\left(c\left(f^L,\, f^N,\, \lambda\right)\right)$ be the expected ex ante gains from trade for an investor before she learns her type, buyer or seller, and patient or impatient, and whether she chooses to be a maker or taker. The investors' ex ante expected welfare is

$$\begin{aligned} W\left(c\left(f^L,\, f^N,\, \lambda\right)\right) &= W_{base}\left(c\right) - \left(1-\overline{\delta}\left(c\right)\right)\cdot\left[\left(TR\left(c\right)-\varphi_3\left(c\right)-\varphi_6\left(c\right)\right)\right. \\ &\left.\cdot\left(L-2\cdot c+\frac{1}{2}\cdot T^*\left(c\right)\right)+\left(1-TR\left(c\right)-\phi_k\cdot\left(\varphi_1\left(c\right)+\varphi_4\left(c\right)\right)\right)\cdot G^d\right] \end{aligned} \tag{8}$$

where $W_{base}\left(c\right)\equiv\frac{1}{2}\cdot\left(\varphi_3\left(c\right)+\varphi_6\left(c\right)\right)\cdot\left(G^l-S^*\left(c\right)\right)+\left(\varphi_2\left(c\right)+\varphi_5\left(c\right)\right)\cdot G^l+\left(\varphi_1\left(c\right)+\varphi_4\left(c\right)\right)\cdot\left(1-\phi_k\right)\cdot G^d$, and $k\in\{H,\, L\}$. The weighted average of patient and impatient discount factors is $\overline{\delta}\left(c\right)$, $TR\left(c\right)$ is the stationary probability of a match between two investors, and $S^*\left(c\right)$ and $T^*\left(c\right)$ are the equilibrium bid-ask spread and total trading cost, respectively. The likelihood that a patient [impatient] investor chooses to submit a non-marketable limit order, a marketable order that executes against the quotes posted by an investor, or a marketable order that hits the prices posted by an electronic market maker are $\varphi_1\left(c\right),\, \varphi_2\left(c\right)$, or $\varphi_3\left(c\right)$ [$\varphi_4\left(c\right),\, \varphi_5\left(c\right)$, or $\varphi_6\left(c\right)$], respectively.

If the waiting costs are zero, that is, $\delta_L=\delta_H=1$, then $W\left(c\left(f^L,\, f^N,\, \lambda\right)\right)=W_{base}\left(c\left(f^L,\, f^N,\, \lambda\right)\right)$, because the indicator function, $1-\overline{\delta}\left(c\right)$, takes on the value of 0. In other words, the welfare is a weighted average of the gains of trade when a non-marketable limit and marketable order are executed on an exchange and unexecuted non-marketable limit order is cleared in the dealer market. In particular, $\frac{1}{2}\cdot\left(\varphi_3\left(c\right)+\varphi_6\left(c\right)\right)\cdot\left(G^l-S^*\left(c\right)\right)$ is the expected payoff for a marketable order hitting the quotes posted by an electronic market maker, $\left(\varphi_2\left(c\right)+\varphi_5\left(c\right)\right)\cdot G^l$ is the expected payoff to the non-marketable limit and marketable order, if a marketable order executes against a non-marketable order posted by an investor, and $\left(\varphi_1\left(c\right)+\varphi_4\left(c\right)\right)\cdot\left(1-\phi_k\right)\cdot G^d$ is the expected payoff to an unexecuted non-marketable limit order cleared in the dealer market. If $\delta_k<1$, then waiting costs are incurred, and investors' expected welfare is lower than $W_{base}\left(c\left(f^L,\, f^N,\, \lambda\right)\right)$, because the indicator function $1-\overline{\delta}\left(c\right)$ is no longer 0. The second term in Equation 8 represents the cost of a delay, where $\left(TR\left(c\right)-\varphi_3\left(c\right)-\varphi_6\left(c\right)\right)\cdot\left(L-2\cdot c+\frac{1}{2}\cdot T^*\left(c\right)\right)$ is the expected cost from a delay incurred by a non-marketable limit order executing at the exchange and $\left(1-TR\left(c\right)-\phi_k\cdot\left(\varphi_1\left(c\right)+\varphi_4\left(c\right)\right)\right)\cdot G^d$ is the expected cost of a delay from a non-marketable limit order cleared in the dealer market.

Since the investors' welfare is a function of the brokerage commission, and the commission itself is a function of the fee level and net fee, then the investors' welfare is a function of the fee level in contrast to Colliard and Foucault (2012), who argue that the ex ante welfare is not dependent on the split of the net fee between makers and takers. More specifically, an increase in the taker fee and maker rebate, from a boost in the fee level or net fee, will cause the brokerage commission to rise. An increase in the commission will, in turn, decrease the investor's welfare, because the surplus earned by a non-marketable limit or marketable order, conditional on a trade occurring, is lower.

Prediction: Investors' Welfare

1. *Holding the net fee or fee level constant, if the taker fee and maker rebate increase, then the*
   (a) investors' welfare will strictly decrease.

Since the partial derivative of the investors' welfare with respect to the brokerage commission is strictly negative, then the value of the commission that maximizes the investors' ex ante expected welfare in equilibrium must be in the boundary of the welfare function. The SEC has capped taker (maker) fees at \$0.0030 per share. As a result, the fee level is capped in the model and the minimal order processing cost for an exchange, $\omega > 0$, places a floor on the net fee. For a non-inverted [inverted] exchange, where the taker pays a fee [receives a rebate] and the maker receives a rebate [pays a fee], the fee level is in the interval $\left(1, \frac{\$0.0030}{\omega}\right]$ $\left[\left[1 - \frac{\$0.0030}{\omega}, 0\right)\right]$ and the net fee is in the range of $[\omega, \$0.0030)$ $[[\omega, \$0.0030)]$. If the fee level and net fee are exogenous variables, then the smallest brokerage commission that maximizes the investors' welfare in a non-inverted [inverted] exchange occurs when the fee level takes on the value of $1 + \varepsilon$ $\left[1 - \frac{\$0.0030}{\omega}\right]$ and the net fee of ω $[\omega]$, where ε and ω are small and positive real numbers.

Prediction: Value of Fee Level and Net Fee that Maximize Investors' Welfare

1. If the fee level and net fee are exogenous variables, then the investors' welfare is maximized on
   (a) a non-inverted exchange at $f^L = 1 + \varepsilon$ and $f^N = \omega$; and
   (b) an inverted exchange at $f^L = 1 - \frac{\$0.0030}{\omega}$ and $f^N = \omega$.

On the other hand, if the fee level and net fee is chosen endogenously by at least two competing exchanges, then both exchanges will choose to be inverted where the fee level is $1 - \frac{\$0.0030}{\omega}$ and the net fee is ω, as described in Subsection 1.5.

Prediction: Investors' Welfare When Fee Level and Net Fee Are Endogenous

1. If the fee level and net fee are endogenously chosen by the exchange, then the
   (a) fee level and net fee are $1 - \frac{\$0.0030}{\omega}$ and ω, respectively.

2 Data Description, Sample Selection, and Methodology

2.1 Data Description

2.1.1 SEC Rule 605

On November 17, 2000, the Securities and Exchange Commission (SEC) announced that all U.S. market centers must disclose a set of standardized execution quality statistics as outlined in SEC Rule 605 (formerly known as Rule 11Ac1-5) every month. The reports are intended to increase the visibility of execution quality measures to help investors evaluate broker performance, encourage brokers to choose the destination of best execution, and increase competition among exchanges and electronic communications network (ECNs). For each national market system stock and month, the reports provide statistics on measures of order flow, execution speed, and round-trip realized spreads. Round-trip effective spreads are available only for marketable orders.

The realized spread is calculated as twice the difference between the execution price and quote midpoint, five minutes after the time the marketable or non-marketable limit order was received. This measure is available for market orders, marketable limit orders, inside-the-quote limit orders, at-the-quote limit orders, and near-the-quote limit orders, when applicable, and four different order size categories up to 10,000 shares. Five speed buckets from the time of order receipt to execution are given, that specify the number of shares in each category. In addition, the round-trip effective spread is available only for marketable orders. It is defined as twice the difference between the execution price and quote midpoint, as defined by the National Best Bid and Offer, at the time the order was received. Given the realized and effective spread, the quoted spread and price impact can be backed out, but only for marketable limit and market orders. For these order types, SEC Rule 605 provides the amount of price improvement or money outside-the-quote, time from order receipt to execution, and number of shares receiving price improvement or executed outside the quote. The data set also provides the speed of execution and number of shares executing at the quotes. Not all order types are included in the reports. The orders must be held[16]; limit price, if relevant, must be no more than ten cents from the quote; order must be a straight limit or market order[17]; and the order must be for 10,000 or fewer shares.

The SEC Rule 605 data set has strengths and weaknesses relative to other sources. First, critics will argue that SEC Rule 605 does not contain all order flow and may contain inaccurate data. Although the data set does not contain all orders, it does comprise all straight market and limit orders. Thus, it is useful

[16] A market or limit order that must be handled immediately. The floor broker does not have time and price discretion for this order.

[17] Limit order that trades at the stated price or better or market order filled without delay.

in testing my model, because all brokers accept order flow without complicated handling instructions. The SEC has audited the execution quality reports in the past and did fine two market centers, Instinet, LLC and Inet ATS, Inc., in 2005 for alleged inaccuracies (see SEC Release No. 2005-151). My reasoning is that should a market center be suspected of fabricating execution quality statistics that the large brokerages are using, the penalty would be financially catastrophic in that large brokerages would route order flow elsewhere. This is exactly what happened when the New York Attorney General accused Barclays of altering reports provided to clients to mislead them about how a dark pool executed trades. The following day, *The Wall Street Journal* (Hope, June 26, 2014) reported that broker-dealers such as Deutsche Bank, Royal Bank of Canada, and ITG stopped routing orders to Barclays LX at the request of large institutional clients. The *Financial Times* reported that 66 million shares were traded in Barclays's LX pool in the week beginning June 30th, which represents a drop of two-thirds from 197 million in the prior week. In fact, Barclays' dark pool has fallen from second to 12th place in terms of volumes traded in US dark pools (Bullock, July 21, 2014).

Second, SEC Rule 605 spreads are subject to double counting as an order that is routed from one trading venue to another will be reported in reports from both venues. This feature should not harm my analysis as I can perform robustness testing using only those observations that are filled entirely at the receiving venue. This may induce some bias because the proportion of orders routed out is not the same for all exchanges. In addition, Boehmer, Jennings, and Wei (2005) rank market centers trading a sample of NYSE-listed stocks, according to effective spreads reported in the SEC 605 reports and computed using TAQ. They find that any differences in ranking are temporary.

The SEC Rule 605 data set is ideal for testing my model. First, it is the only data set that has order level data across many market centers. The papers by Skjeltorp, Sojli, and Tham (2012) and Cardella, Hao, Kalcheva (2013) use trade and quote level data, which do not provide information on the portion of orders that do not execute. In addition, Skjeltorp, Sojli, and Tham (2012) and Malinova and Park (2014) focus on the NASDAQ OMX BX exchange and The Toronto Stock Exchange, respectively, while only Cardella, Hao, Kalcheva (2013) examine many trading venues. Second, since SEC Rule 605 is actual order level data, the buy and sell indicator is not inferred using the Lee and Ready algorithm (1991) as is the case with trade and quote data used by Cardella, Hao, Kalcheva (2013). Lastly, the SEC Rule 605 data set has been used by a number of other published papers (Boehmer, 2005; Boehmer, Jennings, and Wei, 2007; O'Hara and Ye, 2011).

The data are reported every month by each market center. SEC Rule 605 permits market centers to engage third party auditors to create monthly reports and make them publicly available. To ensure my sample is comprehensive, I downloaded all available flat files from the following third party vendors: TAG, Thomson

Reuters Transaction Analytics, Sungard Financial Systems, and S3. In addition, I collected data from Wharton Research Data Services, Financial Industry Regulatory Authority, NYSE, and NASDAQ. After combining the reports from all sources and removing duplicates, there are 180,563,464 unique observations with valid exchange, market center[18], ticker, date, and order type and size identifiers from March 2001 through December 2011.

2.1.2 Maker-Taker Fees

Traders Magazine features the maker-taker fees posted by exchanges for many months from November 2007 through approximately August 2013. Using exchange and ECN websites, Factiva, and the Internet Archive[19] I was able to double check many of the maker-taker fee schedules for the lit trading venues. Since the SEC must approve any exchange fee changes, all taker fee and maker rebate changes are reported to the Federal Register[20] and Self-Regulatory Organization filings[21] at the SEC. As a result, I was able to collect and verify nearly all maker-taker fees from November 2007 through December 2011. An example of the fees can be seen in Table 1, and the units are in cents per one hundred shares.

Most equity exchanges have introduced tiered pricing according to a customer's share volume and order mix. Investors providing greater liquidity receive more favorable pricing. For every exchange, I collect the base fees that represent the highest fee and smallest rebate. These prices are offered to investors that do not meet minimum thresholds for liquidity provision and volume.

2.2 Sample Selection

Table 3 provides information on the sample selection criteria used. The initial SEC Rule 605 dataset is matched to CRSP by the ticker symbol and date. Only 6.63% of the SEC Rule 605 sample is unable to be linked. Of the remainder, I retain those observations related to common stocks (with share codes 10 and 11). In addition, all stocks having a mean closing price less than $1 or greater than $1,000 are eliminated; this eliminates a further 3.4% of the sample.

I then run a series of logical tests on the variables to ensure that the data set is internally consistent. If an observation is incomplete or has negative values in variables that are defined as being non-negative I delete the observation. Through this cleaning process 7.4% of the sample is eliminated. The New York Stock Exchange began offering maker rebates to all investors as of March 1, 2009. As a consequence, I restrict the sample to the period from March 2009 through December 2011. After eliminating AMEX-listed

[18] Defined in SEC Rule 600(b)(38) as "any exchange market maker, OTC market maker, alternative trading system, national securities exchange, or national securities association."

[19] archive.org.

[20] www.federalregister.gov

[21] www.sec.gov/rules/sro.shtml

stocks and non-lit market centers, such as dark pools and over-the-counter dealers, I have a sample of 16,783,863 observations containing 1,477 and 2,759, NYSE-listed and NASDAQ-listed securities (see Table 6), respectively. I focus on stocks listed on these two exchanges, as the number listed on AMEX is relatively small. The list of trading venues included appears in Table 1. The number of stocks featured in each panel regression is a function of the control variables included in the specification. Stocks are excluded from a particular regression when data are unavailable for at least one of the control variables.

Table 4 provides the percentage of orders, shares, and executed shares by exchange. For NYSE-listed stocks, BATS BZX receives 14.60% of all shares and executes 11.22% of the total share volume. Even though NASDAQ only takes in 4.94% of all shares, it manages to clear 10.85% of traded shares from all exchanges. This is same pattern holds true for NASDAQ-listed shares as well. Tables 5A and 5B provide statistics on the fraction of shares executed at the receiving venue, routed away for execution, cancelled, or unaccounted for as well as the dollar quoted and effective spread of marketable orders. The number of shares cancelled or unaccounted for in the "other" category varies according to the order types permitted at an exchange, order type mix chosen by investors, and accounting methodology used by the exchange. For instance, BATS requires all marketable orders to be immediate or cancel[22] (IOC). In Table 5A, 48.80% of the shares from market orders submitted to BATS BZX are in the other category; this suggests that a large portion of the orders have instructions not to route out. Similarly, Direct Edge offers different types of market orders on EDGA and EDGX, many of which are non-routable, and expire once any portion of the order does not fill.

The effective spread is the non-commission out-of-pocket costs an investor incurs when trading with a marketable order. The dollar realized spread is calculated for at-the-quote limit orders, and reflects the temporary component of the spread that is the expected profit to the liquidity provider. The price impact is estimated for marketable orders and represents the part of the spread earned by an informed trader. For example, according to Table 5A over 96% of non-marketable limit order shares are cancelled at the NYSE. Approximately 2.64% of shares are executed at the exchange, 0.01% are routed to other venues for execution, and 1.32% are in the other category. Over 59% of marketable limit orders are cancelled at the NYSE but only 0.18% of market orders are. However, 31.61% of the market orders are routed and executed elsewhere. This strongly suggests that many of the marketable limit order types chosen by investors are non-routable.

In addition, consistent with my theory and that of Colliard and Foucault (2012), BATS BZX, which is known for offering generous rebates to liquidity providers, has the narrowest effective spread at $0.0057 for NYSE-listed stocks. The relatively small share-weighted average effective spread for NYSE-listed stocks traded on BATS BZX is consistent with 30.2% of market orders receiving $0.0102 of price improvement on average and only 3.3% of shares executing outside-the-quote, respectively. Table 6 supplies descriptive

[22] IOC orders are executed immediately. If an IOC order is partially executed, the remainder will be cancelled immediately.

statistics on stocks included in the analysis. All data are taken from CRSP. As expected, the NYSE-listed stocks are for larger firms, having more turnover and volume, than NASDAQ-listed stocks. The latter stocks have a smaller median return and greater variance.

2.3 Empirical Methodology

2.3.1 Regression Specification 1: Bid-Ask Spread, Price Impact, or Fill rate

This paper presents the results for four regression specifications. In the first regression, the dependent variable is a spread measure or fill rate of a non-marketable limit order. The stock-level control variables that I use are lagged from the prior month and include the log of the mean daily closing price, share turnover (volume of shares in month scaled by number of shares outstanding), and the variance of the daily return (Hendershott, Jones, and Menkveld, 2011; Hendershott and Moulton, 2011; Malinova and Park, 2014; Stoll, 2000).

Motivation for Interaction Term in Regression Specification

Colliard and Foucault (2012) argue that in the absence of frictions only changes in the net fee affect liquidity and trading volume. My model predicts that the fee level also affects the liquidity and trading volume for a subset of investors that pay a flat-rate brokerage commission. In order to test the implications of my theoretical model, I need to differentiate between the effects of the fee level and net fee on the respective dependent variable. An equity exchange chooses its prices for liquidity suppliers and demanders, respectively, and charges a taker fee and pays a maker rebate to the broker. For each month and exchange, I calculate the fee level and net fee from the taker fee and maker rebates. The net fee and fee level are defined as the taker fee less the maker rebate and the taker fee divided by the net fee, respectively.

The taker fee or maker rebate, selected by an equity exchange, represents an interaction between the fee level and net fee. The investor decides whether to trade, her order type, and quotation strategy, if relevant, based on the brokerage fee which is a weighted average of the exchange and dealer fees. The precise effect of the taker fee on the investor's decision to make or take liquidity depends on the maker rebate. As a result, the investor's choice is impacted by not only the fee level and net fee but how these two variables interact to provide a taker fee and maker rebate pair. An investor's perception of a given net fee, depends on its relative size, but also how heavy a burden it represents to liquidity demanders. For a given net fee, a relatively small fee level implies a small taker fee and maker rebate but a relatively large fee level represents a huge hit for liquidity demanders and benefit to liquidity suppliers (conditional on non-marketable limit order executing).

For example, if the net fee is \$0.0004 and the fee level is 1.25, then the taker fee is \$0.0005 and the maker rebate is \$0.0001 (a maker fee of -\$0.0001). However for the same exact net fee, if the fee level increases to 7.50 then the taker fee is \$0.0030 and the maker rebate is \$0.0026 (a maker fee of -\$0.0026). That is, for the same exact net fee, the taker fee increases by 500% and maker rebate increases (maker fee decreases) by 96.15% for a 6.25 increase in the fee level. To state this differently, the interaction of fee level and net fee determines how the exchange trading cost is distributed across both sides of the market.

This intuition from the model is corroborated by the data. Figure 2 shows that the slope between the share-weighted average effective spread and net fee (fee level) varies according to the value of the fee level (net fee). The same is also true of the relationship between share-weighted average effective spread and the taker or maker rebate in Figure 3. To summarize, my theoretical model and data suggest that the regression function should not be assumed to be linear. In the empirical analysis that follows only exchanges offering a taker fee and maker rebate are included.

Since the interaction effect of the fee level and the net fee have a differential impact on the dependent variable, I center the control and fee variables on the mean and scale them by dividing by two standard deviations. The resulting coefficients are then easier to interpret and on the same scale as the untransformed dummy predictors (Gelman, 2008). For each measure I estimate

$$DV_{i,t,z} = \alpha + \beta_1 f^L_{t,z} + \beta_2 f^N_{t,z} + \beta_3 \left(f^L_{t,z} \cdot f^N_{t,z} \right) + \sum_{l=2}^{2\,or\,3} \kappa_l Type_{i,t,z} + \sum_{m=2}^{4} \gamma_m Size_{i,t,z} + \sum_{k=1}^{3} \delta_k X_{i,t-1,k} + \varepsilon_{i,t,z} \quad (9)$$

where $DV_{i,t,z}$ is the effective, quoted or realized spread, effective or quoted spread plus two times the taker fee, realized spread plus two times the maker rebate, price impact, or the fill rate of limit order shares including cancelled shares for stock i on month-year t at trading venue z; $f^L_{t,z}$ is the fee level assigned by the executing venue, z, on month-year t; $f^N_{t,z}$ is the net fee charged by the executing venue, z, on month-year t; $\left(f^L_{t,z} \cdot f^N_{t,z} \right)$ is the corresponding interaction term from executing venue, z, on month-year t; $Type_{i,t,z}$, represents a dummy variable for the order type for stock i on month-year t at trading venue z; $Size_{i,t,z}$ is a dummy variable for the order size bucket associated with stock i on month-year t at trading venue z; $X_{i,t-1,k}$ represents the security-level control variables for stock i on month-year t at trading venue z; and α is an intercept.

In those regressions having dummy variables for order type, if the underlying observations are marketable orders, a dummy for marketable limit orders appears (the one for market orders is dropped), and when the underlying data are composed of non-marketable limit orders, dummies are provided for at-the-quote and near-the-quote limit orders (the one for inside-the-quote is dropped). Similarly, regressions containing order size drop the dummy for the 100-499 shares bucket, and include dummies for 500-1,999 shares, 2,000-4,999 shares, and 5,000 or more shares categories. In addition, the effective, quoted, and realized spread, price impact, and fill rate are only estimated from shares executed at the receiving venue or not routed away.

Coefficient Signs Corresponding to Model Predictions

First, Prediction 1a (3a) of my model indicates that when the dependent variable is the effective or quoted spread (fill rate) that the effect for the fee level and net fee are will be negative (positive) and the coefficient for the interaction term will be statistically significant. The model only has predictions for the effect of the fee level or net fee, but not for coefficient sign of the interaction term in isolation. An increase in the taker fee and maker rebate, will be associated with a declining spread and an increasing fill rate.

Second, in the model of Colliard and Foucault (2012), the total trading cost represents the difference between the price paid by a marketable buy and the price received for a marketable sell and is proxied by the share-weighted average effective or quoted spread plus two times the taker fee in the model of Colliard and Foucault (2012). Evidence consistent with Differential Prediction 1a from their model would be a positive and statistically significant coefficient for the net fee and a coefficient for the fee level that is not statistically different from zero. The coefficient for the interaction term will be statistically significant. If the coefficient for the fee level is statistically different from zero, then I have identified evidence that contradicts their model.

Third, Differential Prediction 1b from Brolley and Malinova (2013) predicts that when the dependent variable is price impact, the coefficient for the net fee and fee level should be negative and statistically significant. The realized spread or the realized spread plus two times the maker rebate are proxies for the profit, net of losses to informed traders, to electronic market makers having direct market access. If adverse selection falls, then a positive coefficient for the net fee or fee level when the dependent variable is the realized spread or the realized spread plus two times the maker rebate serves to confirm the implication of Brolley and Malinova (2013). However, if the coefficient for the net fee or fee level is zero or negative and statistically significant, then I cannot confirm that price impact fell and liquidity providers do not benefit from interacting with less informed traders.

Interpreting Interactions Between Two Continuous Variables

Interpreting interaction effects between continuous variables is difficult. From Equation 9, I observe the the effect of the fee level (net fee), $f^L_{t,z}$ $\left(f^N_{t,z}\right)$, on the dependent variable is $\beta_1 + \beta_3 f^N_{t,z}$ $\left(\beta_2 + \beta_3 f^L_{t,z}\right)$, where $f^N_{t,z}$

$\left(f^N_{t,z}\right)$ represents a given net fee (fee level). The continuous independent variables are mean centered[23] and then the interaction term is computed. This has two effects (Aiken and West, 1991; Jaccard and Turrisi, 2003; Stock and Watson, 2011). First, it reduces the correlation between the fee level or net fee and the interaction term. For example, the correlation between the mean centered net fee (fee level) and the interaction term is 3.8% (−57.6%). Second, it will not change what the model predicts but will make the coefficients more interpretable.

When the net fee is centered at its mean value it takes on a value of zero in expectation. Thus Equation 9 becomes

$$DV_{i,t,z} = \alpha + \beta_1 f^L_{t,z} + \beta_2 \cdot 0 + \beta_3 \left(f^L_{t,z} \cdot 0\right) + \sum_{l=2}^{2\ or\ 3} \kappa_l Type_{i,t,z} + \sum_{m=2}^{4} \gamma_m Size_{i,t,z} + \sum_{k=1}^{3} \delta_k X_{i,t-1,k} + \varepsilon_{i,t,z} \tag{10}$$

$$DV_{i,t,z} = \alpha + \beta_1 f^L_{t,z} + \sum_{l=2}^{2\ or\ 3} \kappa_l Type_{i,t,z} + \sum_{m=2}^{4} \gamma_m Size_{i,t,z} + \sum_{k=1}^{3} \delta_k X_{i,t-1,k} + \varepsilon_{i,t,z} \tag{11}$$

where a one unit increase in the fee level produces on average a β_1 increase in the dependent variable when the net fee is at zero. The statistical software will identify whether β_1 is statistically different from zero. Only at this point, can I interpret β_1 as an unconditional relationship between the fee level and the dependent variable in the presence of the interaction term.

Suppose we run the regression in Equation 9 where the dependent variable is the share-weighted average effective spread. Given the mean value and 0th, 25th, 50th, 75th, and 100th percentiles for the fee level and net fee, I can graph the effective spread against the net fee (fee level), while holding the fee level (net fee) constant. In Figure 4A, I notice that the slope between the effective spread and net fee is negative and constant for a given value of the fee level but changes when moving from one fee level to another. In addition, the slope of all five lines is negative, which is consistent with Prediction 1a of my model. Figure 4B demonstrates that the linear functions for different values of the net fee may intersect. Note that only four percentiles appear because the 75th (0th) and 100th (25th) percentiles are the same for the fee level (net fee). The linear functions in Figures 4A and 4B are calculated for percentiles, instead of deviations from the mean, because the fee level and net fee are not normally distributed.

2.3.2 Regression Specification 2: Number or Proportion of Order Type Shares

The second specification is similar to the first one but with three differences. First, the dependent variables, $DV_{i,t,z}$, are the log number of marketable order shares submitted excluding cancelled shares, log number

[23] The corresponding mean is subtracted.

of non-marketable limit order shares submitted excluding cancelled shares, log sum of the number of marketable and non-marketable limit order shares submitted excluding cancelled shares, and the proportion of marketable order shares submitted excluding cancelled shares. Second, in addition to the stock-level control variables previously described there are two additional control variables that are lagged values from the prior month. The first control variable is the share-weighted average effective spread for the stock in the prior month across all exchanges. The second control variable is the mean absolute value of the daily stock return in the prior month. It should be associated with the number of marketable orders when momentum traders are active. Third, this specification does not contain dummy variables for order type or size.

The specification is

$$DV_{i,t,z} = \alpha + \beta_1 f^L_{t,z} + \beta_2 f^N_{t,z} + \beta_3 \left(f^L_{t,z} \cdot f^N_{t,z}\right) + \sum_{k=1}^{5} \delta_k X_{i,t-1,k} + \varepsilon_{i,t,z} \tag{12}$$

where $DV_{i,t,z}$ represents the four dependent variables just described; $f^L_{t,z}$ is the fee level assigned by the executing venue, z, on month-year t; $f^N_{t,z}$ is the net fee charged by the executing venue, z, on month-year t; $\left(f^L_{t,z} \cdot f^N_{t,z}\right)$ is the corresponding interaction term from executing venue, z, on month-year t; $X_{i,t-1,k}$ represents the five security-level control variables for stock i on month-year t at trading venue z; and α is an intercept. Since the proportion of marketable order shares is a proportion between zero and one, a logistic transformation is applied to this response variable so that a more linear relationship exits with the explanatory variables.

Prediction 2a of my theoretical model predicts that when the dependent variable is the log number of non-marketable limit or marketable order shares submitted excluding cancelled shares or the log sum of the number of marketable and non-marketable limit order shares submitted excluding cancelled shares, the effect for the fee level and net fee will be negative and the coefficient for the interaction term will be statistically significant. As the taker fee and maker rebate increase, the brokerage commission rises and an investor paying the commission is more likely to decide not to trade.

In addition, Prediction 2b - 2c implies that if the dependent variable is the proportion of marketable order shares submitted excluding cancelled shares, then the effect for the fee level and net fee will be positive and the coefficient for the interaction term will be statistically significant. When the taker fee and marker rebate increases, investors paying a brokerage commission are less likely to trade and more likely to switch from using a non-marketable limit order to a marketable order.

2.3.3 Regression Specification 3: Bid-Ask Spread or Fill Rate

The third specification is used to test whether a maker or taker fee has a differential impact on the dependent variable. This set-up is the same as the first specification except that the fee level and net fee are replaced with the maker and taker fees, respectively. For each outcome variable I estimate

$$DV_{i,t,z} = \alpha + \beta_1 f_{t,z}^{ma} + \beta_2 f_{t,z}^{ta} + \beta_3 \left(f_{t,z}^{ma} \cdot f_{t,z}^{ta}\right) + \sum_{l=2}^{2\,or\,3} \kappa_l Type_{i,t,z} + \sum_{m=2}^{4} \gamma_m Size_{i,t,z} + \sum_{k=1}^{3} \delta_k X_{i,t-1,k} + \varepsilon_{i,t,z} \quad (13)$$

where $DV_{i,t,z}$ is the effective or quoted spread or the fill rate including cancelled shares for stock i on month-year t at trading venue z; $f_{t,z}^{ma}$ is the maker fee assigned by the executing venue, z, on month-year t; $f_{t,z}^{ta}$ is the taker fee charged by the executing venue, z, on month-year t; $\left(f_{t,z}^{ma} \cdot f_{t,z}^{ta}\right)$ is the corresponding interaction term from executing venue, z, on month-year t; $Type_{i,t,z}$, represents a dummy variable for the order type for stock i on month-year t at trading venue z; $Size_{i,t,z}$ is a dummy variable for the order size bucket associated with stock i on month-year t at trading venue z; $X_{i,t-1,k}$ represents the three security-level control variables for stock i on month-year t at trading venue z; and α is an intercept.

The primary implication that my theoretical model has when the dependent variable is the effective or quoted spread (Prediction 5a) or the fill rate (Prediction 5e) is an increase in the taker fee has a larger impact than a commensurate decrease in the maker rebate (increase in the maker fee), and the coefficient for the interaction term will be statistically significant. The F-test or Chi-square test will indicate whether the effect of the maker fee, when the mean centered taker fee is at its mean value of zero in expectation, is less influential than the taker fee, when the centered maker fee is at its mean value of zero in expectation. The F-test assumes errors are distributed normally, whereas the Chi-square test assumes errors are heteroscedastic. In addition, Prediction 4a (4e) forecasts that an increase in the maker fee or taker fee will be associated with a decrease (increase) in the bid-ask spread (fill rate) since the brokerage commission will increase.

2.3.4 Regression Specification 4: Number or Proportion of Order Type Shares

The fourth specification is used to test whether a maker or taker fee has a differential impact on the number of shares by order type or the proportion of marketable order shares submitted. This set-up is the same as the second specification except that the fee level and net fee are replaced with the maker and taker fees, respectively. The specification is

$$DV_{i,t,z} = \alpha + \beta_1 f_{t,z}^{ma} + \beta_2 f_{t,z}^{ta} + \beta_3 \left(f_{t,z}^{ma} \cdot f_{t,z}^{ta}\right) + \sum_{k=1}^{5} \delta_k X_{i,t-1,k} + \varepsilon_{i,t,z} \quad (14)$$

where $DV_{i,t,z}$ represents the five dependent variables described for specification two; $f^{ma}_{t,z}$ is the maker fee assigned by the executing venue, z, on month-year t; $f^{ta}_{t,z}$ is the taker fee charged by the executing venue, z, on month-year t; $\left(f^{ma}_{t,z} \cdot f^{ta}_{t,z}\right)$ is the corresponding interaction term from executing venue, z, on month-year t; $X_{i,t-1,k}$ represents the three security-level control variables for stock i on month-year t at trading venue z; and α is an intercept.

Predictions 5b - 5d of my model indicate that when the dependent variable is the log number of non-marketable limit or marketable order shares submitted excluding cancelled shares, the log sum of the number of marketable and non-marketable limit order shares submitted excluding cancelled shares, or the proportion of marketable order shares submitted excluding cancelled shares, an increase in the taker fee has a larger impact than a commensurate decrease in the maker rebate (that is, an increase in the maker fee), and the coefficient for the interaction term will be statistically significant. The F-test or Chi-square test will indicate whether the effect of the maker fee, when the centered taker fee is at its mean value of zero in expectation, is less influential than the taker fee, when the centered maker fee is at its mean value of zero in expectation. The F-test assumes errors are distributed normally, whereas the Chi-square test assumes errors are heteroscedastic. In addition, an increase in the maker fee or taker fee will be associated with a decrease in the number of shares submitted for all order types (Prediction 4b), since the brokerage commission increases, and an increase in the proportion of marketable order shares (Predictions 4c and 4d), because an investor is more likely to switch to a marketable order from a non-marketable limit order.

2.3.5 All Regression Specifications

As a reminder, any independent variables that are stock-level control variables, maker-taker fees, or estimated from these fees are standardized by subtracting the mean and dividing the difference by two times the standard deviation. All panel regressions include exchange and time fixed effects. The standard errors in all cases are corrected for heteroscedastic residuals using White's heteroscedasticity-consistent estimator. For brevity, the coefficients of the time and exchange dummies are not reported.

3 Empirical Analysis

These analyses examine the base fees for non-inverted trading venues, where the maker receives a rebate and the taker pays a fee, and the net fee is positive. The March 2009 through December 2011 window is chosen because all exchanges use maker-taker pricing for base fees.

3.1 *Is the bid-ask spread affected by a change in the taker fee and maker rebate?*

I concentrate on two measures of the spread: quoted and effective spread. For marketable orders, SEC Rule 605 provides the share-weighted average effective spread, amount prices were inside the quote (price improvement) and outside the quote. The number of shares for in each of these categories is provided along with the number of shares executed at-the-quote. Given this data, I re-construct the share-weighted average quoted spread for each stock by month and exchange, and if relevant, by marketable order type and size.

The effective spread represents the non-commission cost of trading with a marketable order, and the quoted spread, represents the advertised cost of trading if the liquidity provider is an investor submitting a non-marketable limit order (that is, not a market maker). The quoted spread is inferred only when a trade executes. When the dependent variable is the quoted spread no order type or size dummies are used, as the posted quotes may be hit by any size market or marketable limit order; however, orders having a size greater than that of the associated quote will not completely fill.

When the net fee (fee level) is at its mean value of zero in expectation, -0.06563 (-0.05898) is the effect of a one unit increase in the fee level (net fee) on the quoted spread in Column 1 of Table 7. Both coefficients are statistically significant at the 0.01% level. The coefficients of the log closing price, turnover, and variance of daily return have signs consistent with the literature and the first two are statistically significant at the 0.01% level and the last one at the 1.0% level. When the effective spread is the dependent variable, the coefficient of the fee level (net fee) is negative and statistically significant if the net fee (fee level) is at its mean. This is very strong evidence in support of Prediction 1a from my model and is also an implication of Colliard and Foucault (2012), that the bid-ask spread decreases when the fee level or net fee increases. It should be noted that the coefficients of the size bucket dummies are negative. The sign is counterintuitive but suggests that investors submitting relatively larger orders are executing them when the effective spread is relatively narrow. From these two regression I conclude that an exchange can adjust its bid-ask spread by raising or lowering the fee level or net fee.

3.2 *Is the volume of shares or proportion of marketable order shares impacted by an increase in the taker fee and maker rebate?*

In Columns 1 and 2 of Table 8, the coefficient of the fee level (net fee) is negative and statistically significant for the number of non-marketable limit or marketable order shares when the net fee (fee level) is at its centered mean value of zero. The same pattern holds when the dependent variable is the total number of non-marketable limit and marketable order shares in Column 3. Since the coefficients of the fee level and net fee are of a larger magnitude when the dependent variable is the log number of non-marketable limit than marketable order shares, the decrease in the number of non-marketable limit order shares is relatively greater.

Before running the regression in Column 4, I linearize the relationship between the proportion of marketable order shares and independent variables, by performing a logit transformation on the proportion as it is bounded zero and one. When the net fee (fee level) is at its mean centered value of zero, the coefficient of the fee level (net fee) is positive and statistically significant when the dependent variable is the proportion of marketable order shares submitted. This evidence is consistent with Prediction 2b of my model that investors are more likely to switch to a marketable order from a non-marketable limit order when the net fee increases. Note that the four dependent variables exclude cancelled shares. The results do not appear to be subject to endogeneity, because the conclusions do not change when the regressions are re-run using variables including the number of cancelled shares.

3.3 *Does an increase in the taker fee and maker rebate increase the probability that a non-marketable limit order executes?*

Table 9 presents the results of the panel regression for the fill rate. I perform a logit transformation on the fill rate, a proportion bounded zero and one, in order to linearize the relationship between it and the independent variables. I observe that the coefficient of the fee level (net fee) is positive and statistically significant at the 0.01% level, when the net fee (fee level) is at its expected value. Consequently, an increase in the fee level (net fee) is associated with a higher fill rate. This result is consistent with the finding in Subsection 3.2 that the fraction of marketable order shares increases when the taker fee and maker rebate increase, because a non-marketable limit buy (sell) can only execute if a marketable sell (buy) arrives in the following time period.

Evidence that the fee level affects the fill rate suggests that an exchange may effect the state of the equilibrium by adjusting the fee level independent of the net fee. In addition to Prediction 3a of my model, this finding is also consistent with the implication from Foucault, Kadan, and Kandel (2013), that an investor's monitoring intensity can be influenced by an adjustment in the fee level. The order type dummy does not appear as an independent variable, because the underlying data are for at-the-quote limit orders only. The conclusion drawn from this regression does not change, if cancelled shares are excluded from the fill rate. I include the cancelled shares, because it reduces the fill rate, and consequently makes rejecting the null hypothesis, that the fill rate coefficient is not statistically different from zero, more challenging to overturn.

3.4 *Does an increase in the taker fee and maker rebate change the total trading cost?*

Table 10 describes the regression result when the total trading cost as defined by Colliard and Foucault (2012) is the dependent variable. Recall that this total trading cost has a different definition than the one in my model. Columns 1 and 2 report that the coefficient for the fee level (net fee) is negative and statistically significant at the 0.01% level, when the net fee (fee level) is at its expected value. These findings contrast with Differential Prediction 1a from the model by Colliard and Foucault (2012). In addition, another implication from their work is an increase in the taker fee should cause the total trading cost to rise. However, I find that the coefficient of the net fee is negative instead of positive. This fact suggests that the fall in effective spread more than compensates for the increase in the taker fee. Such an outcome clearly benefits investors with direct market access using marketable orders.

3.5 *Does an increase in taker fee have a larger impact on execution quality measures than a commensurate decrease in the maker rebate?*

In Table 11, the coefficient for the taker (maker) fee is statistically significant and negative when the maker (taker) fee is held at it expected value. In contrast to Prediction 5a of my model the difference between the taker and maker fees is not statistically different from zero when the taker or maker fee is at its respective expected value. One reason I might not find that the taker fee is more influential than the maker rebate, could be because exchanges reduce the fee level when increasing the net fee. If the taker fee is in fact more influential than the maker rebate, an exchange might reduce the fee level whenever it increases the net fee to prevent the taker fee from rising more. In fact, the correlation between the net fee and fee level is -83.8%.

From Table 12, I observe that the coefficient for the maker (taker) fee is negative and statistically significant when the dependent variable is the number of shares of marketable, non-marketable, or total orders and the taker (maker) fee is held at its expected value. According to the F and Chi-square tests the maker fees are larger in magnitude than the taker fees for these regressions in contrast to the Prediction 5b. In Column 4, the coefficient of the maker (taker) fee is not statistically different from zero when the taker (maker) fee is at its expected value. In addition, the maker fee is larger in absolute value than the taker fee. These findings contradict Predictions 4d and 5d, respectively.

My model assumes that the net fee is positive and the fee level is greater than one under a non-inverted pricing structure. Aside from the fact that the taker fee is positive and the maker receives a rebate, no other restrictions are assumed. In the real world, the SEC restricts the taker fee from being no larger than \$0.0030. For the time period of interest, the mean taker fee is \$0.0028 and the median and mode values are

\$0.0030. This implies that many equity exchanges have set their taker fees near the largest permissible value and are unable to increase this fee much further. In fact, the standard deviation of the taker or maker fee is 3.833×10^{-4} or 4.988×10^{-4}, respectively, which means that the taker fee varies relatively less.

Table 13 shows that when fill rate (including cancelled shares) is regressed on the maker (taker) fee the coefficient is positive and statistically significant when the taker (maker) fee is at its expected value. In addition, the taker fee is larger than the maker fee in absolute value and is statistically significant. These results together confirm Predictions 4e and 5e of my model. The regressions found in Tables 12 and 13 are re-run using the dependent variables that include the number of cancelled shares; the conclusions do not change.

3.6 *Does the an increase in the taker fee and maker rebate reduce the informational content of orders?*

The effective spread can be broken-up into two parts called the realized spread and price impact, respectively. Since SEC Rule 605 provides the share-weighted average realized spread and effective spread, the share-weighted average price impact can be calculated as the effective less the realized spread for a given stock, exchange, and month.

In Column 1 of Table 14, the coefficient of the fee level (net fee) is negative and statistically significant at the 0.01% level when the net fee (fee level) is at its expected value. This is consistent with Differential Prediction 1b from Brolley and Malinova (2013). The result is somewhat surprising because in reality much of the uninformed order flow that brokers receive will be internalized or sold to third market dealers. In Columns 2 and 3, I observe that the fee level or net fee is negatively associated with the realized spread for non-marketable limit orders or at-the-quote limit orders only, respectively. If the price impact is in fact declining when the fee level or net fee increases, the value of the fall in adverse selection is not being captured by liquidity suppliers.

When the dependent variable is the realized spread plus twice the maker rebate, the coefficient for the fee level (net fee) is negative and statistically significant when the net fee (fee level) is at its expected value. This implies that the fall in the realized spread is large enough not to be offset by the higher maker rebate when the fee level or net fee rises. This situation could arise if electronic market makers face nearly perfect competition. This empirical finding contrasts with that of Malinova and Park (2014), who find that revenues to liquidity providers with direct market access increase. My empirical findings suggest that an increase in the taker fee and maker rebate, does not redistribute welfare from informed investors to liquidity suppliers having direct market access, such as electronic market makers.

4 Conclusion

I develop a theoretical model of make-taker fees in the presence of a broker and equity exchanges and test the model empirically using order level data from SEC Rule 605. My primary objective is to determine whether a change in the taker fee and maker rebate impacts investor behavior and trading outcomes. Malinova and Park (2014) find empirical evidence consistent with Colliard and Foucault (2012) and Angel, Harris, and Spatt (2011) that only the amount booked by exchanges affects the total trading costs to liquidity takers and an increase in the fee level[24] is completely offset by a decrease in the bid-ask spread. I find empirical evidence that changes in the fee level affect the total trading cost as defined by Colliard and Foucault (2012), and consequently, change investor order choice decisions. In fact, an increase in the taker fee and maker rebate encourages investors using brokers to reduce market participation and choose a marketable order instead of a non-marketable limit order. In contrast to Malinova and Park (2014), I discover strong evidence that as the taker fee and marker rebate increase, holding constant the fee retained by the exchange, that the fill rate actually increases. Non-marketable limit order investors will post more aggressive prices in order to increase the probability of execution. This in turn, will increase the expected profit of the liquidity provider.

My model provides intuition for why Cardella, Hao, and Kalcheva find evidence that a change in the taker fee has a stronger effect than a change in the maker fee on share volume and bid-ask spread. In contrast, I find empirical evidence that the maker rebate has a bigger impact than the taker fee on the number of non-marketable limit, marketable, or total order shares submitted. In contrast, the taker fee is associated with a larger change in the fill rate compared to the maker rebate.

The model of Brolley and Malinova (2013) predicts that the price impact of market orders submitted by investors using a broker decreases as the taker fee and maker rebate increase. The evidence from my regressions suggests that realized spreads decline and that the loss to liquidity suppliers not using a broker is not offset by the higher rebates. There is evidence that the price impact of marketable orders decline. However if this occurs the liquidity suppliers having direct market access are unable to benefit from the fall in adverse selection. These findings are in contrast to Malinova and Park (2014), who find that price impact falls and the gain from less adverse selection is captured by liquidity providers through the larger realized spread plus twice the maker rebate.

These results suggests that the taker fee and maker rebate affect the total trading cost even after controlling for the amount of the fee booked by exchanges as profit. In effect, this evidence supports the prediction from my model that the change in the bid-ask spread does not adjust to perfectly offset the change in the taker fee and maker rebate. This is the essential message derived out of my model and is in contrast to that

[24] An increase (fall) in the fee level will increase (decrease) the taker fee and maker rebate, holding constant the dollar amount of the fee booked by the exchange as profit. The fee level determines the degree to which the takers subsidize the maker rebates.

of Colliard and Foucault (2012). In addition, this empirical analysis is the only one that finds evidence of an association between adjustments in the fee level and changes in investor order choice, trading rate, and execution probability of non-marketable limit orders.

References

Aiken, L. S., and S. G. West. 1991. *Multiple regression: Testing and interpreting interactions*. Newbury Park, CA: Sage Publications.

Angel, J. J., L. E. Harris, and C. S. Spatt. 2011. Equity trading in the 21st century. *Quarterly Journal of Finance* 01:1–53.

Battalio, R. H., S. A. Corwin, and R. H. Jennings. 2014. Can brokers have it all? On the relation between make take fees and limit order execution quality. *Available at SSRN: http://ssrn.com/abstract=2367462* .

Boehmer, E. 2005. Dimensions of execution quality: Recent evidence for U.S. equity markets. *Journal of Financial Economics* 78:553–82.

Boehmer, E., R. Jennings, and L. Wei. 2007. Public disclosure and private decisions: Equity market execution quality and order routing. *Review of Financial Studies* 20:315–58.

Brolley, M., and K. Malinova. 2013. Informed trading and maker-taker fees in a low-latency limit order market. *Available at SSRN: http://ssrn.com/abstract=2178102* .

Bullock, N. July 21, 2014. Barclays' 'dark pool' trades dry up after high-frequency suit in us. *Financial Times* .

Cardella, L., J. Hao, and I. Kalcheva. 2013. Make and take fees in the U.S. equity market. *Available at SSRN: http://ssrn.com/abstract=2149302* .

Colliard, J.-E., and T. Foucault. 2012. Trading fees and efficiency in limit order markets. *Review of Financial Studies* 25:3389–421.

Darroch, J. N., and E. Seneta. 1965. On quasi-stationary distributions in absorbing discrete-time finite markov chains. *Journal of Applied Probability* 2:88–100.

Duffie, D., N. Gârleanu, and L. H. Pedersen. 2005. Over-the-counter markets. *Econometrica* 73:1815–47.

Foucault, T., O. Kadan, and E. Kandel. 2013. Liquidity cycles and make/take fees in electronic markets. *The Journal of Finance* 68:299–341.

Gelman, A. 2008. Scaling regression inputs by dividing by two standard deviations. *Statistics in medicine* 27:2865–73.

Goettler, R. L., C. A. Parlour, and U. Rajan. 2005. Equilibrium in a dynamic limit order market. *The Journal of Finance* 60:2149–92.

———. 2009. Informed traders and limit order markets. *Journal of Financial Economics* 93:67 – 87.

Hendershott, T., C. M. Jones, and A. J. Menkveld. 2011. Does algorithmic trading improve liquidity? *The Journal of Finance* 66:1–33.

Hendershott, T., and P. C. Moulton. 2011. Automation, speed, and stock market quality: The NYSE's hybrid. *Journal of Financial Markets* 14:568–604.

Hollifield, B., R. A. Miller, and P. Sandås. 2004. Empirical analysis of limit order markets. *Review of Economic Studies* 71:1027–63.

Hope, B. June 26, 2014. Major brokers cut ties to Barclays' dark pool. *The Wall Street Journal* .

Jaccard, J., and R. Turrisi. 2003. *Interaction effects in multiple regressions*. No. 07-072 in Sage University Papers Series on Quantative Applications in Social Sciences, 2nd edition ed. Thousand Oaks, CA: Sage Publications.

Kaniel, R., and H. Liu. 2006. So what orders do informed traders use? *The Journal of Business* 79:1867–913.

Lee, C., and M. J. Ready. 1991. Inferring trade direction from intraday data. *The Journal of Finance* 46:733–46.

Malinova, K., and A. Park. 2014. Subsidizing liquidity: The impact of make/take fees on market quality. *Available at SSRN: http://ssrn.com/abstract=1787110* .

Menkveld, A. J. 2013. High frequency trading and the new market makers. *Journal of Financial Markets* 16:712–40.

O'Hara, M., and M. Ye. 2011. Is market fragmentation harming market quality? *Journal of Financial Economics* 100:459 − 474.

Pagnotta, E. 2010. Information and liquidity trading at optimal frequencies. *Available at SSRN: http://ssrn.com/abstract=1684297* .

Rosu, I. 2014. Liquidity and information in order driven markets. *Available at SSRN: http://ssrn.com/abstract=1286193* .

Skjeltorp, J. A., E. Sojli, and W. W. Tham. 2012. Identifying cross-sided liquidity externalities. *Available at SSRN: http://ssrn.com/abstract=2026593* .

Stock, J. H., and M. W. Watson. 2011. *Introduction to econometrics*. 3rd edition ed. Boston, MA: Addison-Wesley.

Stoll, H. R. 2000. Presidential address: Friction. *The Journal of Finance* 55:1479–514.

TD Ameritrade. 2014. TD Ameritrade discloses order routing revenue sharing. *Business Wire* .

Table 1.
Pricing schedule for May 2013 across select equity exchanges.

The maker-taker fees are collected from exchanges in May 2013. The net fee is the sum of the maker and taker fees and represents the gross profit earned by the exchange when a trade executes. The fee level is the factor that is multiplied by the net fee to yield the taker fee. All fees are measured as cents per one hundred shares. A non-inverted exchange uses the more common maker-taker pricing, where the taker pays a fee and the maker receives a rebate. An inverted exchange is one that uses taker-maker pricing, where the taker receives a rebate and the maker pays a fee. The International Securities Exchange is no longer operational as of May 2013 but its fees and SEC Rule 605 data are included in analyses for earlier months. CBSX is non-inverted for some months during the period of study.

Maker-taker Pricing (Non-Inverted: Fee level > 1)		NYSE-listed				NASDAQ-listed			
Exchange Acronym	Exchange Name	Maker Rebate	Taker Fee	Net Fee	Fee Level	Maker Rebate	Taker Fee	Net Fee	Feel Level
BATS BZX	BATS BZX Exchange (merging with Direct Edge)	-25	29	4	7.25	-25	29	4	7.25
CHX	Chicago Stock Exchange	-22	30	8	3.75	-1	6	5	1.20
EDGX	Direct Edge X (merging with BATS Exchange)	-21	30	9	3.33	-21	30	9	3.33
ISE	International Securities Exchange (acquired by Direct Edge)	----	----	----	----	----	----	----	----
NASDAQ	NASDAQ	-20	30	10	3.00	-20	30	10	3.00
NASDAQ OMX PSX	(formerly Philadelphia Stock Exchange)	-26	30	4	7.50	-26	30	4	7.50
NSX	National Stock Exchange (acquired by CBOE)	-24	30	6	5.00	-24	30	6	5.00
NYSE	New York Stock Exchange (acquired by Intercontinental Exchange)	-15	25	10	2.50	----	----	----	----
NYSE ARCA	(formerly Pacific Exchange)	-21	30	9	3.33	-22	25	3	8.33
NYSE MKT	(formerly AMEX)	----	----	----	----	-25	30	5	6.00

Taker-maker Pricing (Inverted: Fee level < 0)		NYSE-listed				NASDAQ-listed			
Exchange Acronym	Exchange Name	Maker Fee	Taker Rebate	Net Fee	Fee Level	Maker Fee	Taker Rebate	Net Fee	Fee Level
BATS BYX	BATS BYX Exchange (merging with Direct Edge)	7	-5	2	-2.50	7	-5	2	-2.50
CBSX	The CBOE Stock Exchange	18	-15	3	-5.00	18	-15	3	-5.00
EDGA	Direct Edge A (merging with BATS Exchange)	6	-4	2	-2.00	6	-4	2	-2.00
NASDAQ OMX BX	(formerly Boston Stock Exchange)	20	-4	16	-0.25	20	-4	16	-0.25

Table 2.
One equilibrium with five possible states in the limit order book.

The maker rate is the probability that a non-marketable limit order buy or sell is submitted by an investor; it has a non-zero probability of non-execution. The fill rate is the probability that a non-marketable limit buy or sell submitted by an investor executes.

Investor Type and Fill Rate	High Maker Rate	Low Maker Rate	Zero Maker Rate
High Fill Rate (ϕ_H)			
State Type	1	2	----
Patient Investor	Maker and Taker	Maker and Taker	----
Impatient Investor	Maker and Taker	Only Taker	----
Low Fill Rate (ϕ_L)			
State Type	3	4	----
Patient Investor	Only Maker	Only Maker	----
Impatient Investor	Maker and Taker	Only Taker	----
Zero Fill Rate (0)			
State Type	----	----	5
Patient Investor	----	----	Only Taker
Impatient Investor	----	----	Only Taker

Table 3.
Sample selection criteria.

SEC Rule 605 data are collected from several data depositories. Observations are excluded if they cannot be match to CRSP by stock ticker and date, are not U.S. common stocks, have a price less than $1 or more than $1,000, have a routing destination other than a lit exchange, or are listed on American Stock Exchange (AMEX).

Criterion	**Number of Observations**
Panel A: Filters	
All observations from March 2009 - December 2011	69,456,801
Matched to CRSP by ticker and date	64,850,138
Common U.S. stocks only	45,748,304
Mean closing price between $1.00 and $1,000, inclusively	44,192,488
Observations without errors or duplicates	40,902,491
Trading venues of interest	17,617,061
Excludes dark pools, other ECNs, and OTC dealers.	
Restrict sample to NYSE- and NASDAQ-listed stocks	16,783,863
Panel B: Subsample Description	
NYSE-listed stock observations	7,766,430
Market orders	740,281
Marketable limit orders	1,893,637
Inside-the-quote limit orders	1,619,040
At-the-quote limit orders	1,754,440
Near-the-quote limit orders	1,759,032
NASDAQ-listed stock observations	9,017,433
Market orders	467,708
Marketable limit orders	2,188,770
Inside-the-quote limit orders	2,068,849
At-the-quote limit orders	2,226,544
Near-the-quote limit orders	2,065,562

Table 4.
Percent of all orders, all shares, and all shares executed by exchange according to SEC Rule 605 from March 2009 - December 2011.

Data set is composed of all SEC Rule 605 reports available for download. The denominator for each variable is derived from all market centers; thus, columns will not sum to 100%. BATS BYX and BATS BZX are missing reports for October 2010 and December 2010, respectively. CBSX is missing data for April and December 2009. NASDAQ OMX BX and PSX are missing reports for March 2009 through November 2011 and October 2010 through November 2011, respectively.

	NYSE-listed Securities			NASDAQ-listed Securities		
Exchange	Percent of All Orders	Percent of All Shares Entered	Percent of All Shares Executed	Percent of All Orders	Percent of All Shares Entered	Percent of All Shares Executed
BATS BYX	3.80%	1.90%	1.32%	5.86%	2.90%	1.75%
BATS BZX	20.26%	14.60%	11.22%	36.00%	25.90%	20.38%
CBSX	0.25%	0.57%	0.00%	0.39%	0.70%	0.00%
CHX	0.12%	0.20%	0.08%	0.20%	0.32%	0.14%
EDGA	5.39%	4.16%	6.09%	7.39%	5.60%	6.56%
EDGX	5.63%	4.76%	8.27%	9.14%	7.80%	13.19%
ISE	3.77%	8.28%	1.23%	5.97%	15.64%	1.78%
NASDAQ	5.16%	4.94%	10.85%	11.20%	11.82%	26.92%
NASDAQ OMX BX	0.06%	0.04%	0.03%	0.08%	0.05%	0.04%
NASDAQ OMX PSX	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%
NSX	0.16%	0.12%	0.31%	0.24%	0.19%	0.38%
NYSE	41.17%	43.46%	41.83%	0.00%	0.01%	0.01%
NYSE ARCA	4.82%	5.05%	3.60%	6.65%	6.12%	5.15%
NYSE MKT (AMEX)	0.00%	0.00%	0.00%	1.10%	1.47%	0.54%

Table 5A.
Order execution quality variables for NYSE-listed stocks by exchange from March 2009 - December 2011.

All statistics are estimated from SEC Rule 605. The order types are: non-marketable limit orders (LO), marketable limit orders (MLO), and market orders (MO). In addition, the limit orders (LO) are composed of inside-the-quote, at-the-quote, and outside-the-quote limit orders. Percentages in columns (3)-(6) are out of the number of shares entered and sum to 100%. The spreads are calculated from orders, where the receiving venue executes 70% or more of the total shares executed. Dollar quoted and effective spread and price impact are only available for marketable orders. Realized spread is estimated using at-the-quote limit orders only. All marketable orders submitted to BATS BYX and BZX are immediate or cancel. Marketable orders submitted to EDGA or EDGX that do not fill immediately become expired. In addition, these orders may be defined as non-routable or specify a minimum fill quantity. All marketable orders submitted to NASDAQ, NASDAQ OMX BX, or NASDAQ OMX PSX are required to specify a limit price. NYSE MKT (AMEX) is not listed as it does not trade NYSE-listed stocks.

Exchange	Order Type	Percent of Shares Executed at Receiving Venue	Percent of Shares Executed at non-Receiving Venue	Percent of Shares Cancelled	Percent of Shares Other	Share-Weighted Quoted Spread	Share-Weighted Effective Spread	Share-Weighted Price Impact	Share-Weighted Realized Spread
BATS BYX	LO	2.90%	0.09%	96.89%	0.12%	-------	-------	-------	-$0.0042
	MLO	28.98%	1.50%	69.41%	0.11%	$0.0118	$0.0121	$0.0053	-------
	MO	9.60%	18.65%	71.65%	0.10%	$0.0098	$0.0086	$0.0025	-------
BATS BZX	LO	3.72%	0.13%	94.02%	2.14%	-------	-------	-------	-$0.0008
	MLO	30.25%	3.91%	38.43%	27.41%	$0.0107	$0.0106	$0.0068	-------
	MO	22.92%	16.36%	11.91%	48.80%	$0.0083	$0.0057	$0.0026	-------
CBSX	LO	0.01%	0.00%	99.99%	0.00%	-------	-------	-------	-$0.0022
	MLO	0.94%	0.09%	98.96%	0.00%	$0.0411	$0.0508	$0.0266	-------
	MO	6.95%	0.00%	93.05%	0.00%	$0.0464	$0.0427	$0.0188	-------
CHX	LO	1.52%	0.00%	98.16%	0.32%	-------	-------	-------	$0.0037
	MLO	8.47%	0.00%	90.95%	0.58%	$0.0135	$0.0160	$0.0211	-------
	MO	20.45%	0.00%	79.55%	0.00%	$0.0114	$0.0114	$0.0138	-------
EDGA	LO	6.59%	1.96%	85.67%	5.77%	-------	-------	-------	-$0.0026
	MLO	25.42%	12.33%	29.46%	32.78%	$0.0104	$0.0104	$0.0056	-------
	MO	9.94%	43.60%	1.49%	44.98%	$0.0098	$0.0092	$0.0055	-------
EDGX	LO	8.84%	0.60%	84.74%	5.82%	-------	-------	-------	-$0.0009
	MLO	36.29%	6.14%	40.15%	17.42%	$0.0107	$0.0108	$0.0090	-------
	MO	25.14%	23.37%	1.40%	50.09%	$0.0103	$0.0094	$0.0043	-------
ISE	LO	0.55%	0.00%	99.44%	0.01%	-------	-------	-------	$0.0000
	MLO	11.60%	0.00%	88.40%	0.00%	$0.0126	$0.0115	$0.0189	-------
	MO	6.74%	0.42%	92.85%	0.00%	$0.0105	$0.0082	$0.0100	-------
NASDAQ	LO	10.51%	1.09%	88.31%	0.09%	-------	-------	-------	-$0.0019
	MLO	65.42%	11.86%	22.62%	0.11%	$0.0113	$0.0109	$0.0073	-------
NASDAQ OMX BX	LO	2.61%	0.12%	97.27%	0.00%	-------	-------	-------	-$0.0041
	MLO	8.74%	7.23%	84.02%	0.00%	$0.0091	$0.0087	$0.0047	-------
NASDAQ OMX PSX	LO	0.82%	0.30%	98.87%	0.00%	-------	-------	-------	-$0.0022
	MLO	11.30%	16.30%	72.40%	0.00%	$0.0125	$0.0122	$0.0076	-------
NSX	LO	10.79%	0.04%	89.16%	0.02%	-------	-------	-------	$0.0107
	MLO	42.34%	1.33%	56.33%	0.00%	$0.0111	$0.0110	$0.0213	-------
	MO	72.98%	21.52%	5.48%	0.02%	$0.0134	$0.0136	$0.0121	-------
NYSE	LO	2.64%	0.01%	96.03%	1.32%	-------	-------	-------	$0.0011
	MLO	36.81%	2.72%	59.50%	0.97%	$0.0109	$0.0111	$0.0136	-------
	MO	68.14%	31.61%	0.18%	0.07%	$0.0124	$0.0141	$0.0099	-------
NYSE ARCA	LO	3.59%	0.33%	93.58%	2.50%	-------	-------	-------	$0.0047
	MLO	30.36%	8.65%	50.50%	10.48%	$0.0125	$0.0124	$0.0089	-------
	MO	58.17%	41.40%	0.30%	0.13%	$0.0092	$0.0074	$0.0051	-------

Table 5B.
Order execution quality variables for NASDAQ-listed stocks by exchange from March 2009 - December 2011.

All statistics are estimated from SEC Rule 605. The order types are: non-marketable limit orders (LO), marketable limit orders (MLO), and market orders (MO). In addition, the limit orders (LO) are composed of inside-the-quote, at-the-quote, and outside-the-quote limit orders. Percentages in columns (3)-(6) are out of the number of shares entered and sum to 100%. The spreads are calculated from orders, where the receiving venue executes 70% or more of the total shares executed. Dollar quoted and effective spread and price impact are only available for marketable orders. Realized spread is estimated using at-the-quote limit orders only. All marketable orders submitted to BATS BYX and BZX are immediate or cancel. Marketable orders submitted to EDGA or EDGX that do not fill immediately become expired. In addition, these orders may be defined as non-routable or specify a minimum fill quantity. All marketable orders submitted to NASDAQ, NASDAQ OMX BX, or NASDAQ OMX PSX are required to specify a limit price. NYSE is not listed as it does not trade NASDAQ-listed stocks.

Exchange	Order Type	Percent of Shares Executed at Receiving Venue	Percent of Shares Executed at non-Receiving Venue	Percent of Shares Cancelled	Percent of Shares Other	Share-Weighted Quoted Spread	Share-Weighted Effective Spread	Share-Weighted Price Impact	Share-Weighted Realized Spread
BATS BYX	LO	2.67%	0.09%	97.16%	0.08%	-------	-------	-------	-$0.0048
	MLO	27.18%	1.43%	71.36%	0.04%	$0.0123	$0.0126	$0.0058	-------
	MO	5.84%	19.08%	75.06%	0.01%	$0.0152	$0.0134	$0.0020	-------
BATS BZX	LO	3.90%	0.14%	94.11%	1.84%	-------	-------	-------	-$0.0013
	MLO	33.23%	4.34%	36.12%	26.31%	$0.0112	$0.0110	$0.0073	-------
	MO	18.23%	29.33%	11.05%	41.38%	$0.0085	$0.0062	$0.0035	-------
CBSX	LO	0.02%	0.00%	99.98%	0.00%	-------	-------	-------	-$0.0023
	MLO	0.89%	0.06%	99.05%	0.00%	$0.0574	$0.0709	$0.0448	-------
	MO	6.59%	0.00%	93.41%	0.00%	$0.0503	$0.0489	$0.0132	-------
CHX	LO	1.96%	0.00%	97.77%	0.26%	-------	-------	-------	$0.0108
	MLO	6.76%	0.00%	92.69%	0.55%	$0.0168	$0.0193	$0.0277	-------
	MO	5.63%	0.00%	94.37%	0.00%	$0.0110	$0.0112	$0.0045	-------
EDGA	LO	5.66%	1.05%	86.96%	6.33%	-------	-------	-------	-$0.0034
	MLO	20.90%	7.10%	38.36%	33.64%	$0.0107	$0.0107	$0.0052	-------
	MO	16.94%	27.65%	3.93%	51.48%	$0.0434	$0.0415	$0.0264	-------
EDGX	LO	9.13%	0.71%	83.05%	7.11%	-------	-------	-------	-$0.0008
	MLO	33.94%	6.33%	39.22%	20.51%	$0.0140	$0.0141	$0.0111	-------
	MO	15.78%	18.30%	3.81%	62.11%	$0.0200	$0.0186	$0.0055	-------
ISE	LO	0.47%	0.00%	99.52%	0.02%	-------	-------	-------	$0.0000
	MLO	9.00%	0.00%	90.99%	0.00%	$0.0178	$0.0167	$0.0242	-------
	MO	4.98%	0.49%	94.53%	0.00%	$0.0124	$0.0093	$0.0058	-------
NASDAQ	LO	11.35%	1.06%	86.69%	0.90%	-------	-------	-------	-$0.0010
	MLO	67.60%	8.75%	23.56%	0.08%	$0.0150	$0.0142	$0.0095	-------
NASDAQ OMX	LO	2.70%	0.26%	97.04%	0.00%	-------	-------	-------	-$0.0039
BX	MLO	7.25%	7.18%	85.57%	0.00%	$0.0114	$0.0113	$0.0020	-------
NASDAQ OMX	LO	1.34%	1.07%	97.58%	0.00%	-------	-------	-------	-$0.0059
PSX	MLO	14.54%	22.06%	63.40%	0.00%	$0.0162	$0.0159	$0.0137	-------
NSX	LO	10.03%	0.26%	89.60%	0.11%	-------	-------	-------	$0.0096
	MLO	27.76%	1.53%	70.70%	0.00%	$0.0153	$0.0152	$0.0232	-------
	MO	61.07%	21.67%	17.24%	0.02%	$0.0158	$0.0163	$0.0109	-------
NYSE ARCA	LO	4.50%	0.23%	92.45%	2.82%	-------	-------	-------	$0.0046
	MLO	31.48%	7.82%	55.05%	5.65%	$0.0152	$0.0148	$0.0096	-------
	MO	55.78%	43.93%	0.14%	0.15%	$0.0104	$0.0091	$0.0041	-------
NYSE MKT	LO	1.12%	0.01%	98.86%	0.02%	-------	-------	-------	-$0.0013
(AMEX)	MLO	16.60%	0.31%	58.92%	24.17%	$0.0129	$0.0136	$0.0173	-------
	MO	14.36%	59.45%	26.18%	0.00%	$0.0194	$0.0246	$0.0151	-------

Table 6.
Descriptive statistics for securities, March 2009 - December 2011.

All statistics are estimated from data available in CRSP. The stocks included are those found in SEC Rule 605, that can be matched by ticker and date to CRSP. Turnover is the volume of shares divided by the number of shares outstanding.

	NYSE-listed Securities				NASDAQ-listed Securities			
Variables	Number	Mean	Median	Standard Deviation	Number	Mean	Median	Standard Deviation
Number of securities	1,477	----	----	----	2,759	----	----	----
Closing price	----	$30.72	$23.93	34.9	----	$15.35	$9.21	23.5
Market capitalization	----	$7,231,639,844	$1,741,811,489	21,086,978,723	----	$1,420,734,635	$195,112,629	9,590,079,022
Turnover	----	0.0116	0.0086	0.0124	----	0.0078	0.0043	0.0134
Share volume	----	2,929,212	725,628	16,719,896	----	769,820	103,258	3,597,872
Dollar volume	----	$70,500,130	$17,249,442	186,152,967	----	$18,305,104	$859,551	144,295,003
Number of trades	----	14,226	14,315	14,335	----	3,321	539	10,547
Return	----	0.0015	0.0011	0.0068	----	0.0015	0.0008	0.0089
Variance of return	----	0.001085	0.000514	0.0026	----	0.002194	0.000843	0.0611

Table 7.
Effect of an increase in the taker fee and maker rebate on the quoted or effective spread, holding the fee level or net fee constant.

The panel data specification appears in Equation 7. The independent variable is the quoted or effective spread. Intuitively, the quoted spread is the "advertised" cost of trading a security, and the effective spread is the "actual" cost of trading, excluding brokerage commissions. The quoted and effective spread variables are both mean dollar spreads by security per month and exchange and are share weighted. The spread measures only represent shares executed at the receiving venue. The sample period is March 2009 - December 2011. The net fee is in dollars per one hundred shares. It represents the surplus earned by the exchange when a trade executes. The fee level is the factor that is multiplied by the net fee to yield the taker fee. The interaction term accounts for the differential impact of the net fee (fee level), given various fee levels (net fees). Only base fees for non-inverted equity exchanges are used. Net fees are positive. Fixed effects for order type and size are employed. The dummies for market order type and order size from 100 - 499 shares are dropped. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

	Quoted Spread	Effective Spread
Dependent Variable	(1)	(2)
Fee Level: f^L	-0.06563 ***	-0.073 ***
	(0.01146)	(0.00952)
Net Fee: f^N	-0.05898 ***	-0.07268 ***
	(0.00767)	(0.00762)
Fee Level * Net Fee	-0.07456 ***	-0.09227 ***
	(0.01328)	(0.01229)
Marketable limit order (not market orders)	----	0.03009 ***
		(0.00027)
500-1,999 shares	----	-0.00738 ***
		(0.00025)
2,000-4,999 shares	----	-0.02256 ***
		(0.00027)
≥ 5,000 shares	----	-0.0338 ***
		(0.00031)
Log closing price	0.01266 ***	0.01198 ***
	(0.00030)	(0.00018)
Turnover	-0.0251 ***	-0.01339 ***
	(0.00076)	(0.00032)
Variance of daily return	0.0029 *	0.00223 ***
	(0.00110)	(0.00058)
Constant	0.03592 ***	0.02652 ***
	(0.00320)	(0.00292)
Observations	383,544	731,918
Adjusted R^2	0.0681	0.0948
Exchange and time fixed effects	Yes	Yes

Table 8.

Effect of an increase in the taker fee and maker rebate on the number of marketable, non-marketable limit, or non-marketable limit and marketable order shares submitted or the proportion of marketable order shares submitted, holding the fee level or net fee constant.

The panel data specification appears in Equation 10. The independent variable is the log of the number of marketable order shares submitted (excluding cancelled shares), log of the number of non-marketable limit order shares submitted (excluding cancelled shares), log of the sum of the number of marketable and non-marketable limit order shares submitted (excluding cancelled shares), or the proportion of marketable order shares submitted (excluding cancelled shares). A logistic transformation is applied to the proportion of marketable order shares. The sample period is March 2009 - December 2011. The net fee is in dollars per one hundred shares. It represents the surplus earned by the exchange when a trade executes. The fee level is the factor that is multiplied by the net fee to yield the taker fee. The interaction term accounts for the differential impact of the net fee (fee level), given various fee levels (net fees). Only base fees for non-inverted equity exchanges are used. Net fees are positive. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Effective spread is the mean share-weighted measure for a stock across all exchanges. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Absolute value of daily return is the mean value across the absolute value of a stock's daily return. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

	Log Number of Marketable Order Shares	Log Number of Non-marketable Limit Order Shares	Log Number of Non-marketable Limit and Marketable Order Shares	Proportion of Marketable Orders Shares
Dependent Variable	(1)	(2)	(3)	(4)
Fee Level: f^L	-1.36237 ***	-2.60723 ***	-2.94504 ***	5.66526 ***
	(0.15530)	(0.11962)	(0.14459)	(0.21066)
Net Fee: f^N	-2.86074 ***	-3.70517 ***	-3.80651 ***	3.47891 ***
	(0.09582)	(0.07741)	(0.08996)	(0.13671)
Fee Level * Net Fee	-0.18067	-1.23857 ***	-1.8296 ***	5.91162 ***
	(0.17220)	(0.13258)	(0.15977)	(0.23933)
Log closing price	1.45367 ***	1.66985 ***	1.54179 ***	-0.3428 ***
	(0.00988)	(0.00937)	(0.00929)	(0.01008)
Effective spread	-2.76645 ***	-2.42824 ***	-2.45494 ***	-0.68628 ***
	(0.01229)	(0.01150)	(0.01137)	(0.01671)
Turnover	1.36149 ***	1.23183 ***	1.29741 ***	0.03059 ***
	(0.02692)	(0.02515)	(0.02576)	(0.00665)
Absolute value of daily return	0.0439 **	0.10156 ***	0.05216 ***	-0.0227
	(0.01265)	(0.01199)	(0.01179)	(0.01407)
Variance of daily return	-0.01966	-0.03321	-0.02381	0.01489 ***
	(0.01643)	(0.01627)	(0.01610)	(0.00306)
Constant	11.67194 ***	12.18845 ***	12.48752 ***	0.36865 ***
	(0.04545)	(0.03876)	(0.04255)	(0.06494)
Observations	779,897	779,897	779,897	702,979
Adjusted R^2	0.7525	0.8086	0.8041	0.3966
Exchange and time fixed effects	Yes	Yes	Yes	Yes

Table 9.
Effect of an increase in the taker fee and maker rebate on the fill rate, the probability that a non-marketable limit order executes, holding the fee level or net fee constant.

The panel data specification appears in Equation 7. The independent variable is the fill rate of a limit order, including cancelled shares. Intuitively, the fill rate is the probability that a limit order share executes. A logistic transformation is applied to the fill rate since it is a proportion. The fill rate only represents shares executed at the receiving venue or not routed away. The sample period is March 2009 - December 2011. The net fee is in dollars per one hundred shares. It represents the surplus earned by the exchange when a trade executes. The fee level is the factor that is multiplied by the net fee to yield the taker fee. The interaction term accounts for the differential impact of the net fee (feel level), given various fee levels (net fees). Only base fees for non-inverted equity exchanges are used. Net fees are positive. The dummy for order size from 100 - 499 shares is dropped. Order type dummies are not used, as only at-the-limit quote limit orders are evaluated. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

	Fill Rate
Dependent Variable	(1)
Fee Level: f^L	24.77263 ***
	(0.24108)
Net Fee: f^N	15.63585 ***
	(0.14086)
Fee Level * Net Fee	27.47642 ***
	(0.27316)
500-1,999 shares	0.41837 ***
	(0.00381)
2,000-4,999 shares	0.35683 ***
	(0.00477)
≥ 5,000 shares	-0.02041 **
	(0.00547)
Log closing price	0.00584
	(0.00360)
Turnover	0.26094 ***
	(0.00377)
Variance of daily return	-0.00603 **
	(0.00190)
Constant	4.11694 ***
	(0.06672)
Observations	2,068,255
Adjusted R^2	0.1355
Exchange and time fixed effects	Yes

Table 10.
Effect of an increase in the taker fee and maker rebate on the quoted or effective spread plus twice the taker fee, holding the fee level or net fee constant.

The panel data specification appears in Equation 7. The independent variable is the quoted or effective spread plus twice the taker fee. This measure is the total trading cost for investors that do not use a broker and have direct market access. It is the difference between the price paid to acquire a share using a marketable order plus the price received for selling a share with the same order type. The quoted and effective spread variables are both mean dollar spreads by security per month and exchange, but the effective spread is weighted by share volume. The spread measures only represent shares executed at the receiving venue. The sample period is March 2009 - December 2011. The net fee is in dollars per one hundred shares. It represents the surplus earned by the exchange when a trade executes. The fee level is the factor that is multiplied by the net fee to yield the taker fee. The interaction term accounts for the differential impact of the net fee (fee level), given various fee levels (net fees). Only base fees for non-inverted equity exchanges are used. Net fees are positive. Fixed effects for order type and size are employed. The dummies for market order type and order size from 100 - 499 shares are dropped. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

Dependent Variable	Quoted Spread + 2 × Take Fee	Effective Spread + 2 × Take Fee
	(1)	(2)
Fee Level: f^L	-0.0472 ***	-0.05543 ***
	(0.01146)	(0.00952)
Net Fee: f^N	-0.0468 ***	-0.05847 ***
	(0.00767)	(0.00762)
Fee Level * Net Fee	-0.0527 ***	-0.06902 ***
	(0.01328)	(0.01229)
Marketable limit order (not market order)	----	0.03009 ***
		(0.00027)
500-1,999 shares	----	-0.00738 ***
		(0.00025)
2,000-4,999 shares	----	-0.02256 ***
		(0.00027)
≥ 5,000 shares	----	-0.0338 ***
		(0.00031)
Log closing price	0.01266 ***	0.01198 ***
	(0.00030)	(0.00018)
Turnover	-0.0251 ***	-0.01339 ***
	(0.00076)	(0.00032)
Variance of daily return	0.0029 *	0.00223 ***
	(0.00110)	(0.00058)
Constant	0.04619 ***	0.03726 ***
	(0.00320)	(0.00292)
Observations	383,544	731,918
Adjusted R^2	0.0681	0.0946
Exchange and time fixed effects	Yes	Yes

Table 11.
Effect of an increase in the taker or maker fee on the quoted or effective spread, holding the other fee constant.

The panel data specification appears in Equation 11. The independent variable is the quoted or effective spread. Intuitively, the quoted spread is the "advertised" cost of trading a security, and the effective spread is the "actual" cost of trading, excluding brokerage commissions. The quoted and effective spread variables are both mean dollar spreads by security per month and exchange, but the effective spread is weighted by share volume. The spread measures only represent shares executed at the receiving venue. The sample period is March 2009 - December 2011. The maker rebate (-1 × maker fee) is the payment received by a broker or investor having direct market access for adding liquidity to the limit order book. The taker fee is the price paid by a broker or investor having direct market access when an order taking liquidity executes. The interaction term accounts for the differential impact of the maker (taker) fee, given various taker (maker) fees. Fees are in dollars per one hundred shares. Only base fees for non-inverted equity exchanges are used. Net fees are positive. Fixed effects for order type and size are employed. The dummies for market order type and order size from 100 - 499 shares are dropped. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. The White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

Dependent Variable	Quoted Spread	Effective Spread
	(1)	(2)
Maker fee: f^{ma}	-0.01701 ***	-0.01691 ***
(Maker rebate = -1 × maker fee)	(0.00184)	(0.00139)
Taker fee: f^{ta}	-0.02229 ***	-0.01831 ***
	(0.00159)	(0.00116)
Maker fee × taker fee: $f^{ma} \times f^{ta}$	0.00379 ***	0.00214 ***
	(0.00068)	(0.00048)
Marketable limit order (not market order)	----	0.0301 ***
		(0.00027)
500-1,999 shares	----	-0.00737 ***
		(0.00025)
2,000-4,999 shares	----	-0.02251 ***
		(0.00027)
≥ 5,000 shares	----	-0.03378 ***
		(0.00031)
Log closing price	0.01267 ***	0.01199 ***
	(0.00030)	(0.00018)
Turnover	-0.0251 ***	-0.01339 ***
	(0.00076)	(0.00032)
Variance of daily return	0.00289	0.00223 ***
	(0.00110)	(0.00058)
Constant	0.04853 ***	0.04366 ***
	(0.00132)	(0.00094)
H_0: Taker fee = maker fee		
F value	10.01	1.27
Chi-square	7.51	0.79
Observations	383,544	731,918
Adjusted R^2	0.0682	0.0948
Exchange and time fixed effects	Yes	Yes

Table 12.
Effect of an increase in the taker or maker fee on the number of marketable, non-marketable limit, non-marketable limit and marketable order shares submitted or the proportion of marketable order shares submitted, holding the other fee constant.

The panel data specification appears in Equation 12. The independent variable is the log of the number of marketable order shares submitted (excluding cancelled shares), log of the number of non-marketable limit order shares submitted (excluding cancelled shares), log of the sum of the number of marketable and non-marketable limit order shares submitted (excluding cancelled shares), or the proportion of marketable order shares submitted (excluding cancelled shares). A logistic transformation is applied to the proportion of number of marketable order shares to all orders shares. The sample period is March 2009 - December 2011. The maker rebate (-1 × maker fee) is the payment received by a broker or investor having direct market access for adding liquidity to the limit order book. The taker fee is the price paid by a broker or investor having direct market access when an order taking liquidity executes. The interaction term accounts for the differential impact of the maker (taker) fee, given various taker (maker) fees. Fees are in dollars per one hundred shares. Only base fees for non-inverted equity exchanges are used. Net fees are positive. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Effective spread is the mean share-weighted measure for a stock across all exchanges. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Absolute value of daily return is the mean value across the absolute value of a stock's daily return. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

Dependent Variable	Log Number of Marketable Order Shares	Log Number of Non-marketable Limit Order Shares	Log Number of Non-marketable Limit and Marketable Order Shares	Proportion of Marketable Order Shares
	(1)	(2)	(3)	(4)
Maker fee: f^{ma}	-2.46601 ***	-2.50621 ***	-2.44495 ***	-0.10935
(Maker rebate = -1 × maker fee)	(0.03612)	(0.03495)	(0.03372)	(0.04339)
Taker fee: f^{ta}	-1.06797 ***	-1.02197 ***	-1.08925 ***	0.02002
	(0.03091)	(0.03010)	(0.02872)	(0.03483)
Maker fee × taker fee: $f^{ma} \times f^{ta}$	-0.42482 ***	-0.49673 ***	-0.4542 ***	0.07896 ***
	(0.01288)	(0.01195)	(0.01180)	(0.01191)
Log closing price	1.45331 ***	1.66937 ***	1.54138 ***	-0.34243 ***
	(0.00988)	(0.00937)	(0.00929)	(0.01008)
Effective spread	-2.76389 ***	-2.42507 ***	-2.45214 ***	-0.68701 ***
	(0.01228)	(0.01149)	(0.01137)	(0.01671)
Turnover	1.36055 ***	1.23069 ***	1.29639 ***	0.03096 ***
	(0.02691)	(0.02514)	(0.02574)	(0.00665)
Absolute value of daily return	0.04492 **	0.10276 ***	0.05326 ***	-0.0229
	(0.01265)	(0.01199)	(0.01179)	(0.01408)
Variance of daily return	-0.01963	-0.03316	-0.02377	0.01485 ***
	(0.01636)	(0.01620)	(0.01603)	(0.00308)
Constant	11.83557 ***	12.58858 ***	12.99733 ***	-0.9215 ***
	(0.02559)	(0.02373)	(0.02269)	(0.03244)
H_0: Taker fee = maker fee				
F value	2,150.11 ***	2,635.16 ***	2359.96 ***	11.76 **
Chi-square	2,376.75 ***	2,885.52 ***	2553.39 ***	19.47 ***
Observations	779,897	779,897	779,897	702,979
Adjusted R^2	0.7521	0.8080	0.8037	0.3964
Exchange and time fixed effects	Yes	Yes	Yes	Yes

Table 13.
Effect of an increase in the taker or maker fee on the fill rate, the probability that a non-marketable limit order executes, holding the other fee constant.

The panel data specification appears in Equation 11. The independent variable is the fill rate of a limit order, including cancelled shares. Intuitively, the fill rate is the probability that a limit order share executes. A logistic transformation is applied to the fill rate since it is a proportion. The fill rate only represents shares executed at the receiving venue or not routed away. The sample period is March 2009 - December 2011. The maker rebate (-1 × maker fee) is the payment received by a broker or investor having direct market access for adding liquidity to the limit order book. The taker fee is the price paid by a broker or investor having direct market access when an order taking liquidity executes. The interaction term accounts for the differential impact of the maker (taker) fee, given various taker (maker) fees. Fees are in dollars per one hundred shares. Only base fees for non-inverted equity exchanges are used. Net fees are positive. The dummy for order size from 100 - 499 shares is dropped. Order type dummies are not used, as only at-the-limit quote limit orders are evaluated. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

Dependent Variable	Fill Rate
	(1)
Maker fee: f^{ma}	1.15166 ***
(Maker rebate = -1 × maker fee)	(0.02238)
Taker fee: f^{ta}	1.8591 ***
	(0.01883)
Maker fee × taker fee: $f^{ma} \times f^{ta}$	-0.1218 ***
	(0.00832)
500-1,999 shares	0.4187 ***
	(0.00381)
2,000-4,999 shares	0.35619 ***
	(0.00477)
≥ 5,000 shares	-0.01985 ***
	(0.00547)
Log closing price	0.00682
	(0.00360)
Turnover	0.26092 ***
	(0.00377)
Variance of daily return	-0.00588 *
	(0.00185)
Constant	-2.08266 ***
	(0.01629)
H_0: Taker fee = maker fee	
F value	1562.95 ***
Chi-square	1735.47 ***
Observations	2,068,255
Adjusted R^2	0.1342
Exchange and time fixed effects	Yes

Table 14.

Effect of an increase in the taker fee and maker rebate on realized spread or realized spread plus twice the maker rebate of non-marketable limit orders, or price impact of marketable orders, holding the fee level or net fee constant.

The panel data specification appears in Equation 7. The independent variable is the realized spread for all non-marketable limit orders or at-the-quote limit orders only, the realized spread plus twice the maker rebate for at-the-quote limit orders, or the price impact of marketable orders. Intuitively, the realized spread is the temporary component of the effective spread, which when combined with twice the maker rebate, is the total profit to the liquidity provider net of losses to the informed trader. The price impact represents the permanent part of the effective spread, and is the profit earned by the informed trader. The spread measures only represent shares executed at the receiving venue. The sample period is March 2009 - December 2011. The net fee is in dollars per one hundred shares. It represents the surplus earned by the exchange when a trade executes. The fee level is the factor that is multiplied by the net fee to yield the taker fee. The interaction term accounts for the differential impact of the net fee (fee level), given various fee levels (net fees). Only base fees for non-inverted equity exchanges are used. Net fees are positive. Fixed effects for order type and size are employed. The dummies for inside-the-quote limit order, market order, and order size from 100 - 499 shares are dropped. All stocks are listed on the NYSE or NASDAQ exchanges. Log closing price is the log of the mean daily closing price from CRSP. Turnover is the total volume of shares executed scaled by the number of shares outstanding. Variance of daily return is the variance of the stock return for every trading day. All stock-level controls are lagged values from the prior month. All non-binary independent variables are standardized. Data are from SEC Rule 605 and CRSP. White standard errors are in parentheses. * indicates significance of a 2-tailed test at the 1.0% level; ** at the 0.1% level; *** at the 0.01% level.

Dependent Variable	Price Impact	Realized Spread (all non-marketable limit orders)	Realized Spread (only at-the-quote limit orders)	Realized Spread Plus Twice the Maker Rebate (only at-the-quote limit orders)
	(1)	(2)	(3)	(4)
Fee Level	-0.05013 ***	-0.26288 ***	-0.36064 ***	-0.33989 ***
	(0.01276)	(0.01352)	(0.02915)	(0.02915)
Net Fee: f^N	-0.05249 ***	-0.17572 ***	-0.26847 ***	-0.25304 ***
	(0.01021)	(0.00979)	(0.02309)	(0.02309)
Fee Level * Net Fee	-0.05951 **	-0.34067 ***	-0.48705 ***	-0.45823 ***
	(0.01646)	(0.01734)	(0.03934)	(0.03934)
At-the-quote limit order	----	-0.00187 ***	----	----
		(0.00020)		
Near-the-quote limit order	----	-0.00394 ***	----	----
		(0.00020)		
Marketable limit order	0.03484 ***	----	----	----
(not market order)	(0.00054)			
500-1,999 shares	0.00277 ***	0.00028984	-0.00040312	-0.00040312
	(0.00038)	(0.00021)	(0.00036)	(0.00036)
2,000-4,999 shares	0.00466 ***	-0.00062941 *	0.00097958	0.00097958
	(0.00043)	(0.00023)	(0.00040)	(0.00040)
≥ 5,000 shares	0.00201 ***	-0.00147 ***	0.00309 ***	0.00309 ***
	(0.00049)	(0.00024)	(0.00041)	(0.00041)
Log closing price	0.02003 ***	-0.00939 ***	-0.00629 ***	-0.00629 ***
	(0.00036)	(0.00019)	(0.00032)	(0.00032)
Turnover	-0.00917 ***	0.00647 ***	0.00574 ***	0.00574 ***
	(0.00036)	(0.00017)	(0.00028)	(0.00028)
Variance of daily return	0.00155	-0.000633	-0.00073917 *	-0.00073917
	(0.00054)	(0.00025)	(0.00025)	(0.00025)
Constant	-0.00736	-0.10897 ***	-0.14899 ***	-0.13788 ***
	(0.00403)	(0.00414)	(0.00915)	(0.00915)
Observations	734,029	2,415,720	754,005	754,005
Adjusted R^2	0.0200	0.0164	0.0207	0.0219
Exchange and time fixed effects	Yes	Yes	Yes	Yes

Figure 1.
Steps involved in order submission and execution for investor arriving at date τ.

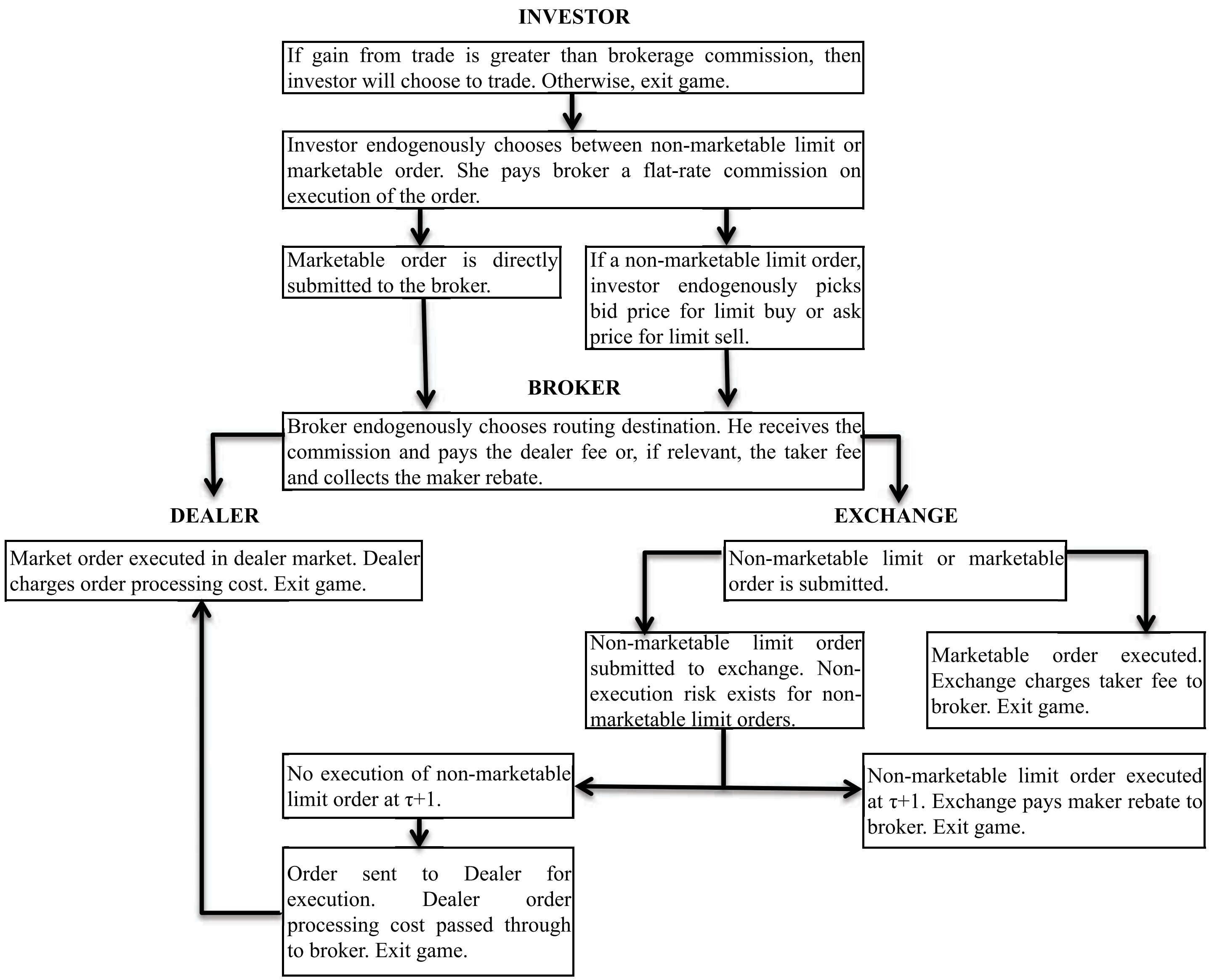

Figure 2.
Three dimensional graph of mean effective spread versus net fee and fee level.
The net fee and fee level are not standardized.

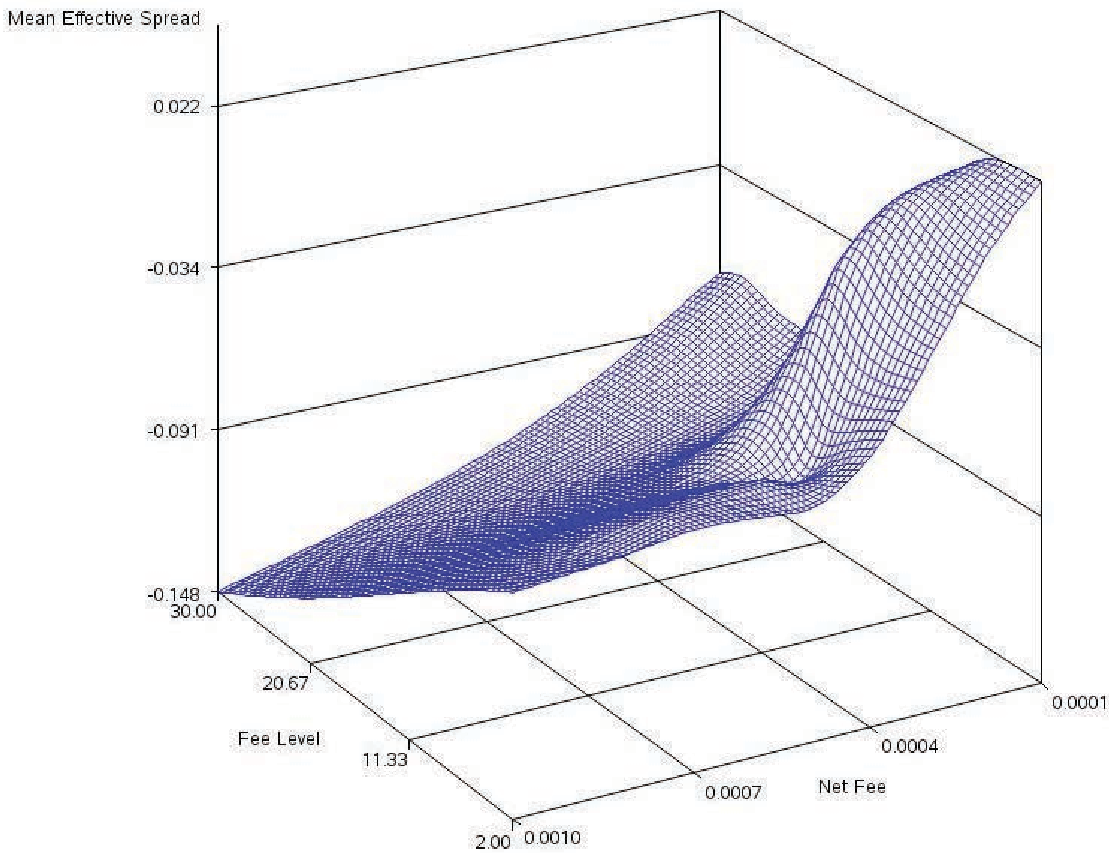

Figure 3.
Three dimensional graph of effective spread versus maker fee and taker fee.
The maker and taker fee are not standardized.

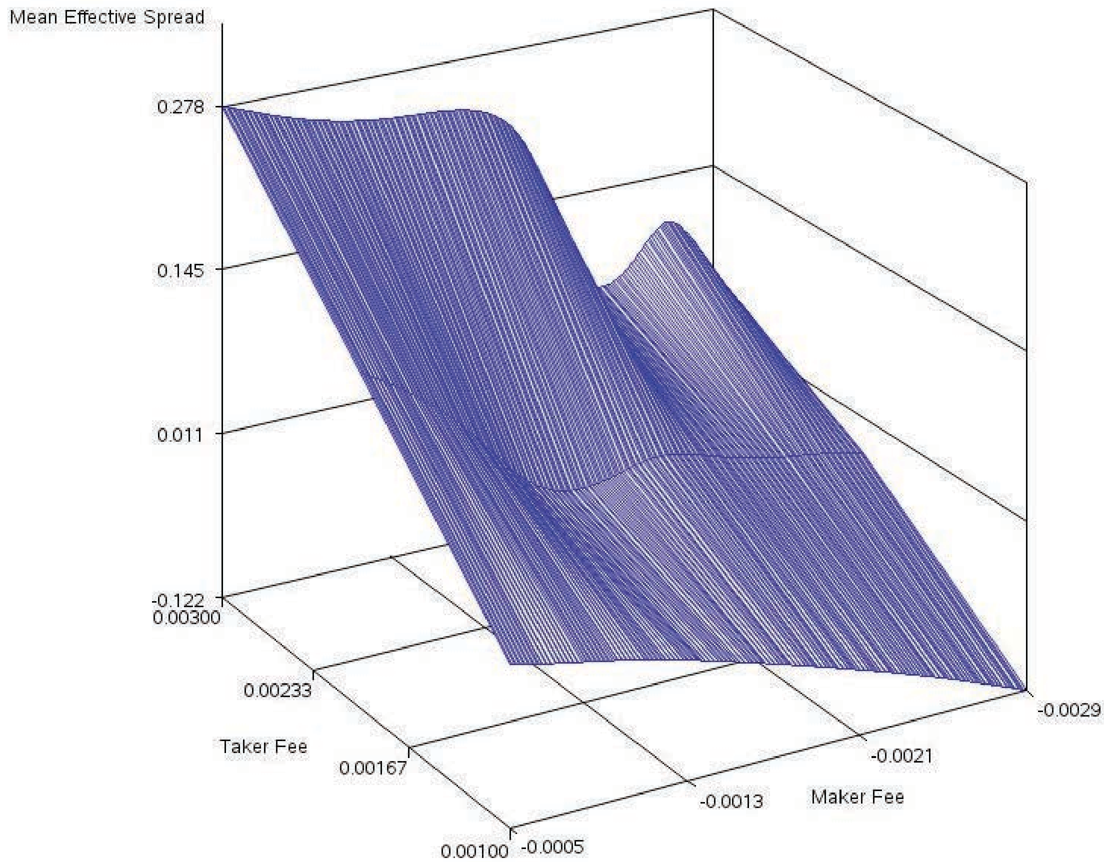

Figure 4A.
Share-weighted average effective spread for different net fee values holding fee level constant.
The net fee and fee level are standardized. The net fees and fee levels represent the 0th, 25th, 50th, 75th, and 100th percentiles and the mean value. The 75th (0th) and 100th (25th) percentiles are the same value for the fee level (net fee).

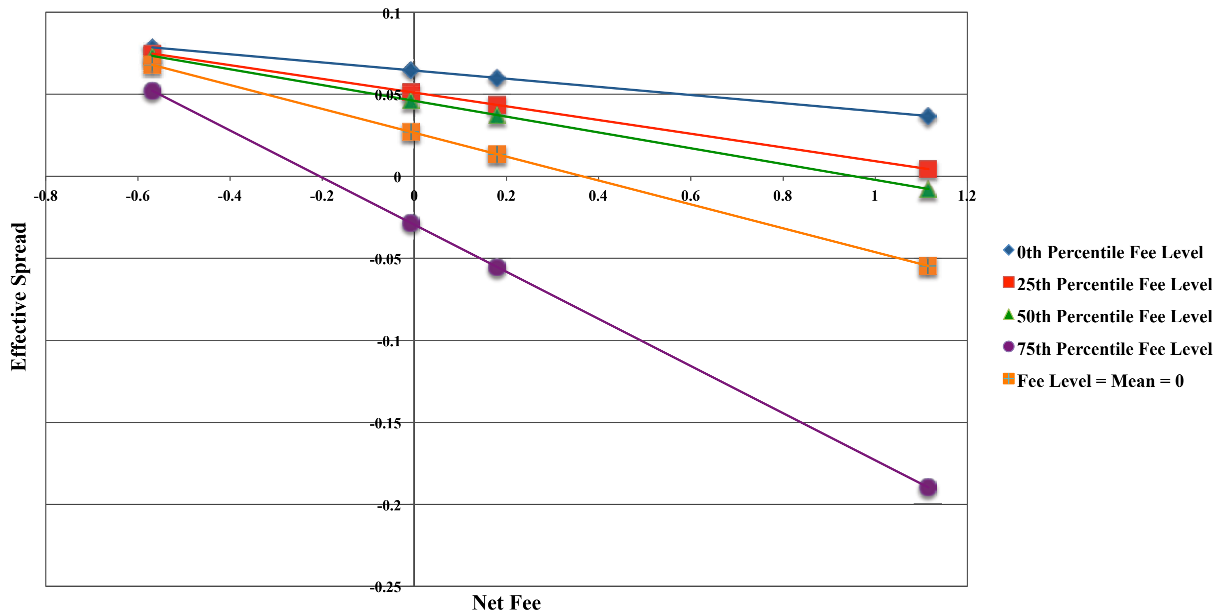

Figure 4B.
Share-weighted average effective spread for different fee level values holding net fee constant.
The net fee and fee level are standardized. The net fees and fee levels represent the 0th, 25th, 50th, 75th, and 100th percentiles and the mean value. The 75th (0th) and 100th (25th) percentiles are the same value for the fee level (net fee).