

# Make-Take Fees versus Order Flow Inducements: Evidence from the NASDAQ OMX PHLX Exchange

Robert Battalio  
University of Notre Dame  
rbattali@nd.edu

Todd Griffith  
University of Mississippi  
tgriffith@bus.olemiss.edu

Robert A. Van Ness  
University of Mississippi  
rvanness@bus.olemiss.edu

---

## Abstract

Exchange competition across U.S. options exchanges facilitates the tailoring and frequent modification of fees to attract particular order flow. We examine whether the maker-taker model or the payment for order flow (PFOF) model offers superior limit order execution quality. On the PHLX exchange, a set of select option classes recently changed pricing models from maker-taker to PFOF. We conduct difference-in-difference tests that suggest that options on stocks that change fee structures exhibit an improvement in limit order execution quality, including an increase in order fill rates, a decrease in order cancellation rates, and faster fills. We do, however, find that limit order volume, in terms of the number of orders submitted, declines following the change to PFOF pricing. Thus, our results seem to suggest that limit order traders on the PHLX exchange are made better off following the change in select options classes from maker-taker to PFOF.

*Keywords:* Maker-Taker, Payment-For-Order-Flow, Order Execution Quality

---

## 1. Introduction

Exchange competition is vigorous among operating U.S. options exchanges (Battalio, Hatch, and Jennings, 2004). Consequently, fees are tailored and frequently modified to attract particular types of order flow, while still incentivizing traders to provide liquidity at the most competitive prices.<sup>1</sup> Even though fees and rebates are a small fraction of trade prices, the total dollar value transferred between market participants is substantial due to high trading volume.<sup>2</sup> Two fee structures dominate the trading landscape in U.S. equity options markets: payment for order flow (PFOF) and maker-taker.

In the more traditional PFOF model, liquidity is provided by market makers, who naturally prefer to trade against less informed orders (Chordia and Subrahmanyam, 1995, Easley, Kiefer and O'Hara, 1996, and Battalio, Shkilko, and Van Ness, 2016). The exchange attracts such order flow by paying brokers to route retail liquidity-demanding orders to the venue.<sup>3</sup> Recent structural changes in the U.S. options markets, however, have resulted in the majority of exchanges adopting a maker-taker payment model in which liquidity is supplied primarily by voluntary limit order traders. To incentivize liquidity provisions in this model, exchanges charge a per-share fee on orders that remove liquidity and rebate a portion of those fees to orders that supply liquidity.

Both payment structures, PFOF and maker-taker, have received significant attention and debate. A critique of the maker-taker model is that the rebates to liquidity providers cause excessive intermediation, which may prevent trades between two “natural” parties. Some argue that small retail traders pay the price for make-take trading because they are generally the ones demanding liquidity

---

<sup>1</sup> See page 1 of the October 20, 2015 memorandum from the Securities and Exchange Commission (SEC) Division of Trading and Markets.

<sup>2</sup> In a letter to the SEC in September 2010 by GETCO, TD Ameritrade was estimated to generate \$78 million annually for options payment for order flow.

<sup>3</sup> StockBrokers.com published an article on Friday, June 13, 2014 entitled “Brokers that Receive Payment for Order Flow,” in which several well-known brokers are listed as recipients of payment for order flow including Charles Schwab, ETRADE, Fidelity Investments, OptionsHouse, Scottrade, and TD Ameritrade.

and paying the higher take fee.<sup>4</sup> A joint concern between the two pricing models is that broker-dealers may put aside their fiduciary responsibility to find best execution for clients, in an effort to locate the trading venues offering the highest rebates and/or order flow payments (Battalio, Corwin, and Jennings, 2015).<sup>5</sup> In addition to the potential agency conflict between broker-dealers and their clients, complex fee schedules create a transparency problem because quoted spreads can differ from net spreads and most retail traders are unaware any difference exists (see Harris, 2013).

In a testimony before the House Financial Services subcommittee on Capital Markets, Insurance, and Government Sponsored Enterprises on October 30<sup>th</sup>, 2003, an active market participant and former Bloomberg Tradebook chief executive officer, Kevin Foley, criticized all forms of order flow payments stating:

*“There is no good reason why market participants entering limit orders should receive a subsidy from participants entering marketable limit orders and plenty of good reasons why they should not. There is also, of course, no defensible argument for payment for flow of market orders. The harm done by access fees to market structure occur in two ways, in their impact on the behavior of those to whom the fees would be charged and in their impact on those who would receive the fees... Access fees tend to distort and alter market behavior.” (Page 19)*

Despite the controversy surrounding make-take fees and order flow inducements, all U.S. equity options exchanges employ one of the two payment schemes. Therefore, it is of interest to all market participants in this trade space to assess which payment structure offers superior order execution quality. In the dynamic model of Parlour and Rajan (2003), PFOF redistributes welfare from traders who demand liquidity to the market makers who supply liquidity, which in turn, impedes

---

<sup>4</sup> See also “Small investors pay the price for high-frequency trading”, The Globe and Mail, January 31, 2011, or IIROC 11-0225, comments by TD Securities.

<sup>5</sup> See also the letters from Senator Carl Levin (D-MI), to Mary Jo White, Chair, SEC (July 9, 2014) and Senator Charles Schumer (D-NY), to Mary Schapiro, Chair, SEC (May 10, 2012).

the competition among market makers. In contrast, the rebates to provide liquidity in the maker-taker model might, *ceteris paribus*, incentivize traders to submit more passive orders (Colliard and Foucault, 2012; Foucault, Kadan, and Kandel, 2013; O'Donoghue, 2015). Because the pricing structures can have asymmetric effects on the supply of liquidity, the change from one pricing model to another can affect order execution quality.

In this study, we examine a sample of option symbols trading on the NASDAQ OMX PHLX (PHLX) that change from the maker-taker model to the PFOF model. The removal of option symbols from the maker-taker program was staggered over time and affected only a subset of stocks. Therefore, we are able to control for market-wide conditions by matching securities that were affected with those that were not. We match each option class that changed from the maker-taker model to the PFOF model with a unique control class with the smallest sum of the squared percentage difference in price and the squared percentage difference in market capitalization.

We then perform difference-in-difference tests to capture the marginal impact of the fee structure change on order flow and execution quality. First, we analyze the difference in order flow between the two pricing models. We find that average order volume for options on stocks that change fee models declines after the switch to PFOF. In our multivariate analysis, we find that the median number of orders submitted for options on fee change stocks declines by 1.63 more than options on control stocks after the change to PFOF pricing, albeit the decline is significant only at the 0.10 level.

Next, we examine the effect of the payment structure change on three order execution quality metrics: the probability of a fill, the probability of a cancellation, and the speed of complete fill. We find that limit order fill rates are significantly higher in the PFOF model than in the maker-taker model. Depending upon the regression model, average fill rates for options on fee change stocks increase from 5.7% to 6.4% more than for options on control stocks following the change from maker-taker pricing to PFOF. In the long-run, we find that order cancellation rates are lower for options in the

PFOF model than in the maker-taker model. Lastly, we find that the time between limit order submission and complete fill is significantly shorter for options in the PFOF model.

Because U.S. options exchanges employ either maker-taker pricing or PFOF, it is important to identify the costs and benefits of each model. In this study, we provide evidence that certain aspects of order execution quality (i.e. probability of a fill, probability of a cancellation, fill speed) are superior in the PFOF model, relative to the maker-taker model on the PHLX exchange. We do, however, note that order volume, in terms of the number of orders submitted, is lower under PFOF pricing.

## **2. The NASDAQ OMX PHLX and its Trading Fees/Rebates**

The Philadelphia Stock Exchange is the oldest exchange in the U.S., founded in 1790. On July 24, 2008, the acquisition of the PHLX by the NASDAQ OMX Group was completed. The PHLX is now the second largest options market in the U.S., accounting for approximately 16.7% of equity options market volume.<sup>6</sup> The PHLX currently is order-driven and offers a combination of electronic and floor-based trading. When an order is submitted to the exchange, it enters the order book queue and is prioritized based on a pro-rata allocation. The pro-rata priority matches marketable orders with all limit orders in the top of the book queue simultaneously, but in proportion to order size. The pro-rata percentage is calculated by dividing the marketable order size by the total quantity limit order volume at a given price.

In contrast to equity market makers, options market makers on the PHLX often do not execute all of the liquidity demanding orders purchased in the PFOF model. The percentage of the order that a purchasing market maker can interact with depends on the number of competing market makers who are willing to match at a given price. In accordance with PHLX rules 1080 and 1014,

---

<sup>6</sup> As of April 13, 2016 provided by the Options Price Reporting Authority (OPRA) available at NasdaqTrader.com.

market makers must interact with at least 60% of purchased orders to continue to receive directed orders (the Directed Order Flow Program).

In an attempt to increase liquidity and attract order flow, the PHLX experimented with the maker-taker pricing model.<sup>7</sup> On January 4, 2010, the PHLX implemented a maker-taker pricing schedule for electronic trading in SPY options, in which a rebate is granted for adding liquidity and a fee is assessed for removing liquidity. The new fee schedule is assessed per contract and no payment for order flow is collected. The exchange then added an additional 77 option classes over the period February 1, 2010 to September 1, 2011. These 77 options classes were gradually removed from the maker-taker program and implanted back into the PFOF pricing schedule over the following years, with the exception of SPY which continues to operate under the make-take fee schedule. The PHLX began to aggregate order level data on September 1, 2010. Therefore, due to data restrictions we are only able to observe order execution quality metrics for these select options classes as they transition back from a maker-taker model to the PFOF model.

### **3. Hypothesis Development – Order Execution Quality**

Fee structure can have a direct impact on both order flow and order execution quality, such as the likelihood of execution, the speed of execution, and cancellation rates (see Battalio, Corwin, and Jennings, 2015). In this section, we develop a set of hypotheses associated with the impact of fee structure on order execution quality.

#### *3.1. Order Volume*

The primary purpose of removing the select option symbols from the maker-taker program was to attract additional order flow to the PHLX exchange.<sup>8</sup> However, theory suggests that make-

---

<sup>7</sup> In the SEC Release No. 34-61480; File No. SR-PHLX-2010-14 under the purpose section it explicitly states the rule change is intended to increase liquidity and attract order flow.

<sup>8</sup> See the purpose sections in SEC release No.'s 34-66252, 34-66488, 34-66756, and 34-67439.

take fees might actually increase order flow, at least liquidity provisions, while PFOF might reduce it. In the traditional maker-taker model, a market venue will charge liquidity demanders and rebate (pay) liquidity suppliers, where the fee is higher than the rebate. Market participants are, therefore, incentivized to place passive orders through a subsidy provided by the takers of liquidity (Colliard and Foucault, 2012 and O'Donoghue, 2015). Foucault, Kadan, and Kandel (2013) develop a model in which the maker-taker pricing scheme intersects with algorithmic trading (use of computers to make trading decisions), which has been shown to be responsible for over 70% of U.S. volume in the equities markets (Chaboud, Chiquoine, Hjalmarsson, and Vega, 2014).<sup>9</sup> These algorithmic traders take advantage of liquidity rebates by using low-latency programs to submit large numbers of non-marketable orders. Therefore, we might expect the maker-taker model to be associated with greater limit order flow.

In contrast to make-take fees, PFOF is theorized to impede the competition among suppliers of liquidity. In the model of Parlour and Rajan (2003), PFOF arrangements make it easier for market makers to sustain wider spreads, thereby reducing competition amongst liquidity providers. The SEC expressed its concern that PFOF contributes to a trading environment in which quote competition can be discouraged.<sup>10</sup> Thus, to the extent that make-take fees encourage liquidity provisions, particularly from high-volume algorithmic traders, and PFOF discourages the submission of passive orders, we expect the following hypothesis to hold.

**H1:** Order volume is lower in the PFOF model, relative to the maker-taker model.

### *3.2. Probability of Order Execution*

---

<sup>9</sup> See also “SEC runs eye over high-speed trading,” Financial Times, July 29, 2009.

<sup>10</sup> See SEC “Special Study: Payment for Order Flow and Internalization in the Options Markets” in December 2000.

Traders could be ex ante worse off if a fee schedule reduces the probability of completing a trade. In fact, Colliard and Foucault (2012) argue that the effect of trading fees on the welfare of traders depends on how these fees affect liquidity suppliers' non-execution risk. Market participants on the PHLX can choose to buy and sell equity options using a combination of marketable and non-marketable orders. Because limit orders are stored in a limit order book and must await the arrival of a marketable order to execute, the execution of a limit order is not guaranteed. Traders, therefore, face an order submission strategy decision each time they trade. They can submit marketable orders and achieve immediacy but be exposed to price risk or, alternatively, they can submit limit orders and execute at a pre-determined price but be exposed to non-execution risk (Hollifield, Miller, and Sandas, 1996; Foucault, 1999; Peterson and Sirri, 2002).<sup>11</sup> Thus, the probability that an order is filled may depend on a number of factors, which includes the type of payment structure (Colliard and Foucault, 2012 and Brolley and Malinova, 2013).

In the maker-taker model, the trading venue pays a rebate to submitters of non-marketable orders, which it finances by levying fees on submitters of marketable orders. The maker rebates provide a clear incentive for traders to submit passive limit orders because, in theory, the rebates make limit orders cheaper than aggressive marketable orders. The resulting increase in competition in liquidity provisions lowers each order's execution probability (Foucault, Kadan, and Kandel, 2013; Malinova and Park, 2015). In contrast, the PFOF method effectively impedes competition among liquidity providers, as market makers, the primary providers of liquidity in this model, are more easily able to sustain high spreads (Parlour and Rajan, 2003). The decreased level of competition in the supply of liquidity may increase the probability of execution on each order. Thus, to the extent that

---

<sup>11</sup> Liu (2009) mentions two types of risk that limit order traders face: picking-off risk and non-execution risk. Picking-off risk is a result of limit orders providing others a free option to transact at a pre-specified price. Non-execution risk arises when the market price diverges from the limit order price.



the probability of execution for an order decreases in the maker-taker model and increases in the PFOF model, we expect the following hypothesis to hold.

**H2:** The probability of order execution is higher in the PFOF model, relative to the maker-taker model.

### 3.3. *Probability of Order Cancellation*

A feature of modern markets is that submitting orders and quickly canceling those orders is common and frequent. Canceling liquidity can adversely impact the ability of a trader to execute an order. Hasbrouck and Saar (2009) show that over 35% of orders are canceled within two seconds of submission in a sample of 100 NASDAQ-listed securities. Van Ness, Van Ness, and Watson (2015) show that order cancellation rates are increasing over time in the equities markets, reaching around 90% in 2010. Advancements in technology, the transition of exchanges to electronic trading venues, and fees are key explanations for the high levels of cancellation rates in current financial markets (Liu, 2009). In fact, in a concept release on market structure the SEC writes

*“Highly automated exchange systems and liquidity rebates have helped establish a business model for a new type of professional liquidity provider that is distinct from the more traditional exchange specialist... In particular, proprietary trading firms and the proprietary trading desks of multi-service broker-dealers now take advantage of low-latency systems and liquidity rebates by submitting large numbers of non-marketable orders (often cancelling a very high percentage of them), which provide liquidity to the market electronically.” (SEC “Concept Release on Equity Market Structure”, Release No. 34-61358; File No. S7-02-10, page 17.)*

In the maker-taker model, designated market makers play a minor role in providing liquidity, instead, limit order traders supply the bulk of the liquidity (Battalio, Shkilko, and Van Ness, 2016). As discussed above, the rebates in this model attract liquidity provisions from these less traditional

exchange specialists. If the dominant purpose of supplying liquidity in this model is to capture market rebates, then we might expect that orders which do not receive near immediate execution will be subsequently canceled. In other words, options exchanges employing the maker-taker model provide incentives for traders to quote more aggressively. Therefore, we might expect the maker-taker model to be associated with high order cancellation rates. In comparison to the maker-taker schedule, liquidity is supplied primarily by market makers in the PFOF model. Because the competition in liquidity provisions is limited to the number of purchasing market makers in this model, the need to quote aggressively is alleviated. Hence, one might expect the cancellation rates to be lower in the PFOF model, other things held constant. This leads to the following hypothesis.

**H3:** The probability of order cancellation is lower in the PFOF model, relative to the maker-taker model.

#### *3.4. Order Fill Speeds*

In addition to the risk of non-execution, orders are exposed to the uncertainty in time-to-execution. The speed dimension of execution quality has grown in importance since the proliferation of alternative trading systems, automated trading algorithms, and online trading (Blume, 2001 and Boehmer, 2005). Execution time may not be important for all traders, but for some, the opportunity cost of waiting can be significant (Lo, MacKinlay, and Zhang, 2002). Time-to-execution is a random function of many factors including order price, order size, and prevailing market conditions. We also expect payment structure to have an important impact on the time-to-execution, as Battalio, Corwin, and Jennings (2015) show that low-fee venues experience more rapid order fills than high-fee venues. In their model, all trading venues employ the make-take fee schedule, whereas we are interested in

analyzing the difference in execution quality between two competing models, the PFOF and maker-taker.

In the maker-taker model, fees to remove liquidity make aggressive orders more expensive and so, other things held constant, one might expect traders to submit less aggressive marketable orders (Malinova and Park, 2015). The depletion of liquidity-demanding orders might slow the speed with which a liquidity-supplying trader finds a counterparty. The opposite might be true in the PFOF model, in which the supply of liquidity is limited and brokers/dealers are eager to submit retail marketable orders to obtain the per-share economic inducements. Thus, we expect the following hypothesis to hold.

**H4:** Order fill speeds are more rapid in the PFOF model, relative to the maker-taker model.

#### 4. Data Description

The NASDAQ OMX PHLX Order data feed provides a real-time (nanosecond) view of simple and complex orders for equity options. This includes orders added and changes made to orders resting on the PHLX limit order book. The PHLX order records also contain the option class and series symbols.<sup>12</sup> For each option series, we extract the following information on limit orders: number of orders, order size, price, cancellations, and fills.<sup>13</sup> The size of the data set makes it difficult to use, as a single underlying stock will have both puts and calls with perhaps ten or more strike prices and 5 expiration dates, giving a total of 100 options per stock. For many stocks, the number of options far

---

<sup>12</sup> The term option class refers to all options under the same underlying stock. An option series refers to a particular option characterized by the underlying stock, option type (put or call), strike price, and expiration date (see Battalio, Hatch, and Jennings, 2004).

<sup>13</sup> This data set only identifies when an order is completely filled on the exchange. Therefore, we are not able to observe each transaction that occurs, forcing us to rely on order execution quality metrics other than bid-ask spreads. An order update is sent each time the PHLX executable volume changes from off-exchange trades, but only the order size is updated.

exceeds 100. Therefore, we eliminate option series that do not trade more than once during the trading day. We also eliminate orders reported before 9:45 a.m. from our sample because the opening rotation impedes option series from trading freely. We exclude orders reported after 3:50 p.m. because equity options are also affected by closing rotations. Complex orders (e.g., spreads and straddles) are priced as a package, so we remove them from our sample. We merge these data with closing prices and shares outstanding obtained from the Center for Research in Security Prices (CRSP).

Because we wish to examine the effect of a payment structure change on select option classes, our sample period ranges from December 2011 to December 2013. During this time period, 72 option classes were deleted from the maker-taker pricing program and placed back into the PFOF model. Of these select option classes, 42 are common stock (share codes 10 and 11) and 34 are active in every day of our sample. A list of the option classes used in this analysis is found in Table 1, along with the effective dates on which the options began trading using the PFOF pricing schedule. Also, we include the release numbers for the notice of filing and immediate effectiveness of the rule changes submitted to the Securities and Exchange Commission by the NASDAQ OMX PHLX LLC.

[Insert Table 1 Here]

In figure 1, we plot the dates of the rule changes on a timeline with the option classes effected by the amendments. There are five distinct event periods. Of the seven option classes deleted from the maker-taker program on February 1, 2012, only American International Group (AIG) meets the criteria outlined in the preceding two paragraphs. On March 1, 2012, an additional nine option classes were moved from the maker-taker model to PFOF, nine more on April 2, 2012, and five on July 2, 2012. The last set of option classes changed payment structures on January, 2, 2013.

[Insert Figure 1 Here]

We narrow our analysis down to options on stocks for which the fee structure changed from maker-taker to PFOF and to options on a sample of matched stocks. The control stock sample is

selected by matching each fee change stock with the non-fee change stock without replacement with the smallest sum, at the beginning of the sample period, of the squared percentage difference in price and the squared percentage difference in market capitalization.<sup>14</sup> We report the distribution of the price and capitalization for both fee change firms and their controls in Panel A of Table 2. The median market capitalization for fee change firms is \$54 billion, while the median capitalization for the matched control firms is \$52 billion. We test for the difference in size between the fee change firms and control firms based on both means and medians and find them to be insignificant. Similarly, the median stock prices for fee change firms and their matched control firms are \$32.75 and \$50.14, respectively. These prices are not significantly different from one another. The differences between mean prices and capitalizations between the fee change stocks and their controls are largely driven by a few stocks in the sample, such as the matched pair of Google (GOOG) and Apple (AAPL). For instance, at the time of the match, Google has a price of over \$600 and a market capitalization of \$172 billion, while Apple has a closing price of \$411 and a market capitalization of \$383 billion.

Table 2 also provides order statistics for options on both fee change firms and their matched counterparts. We aggregate the order-level data to the daily level by option series. The mean (median) order size for an option on a fee change stock is 18.26 (10) contracts, or 1,826 (1,000) shares of common stock (assuming 100 shares per contract). Similarly, the mean (median) order size for an option on a control stock is 16.94 (9.5) contracts. The average (median) limit price for an option on a fee change stock is \$10.80 (\$2.21) and \$7.51 (\$2.13) for an option on a control stock.

[Insert Table 2 Here]

The main goal of the paper is to examine the difference in order execution quality for options trading in the maker-taker model versus those in the PFOF model. We focus on four measures of execution quality used in the literature (see Battalio, Corwin, and Jennings, 2015) namely, order

---

<sup>14</sup> A similar matching method is used in Battalio and Schultz (2010) and Malinova and Park (2015).

volume, fill rates, cancel rates, and fill speeds. We measure order volume as the sum of the total number of orders added to the PHLX book for each option series per day. We find that 168 orders are submitted per day for the average option trading on a fee change stock, whereas only 75 orders are submitted daily for the average option on a control stock. The median number of orders submitted for options on a fee change stock, 14, is much closer to that of options on control stocks, 11. The traders in this market appear to be somewhat impatient as the median order is canceled within 56 seconds of order submission.

We estimate the likelihood of execution for limit orders using fill rates, similar to Foucault (1999) and Battalio, Corwin, and Jennings (2015). We estimate fill rates as the number of orders completely filled for a particular option series divided by the total number of orders submitted for that option series during the trading day. Similarly, we calculate cancellation rates as the percentage of orders canceled for an option series by day. We find that the average fill rate for an option on a fee change stock is 35.4% and the average cancellation rate is 61.3%. The average fill rate and cancellation rate for an option on a control stock are 38.0% and 58.6%.

We calculate fill speeds as the passage of time between limit order submission and complete fill. We average fill speeds to the daily level by option series. The average fill speed for an option on a fee change stock is just over 461 seconds, while the median is substantially less at 35.43 seconds. For options on control stocks, the average fill speed is 557.6 seconds with a median of 62.67 seconds. Because both order volume and fill speeds are highly skewed, we tend to focus on median results throughout the analysis.

The value of an option contract, if it were exercised, is determined by the difference between the market price and the strike price. If the strike (market) price for a call (put) option is less than or equal to the market (strike) price, then the option is in-the-money, otherwise it is out-of-the-money. The ratio of market price to strike price ( $S/X$ ) captures the moneyness component of option contracts.

For both fee change firms and control firms, the average option is close to the money, with average S/X ratios of 1.019 and 1.010, respectively. Another feature of equity options is the expiration of the contracts on the third Friday of every month. We estimate the number of days to expiration for each option series and find the median to be 49.8 days for options on fee change stocks and 46.6 days for options on control stocks.

Because prior research shows that option features, such as type (call vs. put) and moneyness, impact trading volume and execution quality (see Rubinstein, 1994; Pan and Poteshman, 2006; Battalio, Shkilko, and Van Ness, 2016), we partition the sample by options series characteristics. We separate series by option type, calls and puts, and moneyness, in-the-money and out-of-the-money. Table 3 provides the results of this analysis. In Panel A, we find that the average order volume is significantly higher for call options than for put options for fee change stocks (difference = 25.97, t-statistic = 1.75) and non-fee change stocks (difference = 19.54, t-statistic = 2.41). This is consistent with Pan and Poteshman (2006) who show that call volume exceeds put volume. Interestingly, we find that fill rates are significantly lower for call options, relative to put options. This result hold at the mean for fee-change option classes and at both the mean and median for control classes. In addition, fill speeds are significantly faster for put options than for call options, as the median fill speed for put options on fee-change stocks is 29 seconds faster than that for call options.

[Insert Table 3 Here]

The last data description that we provide is order execution quality statistics between in-the-money options and out-of-the money options. As expected, in-the-money options are more actively traded than out-of-the-money options, with an average daily order volume of 247.6, relative to 132.0 for out-of-the-money options on fee change stocks. Similar results are reported for non-fee change stocks. Fill rates are significantly higher, while cancellation rates are significantly lower, for out-of-the-money options than in-the-money options, likely due to the differences in order volume between

the option series. Lastly, fill speeds for fee change stocks are 17 seconds faster at the median for out-of-the-money options, relative to in-the-money options. We do not find fill speeds to be significantly different between in-the-money and out-of-the-money options on the control stocks. Overall, there appear to be substantial differences in execution quality across option series, which will need to be controlled for in our multivariate analysis.

## **5. The Marginal Impact of the Fee Change on Order Execution Quality**

### *5.1. Univariate Tests*

We begin to test our hypotheses by examining whether order execution quality changes for option classes that switch from the maker-taker pricing model to the PFOF model. Table 4 presents the results from an event study around the pricing model change for options on both fee change stocks and their controls. We focus on 40-day event windows  $[20, 20]$ , the 20 days before the fee change and the 20 days following the fee change, excluding the event day.

[Insert Table 4 Here]

Panel A of Table 4 reports median order volume for options on fee change stocks and control stocks during the 40-day event windows. We find that the median number of orders on options for fee change stocks decreases significantly from the pre-event window to the post-event window (difference = 1.0, p-value =  $<0.001$ ). The median number of orders on options for matched control stocks increases, however, from 10 to 12 pre- to post-event period. More interestingly, the difference in order volume in options for fee change stocks and control stocks reduces substantially after the switch from maker-taker to PFOF.

[Insert Figure 2 Here]

The top panel of Figure 2 plots 15-day moving averages of median order volume for options on fee change stocks and options on control stocks over the 2-month (40-day) event windows. We



include the event dates in Figures 2 through 5, but exclude them in the univariate analysis of Table 4. We show that order volume is increasing gradually for options on control stocks over the sample period, whereas the order volume for options on fee change stocks reduces abruptly around the event dates. The bottom panel of Figure 2 graphs the differences in order volume between options on fee change stocks and those on control stocks. It appears that the difference in the number of orders for options between the two samples declines significantly following the switch of select options classes from maker-taker to PFOF. Therefore, the findings from Panel A of Table 4 and the plots from Figure 2 provide support for our first hypothesis that limit order volume is lower in the PFOF model, relative to the maker-taker model.

Panel B of Table 4 shows that mean fill rates increase significantly for fee change stocks following the switch from the maker-taker model to the PFOF model. Specifically, the average fill rate for options on fee change stocks is higher by 1.9% in the post-event period, relative to the pre-event window. This decline is significant at the 0.01 level. In comparison, we find that fill rates decline for options on non-fee control stocks over the same time period (difference = -5.4%, t-statistic = -5.79).

[Insert Figure 3 Here]

Figure 3 plots 15-day moving averages of order fill rates for options on fee change stocks and options on control stocks during the 40-day event windows. We observe that fill rates for options on fee change stocks are substantially lower than the fill rates for options on control stocks prior to the switch to PFOF. Immediately following the event dates, fill rates for options on fee change stocks and their control stocks converge. In Panel B of Table 4 we find that mean fill rates for options on fee change stocks are 6.8% lower than fill rates for options on control stocks during the pre-event windows. The difference in fill rates between options on fee change stocks and control stocks completely disappears in the post-event windows (difference = 0.50%, t-statistic = 0.720). Therefore,

it appears that fill rates for options in the PFOF model are lower than for options in the maker-taker model, which lends support for our second hypothesis.

[Insert Figure 4 Here]

Panel C of Table 4 reports mean cancellation rates for option series on both fee change stocks and control stocks. We find that cancellation rates for options on fee change stocks decline from the pre-event period to the post-event period, albeit not significantly. In contrast, cancellation rates for options on control stocks significantly increase by 5.1% during those same time periods. The top panel of Figure 4 graphs 15-day moving averages of order cancellation rates for options on both fee change stocks and control stocks. It appears that order cancellation rates are increasing over the sample period for options on control stocks, and decreasing slightly for options on fee change stocks. The difference in cancellation rates between options on fee change stocks and control stocks, however, declines substantially following the event day.

We find, in Panel C of Table 4, that the difference in order cancellation rates for options on fee change stocks are significantly higher than for options on control stocks, in the pre-event window (difference = 6.10%, t-statistic = 7.29). Similar to order fill rates, this difference completely vanishes in the post-event window, where order cancellation rates of options on fee change stocks are not significantly different from cancellation rates of options on control stocks. The results on cancellation rates might be explained by the external effect of the increasing order fill rates for options on fee change stocks. As the orders for options on fee change stocks better compete with orders for options on control stocks, cancellation rates on orders for options on control stocks might naturally rise. The results from Panel C of Table 4 and Figure 4 suggest that order cancellation rates are not higher for options in the PFOF model, relative to options in the maker-taker model. Therefore, we cannot firmly reject hypothesis three.

We report median fill speeds for options on both control stocks and fee change stocks in Panel D of Table 4. Median fill speeds for options on fee change stocks decrease by 54.35 seconds ( $p$ -value =  $<0.001$ ) in the post-event window, relative to the pre-event window. In contrast, median fill speeds for options on control stocks increase from 51.53 seconds in the pre-event window to 70.44 seconds in the post-event window, albeit the difference is significant only at the 0.10 level. Interestingly, we find that the median fill speed for options on fee change stocks is approximately 14 seconds slower than for options on control stocks during the pre-event window. In the post-event window, however, the median fill speed for options on fee change stocks is significantly faster than for options on matched control stocks (difference = -59.32 seconds,  $p$ -value =  $<0.001$ ). Figure 5 illustrates this finding.

[Insert Figure 5 Here]

In the top panel of Figure 5 we plot 15-day moving averages of median fill rates for options on fee change stocks and options on matched control stocks. Fill speeds for options on fee change stocks substantially decline immediately following the event day, or switch to PFOF model. In contrast, the fill speeds for control stocks show no distinct pattern. We show the difference in fill speeds between options of fee change stocks and options on control stocks in the bottom panel of Figure 4. Here we observe that the shift from maker-taker to PFOF results in an improvement in the time to complete fill on a submitted limit order. Thus, the results from Panel D of Table 4 and Figure 5 provide support for our last hypothesis.

## 5.2. *Multivariate Tests*

Providing evidence that order execution quality changes for options on fee change stocks around the switch from maker-taker pricing to PFOF is not tantamount to identifying a causal link. In addition, examining the execution quality for options on fee change stocks and matched control

stocks around the change in fee structure from maker-taker to PFOF is still not enough. Therefore, we perform difference in difference regression analysis to control for other macroeconomic factors affecting order execution quality. We estimate the following regression using our sample of options on both fee change stocks and their matched control stocks.

$$\begin{aligned}
 \text{Order Execution Quality}_{i,t}^j & \\
 &= \alpha + \beta_1 \text{Post} \times \text{Fee Change}_{i,t} + \beta_2 \text{Post}_t + \beta_3 \text{Fee Change}_i \\
 &+ \beta_4 \text{Total Orders}_{i,t} + \beta_5 \text{Limit Price}_{i,t} + \beta_6 \text{Order Size}_{i,t} \\
 &+ \beta_7 \text{Underlying Size}_{i,t} + \beta_8 S/X_{i,t} + \beta_9 S/X_{i,t}^2 + \beta_{10} \text{Days Expiration}_{i,t} \\
 &+ \beta_{11} \text{Call}_{i,t} + \varepsilon_{i,t}, \quad j \in \{\text{order volume, fill rate, cancel rate, fill speed}\}
 \end{aligned} \tag{1}$$

The dependent variable is set to one of four order execution quality measures: order volume, order fill rates, order cancellation rates, or order fill speeds. We include the following as independent variables. *Post* is an indicator measure set equal to one if an observation is in the 20 (40) day post-event window, and zero otherwise. We exclude the event dates in our regression analyses and, therefore, do not include a pre-event dummy variable as to avoid violating the full column rank assumption for consistent estimates. *Fee Change* is a categorical variable equal to one if the option class transitioned from the maker-taker model to the PFOF model during the sample period, and zero for the matched control stock. *Post*  $\times$  *Fee Change* is the interaction between the two previously mentioned dummy variables. This interaction captures the marginal impact of the fee change on execution quality, or the difference in difference test.

We include the following as control variables. *Total Orders* is the average number of orders submitted for each option series, *i*, on day *t*. *Limit Price* is the average limit order price. *Order Size* is the average number of contracts submitted with a limit order. Each contract is for 100 shares of common stock. We also include the market capitalization on the underlying stock.  $(S/X)$  is the ratio of the underlying stock price to the strike price, which controls for the moneyness of the option.

$(S/X)^2$  is the square value of  $(S/X)$ , which we include to capture any non-linear relation between the moneyness of an option series and execution quality (see Battalio and Schultz, 2010). Lastly, we include the number of days until expiration for each option and an indicator variable if the option is a call. To calculate standard errors, we cluster on the underlying stock. We estimate Equation 1 using least squares, Tobit censored, and quantile (median) regressions. We report the results of this multivariate analysis in Table 5. In Panel A we use 2-month (40-day) event windows, excluding the event dates, whereas in Panel B we extend the event windows to four months (80-days) to capture the long-term effects of the fee change on order execution quality.

[Insert Table 5 Here]

In Column [1] of Panel A, we find that the average number of orders submitted for options on fee change stocks decreases by 56.73 more than options on control stocks following the switch from maker-taker pricing to PFOF, other things held constant. Because the number of orders in our sample is highly skewed, we also perform a quantile regression at the median to control for potential outliers biasing the coefficients. In Column [2] of Panel A, we find that the median number of orders submitted for options on fee change stocks declines by 1.63 more than options on control stocks after the change to PFOF, although the coefficient on the interaction term is only significant at the 0.10 level. We observe even stronger results, reported in Panel B, when we expand the event windows to four months. Thus, our results suggest that limit order volume for select option classes significantly declines following the switch from maker-taker to PFOF pricing on the PHLX exchange, which supports our first hypothesis.

Column [3] of Panel A shows that average fill rates for options on fee change stocks increases by 5.7% more than options on control stocks after the change to PFOF pricing. Because fill rates for options cluster on zero and one, we perform a Tobit regression that censors on those values, and we find similar results as the coefficient on the interaction term is positive and significant at the 0.01 level.

Specifically, average fill rates for options on fee change stocks increase by 6.4% more than for options on control stocks following the change from maker-taker pricing to PFOF. Our results provide support for the notion that order fill rates are higher in the PFOF model, relative to the maker-taker model, which supports our second hypothesis.

Next, we examine the marginal impact of the fee change on order cancellation rates. When we use 2-month event windows, the 20-days before the fee change and the 20-days after, we do not find the coefficient on the interaction term, *Post\*Fee Change*, is significant at any meaningful level. Similar to order fill rates, cancellation rates cluster on zero and one, so we also estimate Equation 1 using a Tobit model. Similar to the OLS model reported in Column [5], we find insignificant evidence that order cancellation rates are impacted by the fee change from maker-taker to PFOF. However, when we expand the event windows to four months, we find that order cancellation rates decrease significantly for options on fee change stocks following the pricing model change. In Columns [5] and [6] of Panel B, we find that cancellation rates decline between 4.6% and 5.3% more for option on fee change stocks than for options on control stocks in the post-event periods. Therefore, the change in fee structure seems to have a positive impact on the patience of limit order traders, as cancellation rates are lower in the PFOF model.

In our final set of tests in this section, we estimate both OLS and quantile (median) regressions on fill speeds for options on fee change stocks and control stocks. We find that the interaction term between *Post* and *Fee Change* is negative and significant in both Columns [7] and [8] of Panel A. These results suggest that fill speeds are significantly faster for options in the PFOF model, relative to the maker-taker model. For instance, the median option is filled 64.3 seconds faster in the PFOF model than in the maker-taker model. Qualitatively similar results are found when we expand the event windows to four months, which we report in Panel B of Table 5. Thus, we fail to reject hypothesis

three, as orders for options on the PHLX appear to fill quicker in the PFOF model, relative to the maker-taker model.

Overall, the results from this section suggest that order execution quality is superior in the PFOF model, relative to the maker-taker model. Specifically, order fill rates are higher, cancellation rates are lower, and the time between order submission and complete fill is faster. However, we do find that limit order flow is significantly lower in the PFOF model than in the maker-taker model, likely attributable to the limited competition in liquidity provisions in the PFOF model (Parlour and Rajan, 2003).

## **6. Robustness**

In this section we report the results of robustness tests that help validate our findings. Because select options classes were removed from the maker-taker model and placed back into the PFOF model over a series of dates, we are less concerned that our event study is biased due to the sample time period. However, it is still possible that order execution quality metrics changed significantly during our particular sample time periods. Therefore, we perform pseudo-event studies, where we examine order execution quality for option on fee change stocks and control stocks around alternative event dates. For the first four event dates outlined in Figure 1, we select the year immediately following the event dates as our new events days. Because our sample period runs from December 2011 to December 2013, we are not able to capture the year following the last event date, which occurs on January 2, 2013. Therefore, we randomly select October 2, 2013 as the event date as it does not conflict with any of the other event dates and it allows us sufficient time to perform our pre- and post-event tests.

[Insert Table 6 Here]

The results of these pseudo-event studies are reported in Table 6. We estimate Equation 1 for each order execution quality metric for options on both fee change stocks and control stocks. We use 40-day event windows, the 20 days before the pseudo-event dates and the 20 days after. We find that the coefficient on the interaction term between *Post* and *Fee Change* is insignificant in each regression, which provides support for our main analysis. Because we do not observe any significant change in order execution quality around the pseudo-event dates, we are more confident the fee change had a causal impact on the quality of execution for limit orders.

## 7. Concluding Remarks

Price competition between equity options markets forces exchange officials to tailor and frequently modify fees in an attempt to attract order flow. U.S. options exchanges currently operate under one of two pricing models: maker-taker or payment for order flow. In the former, liquidity providers are given a rebate, while liquidity demanders are charged a fee. In the latter, market makers pay brokers to route retail liquidity-demanding orders to their trading systems. Both pricing models have been criticized by the popular press and policymakers, as well as studied by academics (see Battalio and Holden, 2001; Foucault, Kadan, and Kandel, 2013; Malinova and Park, 2015; and Battalio, Shkilko, and Van Ness, 2016).

In this paper, we examine a sample of option classes on the PHLX exchange that changed from the maker-taker pricing model to the PFOF model. We control for market wide conditions by matching securities that were affected with those that were not. We match each option class that changed pricing models with a unique control class with the smallest sum of the squared percentage difference in price and the squared percentage difference in market capitalization. In our difference in difference tests, we find that limit order flow for options on the PHLX is significantly lower in the PFOF model, relative to the maker-taker model. However, we also find that order fill rates are higher,



order cancellation rates are lower, and order fill speeds are shorter. Therefore, the decline in order flow seems to be offset by superior order execution quality under the PFOF model, relative to the maker-taker model.

Thus, the fee structure on an exchange appears to significantly impact the execution quality of limit orders, which is important for all market participants including traders, regulators, and policymakers. Traders can be made ex ante better off if a particular fee structure increases the probability of completing a trade, shortens the time-to-execution, and reduces cancellation rates. Overall, our results suggest that for select option classes on the PHLX exchange, maker-taker pricing offers inferior order execution quality, relative to PFOF, although order volume is marginally higher.

## References

- Battalio, R. and C. W. Holden, 2001, "A Simple Model of Payment for Order Flow, Internalization, and Total Trading Cost," *Journal of Financial Markets*, 4(1), 33-71.
- Battalio, R. and P. Schultz, 2011, "Regulatory Uncertainty and Market Liquidity: The 2008 Short Sale Ban's Impact on Equity Option Markets," *The Journal of Finance*, 66(6), 2013-2053.
- Battalio, R., S. Corwin, and R. Jennings, 2014, "Can brokers have it all? On the Relationship between Make Take Fees and Limit Order Execution Quality," working paper.
- Battalio, R., B. Hatch, and R. Jennings, 2004, "Toward a National Market System for US Exchange-listed Equity Options," *The Journal of Finance*, 59(2), 933-962.
- Battalio, R., A. Shkilko, and R. Van Ness, "To Pay or be Paid? The Impact of Taker Fees and Order Flow Inducements on Trading Costs in U.S. Options Markets," forthcoming in the *Journal of Financial and Quantitative Analysis*.
- Blume, M., 2001, "The Structure of the US Equity Markets," unpublished working paper, University of Pennsylvania.
- Boehmer, E., 2005, "Dimensions of Execution Quality: Recent Evidence for US Equity Markets," *Journal of Financial Economics*, 78(3), 553-582.

- Brolley, M. and K. Malinova, 2013, "Informed Trading and Maker-Taker Fees in a Low-Latency Limit Order Market," working paper.
- Chaboud, A., B. Chiquoine, E. Hjalmarsson, and C. Vega, 2014, "Rise of the Machines: Algorithmic Trading in the Foreign Exchange Market," *The Journal of Finance*, 69(5), 2045-2084.
- Chordia, T. and A. Subrahmanyam, 1995, "Market Making, the Tick Size, and Payment-for-Order Flow: Theory and Evidence," *Journal of Business*, 543-575.
- Colliard, J. and T. Foucault, 2012, "Trading Fees and Efficiency in Limit Order Markets," *Review of Financial Studies*, 25(11), 3389-3421.
- Easley, D., N. Kiefer, and M. O'Hara, 1996, "Cream-Skimming or Profit-Sharing? The Curious Role of Purchased Order Flow," *The Journal of Finance*, 51(3), 811-833.
- Foucault, T., 1999, "Order Flow Composition and Trading Costs in a Dynamic Limit Order Market," *Journal of Financial Markets*, 2(2), 99-134.
- Foucault, T., O. Kadan, and E. Kandel, 2013, "Liquidity Cycles and Make/Take Fees in Electronic Markets," *The Journal of Finance*, 68(1), 299-341.
- Harris, L., 2013, "Maker-Taker Pricing Effects on Market Quotations," working paper, University of Southern California.
- Hasbrouck, J. and G. Saar, 2009, "Technology and Liquidity Provision: The Blurring of Traditional Definitions," *Journal of financial Markets*, 12(2), 143-172.
- Hollifield, B., R. Miller, P. Sandas, 1996, "An Empirical Analysis of a Pure Limit Order Market," working paper, Carnegie Mellon University, unpublished.
- Liu, W., 2009, "Monitoring and Limit Order Submission Risks," *Journal of Financial Markets*, 12(1), 107-141.
- Lo, A., A. MacKinlay, and J. Zhang, 2002, "Econometric Models of Limit-Order Executions," *Journal of Financial Economics*, 65(1), 31-71.
- O'Donoghue, S., 2015, "The Effect of Maker-Taker Fees on Investor Order Choice and Execution Quality in US Stock Markets," working paper.
- Pan, J. and A. Poteshman, 2006, "The Information in Option Volume for Future Stock Prices," *Review of Financial Studies*, 19(3), 871-908.
- Parlour, C. and U. Rajan, 2003, "Payment for Order Flow," *Journal of Financial Economics*, 68(3), 379-411.
- Peterson, M. and E. Sirri, 2002, "Order Submission Strategy and the Curious Case of Marketable Limit Orders," *Journal of Financial and Quantitative Analysis*, 37(2), 221-242.

Rubinstein, M, 1994, "Implied Binomial Trees," *The Journal of Finance*, 49(3), 771-818.

Van Ness, B., R. Van Ness, and E. Watson, 2015, "Canceling Liquidity," *Journal of Financial Research*, 38(1), 3-33.

**Table 1**  
**List of Select Option Classes**

This table provides a list of the select option symbols that transitioned from the maker-taker pricing model to the PFOF model during our sample period. We include the effective removal dates and the corresponding SEC filing numbers.

Option Symbol	Removal Date (Make-Take to PFOF)	SEC Release No.
AIG	2/1/2012	34-66252
GS	3/1/2012	34-66488
HAL	3/1/2012	34-66488
LVS	3/1/2012	34-66488
MGM	3/1/2012	34-66488
NVDA	3/1/2012	34-66488
QCOM	3/1/2012	34-66488
V	3/1/2012	34-66488
WYNN	3/1/2012	34-66488
X	3/1/2012	34-66488
AAPL	4/2/2012	34-66756
AMZN	4/2/2012	34-66756
AXP	4/2/2012	34-66756
C	4/2/2012	34-66756
CAT	4/2/2012	34-66756
IBM	4/2/2012	34-66756
JPM	4/2/2012	34-66756
T	4/2/2012	34-66756
XOM	4/2/2012	34-66756
EBAY	7/2/2012	34-67439
PG	7/2/2012	34-67439
SBUX	7/2/2012	34-67439
SNDK	7/2/2012	34-67439
UAL	7/2/2012	34-67439
AA	1/2/2013	34-68674
CSCO	1/2/2013	34-68674
F	1/2/2013	34-68674
GE	1/2/2013	34-68674
INTC	1/2/2013	34-68674
ORCL	1/2/2013	34-68674
PFE	1/2/2013	34-68674
SIRI	1/2/2013	34-68674
VZ	1/2/2013	34-68674
YHOO	1/2/2013	34-68674

**Table 2**  
**Descriptive Statistics**

This table provides the distribution of the price and market capitalization for the firms removed from the maker-taker model and their matched control firms. In Panels B and C, order statistics are provided for the option series included in the analysis. The definitions of the variables are found in the text.

<i>Panel A. Distribution of the price and market capitalization for fee change firms and their control firms</i>						
	Price			Market Capitalization (\$ Billions)		
	Fee Change (34 Stocks)	Control (34 Stocks)	Difference	Fee Change (34 Stocks)	Control (34 Stocks)	Difference
Mean	59.41	74.65	0.66	91.8983	67.1800	1.23
25th Percentile	18.90	28.08		19.7659	15.1382	
Median	32.75	50.14	[0.1957]	54.9614	52.6820	[0.4217]
75th Percentile	66.83	78.59		129.9933	101.1349	

<i>Panel B. Order characteristics - Fee Change Firms (maker-taker to PFOF)</i>						
	Mean	Median	Std. Dev.	Min	Max	
Order Volume (# orders)	168.906	14.000	728.463	2.000	13,150.000	
Order Size (# contracts)	18.261	8.600	36.914	1.000	1895.500	
Limit Price	10.799	2.207	23.827	0.010	862.949	
Fill Rate	0.354	0.286	0.292	0.000	1.000	
Cancel Rate	0.613	0.667	0.305	0.000	1.000	
Fill Speed (seconds)	461.946	35.425	1,229.620	<1	17,758.210	
Cancel Speed (seconds)	462.228	56.015	1,239.940	<1	19,885.160	
S/X	1.019	1.001	0.158	0.496	4.756	
Days-to-Expiration	49.839	19.000	86.689	0.000	546.000	

<i>Panel C. Order characteristics - Control Firms</i>						
	Mean	Median	Std. Dev.	Min	Max	
Order Volume (# orders)	74.691	11.000	257.009	2.000	3,711.000	
Order Size (# contracts)	16.940	9.500	26.412	1.000	439.269	
Limit Price	7.509	2.130	20.782	0.010	1,065.930	
Fill Rate	0.380	0.304	0.302	0.001	1.000	
Cancel Rate	0.586	0.667	0.313	0.000	0.999	
Fill Speed (seconds)	557.570	62.670	1,389.170	<1	18,549.070	
Cancel Speed (seconds)	480.081	58.306	1,301.550	<1	19,512.090	
S/X	1.010	1.000	0.107	0.451	2.316	
Days-to-Expiration	46.616	20.000	77.987	0.000	546.000	

**Table 3**  
**Order Execution Quality by Options Series – Fee Change and Non-Fee Change Option Classes**

This table provides the means and medians for orders execution quality metrics partitioned by option series type. The variables are defined in the text. Panel A reports the results for options separated by calls and puts, while Panel B reports the results for options separated by moneyness. Simple t-tests are used to calculate the difference in means, while Wilcoxon rank-sum tests are used to estimate the difference in medians. \*\*\*, \*\*, and \* denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

<i>Panel A. Fee Change Option Classes</i>													
	<i>Call vs. Put</i>						<i>In-the-Money vs. Out-of-the-money</i>						
	<u>Call Options</u>		<u>Put Options</u>		<u>Difference (Call - Put)</u>		<u>In-the-Money</u>		<u>Out-of-the-Money</u>		<u>Difference (In - Out)</u>		
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	
# Orders	185.379	14.000	159.410	13.000	25.969*	1.000	247.553	16.000	132.048	13.000	115.505***	3.000***	
					(1.750)	[0.361]					(7.550)	[<0.001]	
Fill Rate	0.348	0.286	0.363	0.287	-0.015**	-0.001	0.322	0.250	0.368	0.300	-0.047***	-0.050***	
					(-2.460)	[0.295]					(-7.580)	[<0.001]	
Cancel Rate	0.615	0.667	0.611	0.667	0.005	0.000	0.649	0.714	0.597	0.667	0.052***	0.048***	
					(0.730)	[0.576]					(8.100)	[<0.001]	
Fill Speed (seconds)	493.792	48.897	406.699	19.519	87.093***	29.378***	477.365	46.711	454.720	29.700	22.645	17.011***	
					(3.480)	[<0.001]					(0.870)	[<0.001]	

<i>Panel B. Non-Fee Change Matched Option Classes</i>													
	<i>Call vs. Put</i>						<i>In-the-Money vs. Out-of-the-money</i>						
	<u>Call Options</u>		<u>Put Options</u>		<u>Difference (Call - Put)</u>		<u>In-the-Money</u>		<u>Out-of-the-Money</u>		<u>Difference (In - Out)</u>		
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	
# Orders	86.906	12.000	67.370	10.000	19.535**	2.000**	98.051	17.000	64.220	10.000	33.831***	7.000***	
					(2.410)	[0.029]					(3.990)	[<0.001]	
Fill Rate	0.372	0.290	0.395	0.333	-0.023**	-0.043*	0.310	0.200	0.412	0.333	-0.102***	-0.133***	
					(-2.420)	[0.067]					(-10.300)	[<0.001]	
Cancel Rate	0.592	0.667	0.575	0.636	0.017*	0.030	0.668	0.765	0.549	0.600	0.119***	0.165***	
					(1.690)	[0.277]					(11.660)	[<0.001]	
Fill Speed (seconds)	580.530	77.219	519.255	46.675	61.275	30.543***	540.470	67.305	565.234	60.921	-24.764	6.383	
					(1.400)	[<0.001]					(-0.540)	[0.309]	

**Table 4**  
**Univariate Results**

This table provides univariate tests for both fee change firms and control firms around the pricing schedule change from maker-taker to PFOF for select option classes. We observe 40-day event windows [20, 20], the 20 days before the fee change and the 20 days after the fee change, excluding the event dates. Panels A and D report median order volume and fill speeds, while Panels B and C report mean order fill rates and cancellation rates. Simple t-tests are used to calculate the difference in means, while Wilcoxon rank-sum tests are used to estimate the difference in medians. \*\*\*, \*\*, and \* denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

	Pre	Post	Difference (Post - Pre)
<i>Panel A. Median Order Volume (# Orders)</i>			
Fee Change	14.000	13.000	-1.000*** [<0.001]
Control	10.000	12.000	2.000*** [<0.001]
Difference (Fee Change - Control)	4.000*** [<0.001]	1.000** [0.039]	
<i>Panel B. Mean Order Fill Rates</i>			
Fee Change	0.343	0.362	0.019*** (3.270)
Control	0.411	0.357	-0.054*** (-5.790)
Difference (Fee Change - Control)	-0.068*** (-8.530)	0.005 (0.720)	
<i>Panel C. Mean Order Cancellation Rates</i>			
Fee Change	0.618	0.613	-0.005 (-0.870)
Control	0.557	0.608	0.051*** (5.250)
Difference (Fee Change - Control)	0.061*** (7.290)	0.005 (0.610)	
<i>Panel D. Median Order Fill Speeds</i>			
Fee Change	65.473	11.122	-54.351*** [<0.001]
Control	51.532	70.442	18.910* [0.050]
Difference (Fee Change - Control)	13.941*** [<0.001]	-59.321*** [<0.001]	

**Table 5**  
**Marginal Impact of Fee Change**

This table reports the results of estimating the following equation for both fee change firms and controls firms around the 40-day event windows [-20, 20] where select option classes changed from the maker-taker to PFOF model.

$$Order\ Execution\ Quality_{i,t}^j = \alpha + \beta_1 Post\ x\ Fee\ Change_{i,t} + \beta_2 Post_t + \beta_3 Fee\ Change_{i,t} + \beta_4 Total\ Orders_{i,t} + \beta_5 Limit\ Price_{i,t} + \beta_6 Order\ Size_{i,t} + \beta_7 Underlying\ Size_{i,t} + \beta_8 S/X_{i,t} + \beta_9 S/X^2_{i,t} + \beta_{10} Days\ Expiration_{i,t} + \beta_{11} Call_{i,t} + \varepsilon_{i,t}$$

The variables are defined in the text. Test-statistics are reported in parentheses and are obtained from standard errors clustered by underlying stock. \*\*\*, \*\*, and \* denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

<i>Panel A. 40-Day Event Windows [-20, 20]</i>								
	Order Volume		Fill Rate		Cancel Rate		Fill Speed (seconds)	
	OLS [1]	Quantile (Median) [2]	OLS [3]	Tobit [4]	OLS [5]	Tobit [6]	OLS [7]	Quantile (Median) [8]
Post * Fee Change	-56.729*** (-3.108)	-1.634* (-1.650)	0.057** (2.541)	0.064*** (2.640)	-0.039 (-1.491)	-0.046 (-1.567)	-177.612** (-2.191)	-64.337*** (-3.613)
Post	-0.486 (-0.062)	1.680 (1.620)	-0.053** (-2.415)	-0.059** (-2.506)	0.050* (1.931)	0.057** (1.984)	30.622 (0.454)	18.870 (1.226)
Fee Change	80.521*** (2.832)	2.195 (0.949)	-0.031 (-1.366)	-0.035 (-1.438)	0.023 (0.852)	0.027 (0.924)	37.642 (0.608)	18.870 (0.656)
Total Orders			-0.000*** (-3.377)	-0.000*** (-3.307)	0.000*** (3.513)	0.000*** (3.434)	-0.081*** (-4.417)	0.002 (1.258)
Limit Price	0.169 (0.647)	-0.012 (-0.525)	-0.000 (-0.138)	-0.000 (-0.095)	0.000 (0.554)	0.000 (0.485)	0.083 (0.155)	0.030 (0.355)
Order Size (# contracts)	-0.798** (-2.243)	-0.006 (-0.446)	-0.000** (-2.434)	-0.000*** (-2.606)	0.000* (1.925)	0.000** (2.243)	1.377** (2.084)	0.119 (0.835)
Underlying Size	50.326*** (4.142)	2.430** (2.043)	-0.024** (-2.027)	-0.026** (-2.066)	0.024** (2.020)	0.027** (2.068)	-47.002** (-2.635)	-5.087 (-1.102)
S/X	181.286 (1.346)	8.785 (1.355)	-0.005 (-0.056)	-0.068 (-0.500)	-0.055 (-0.527)	0.004 (0.026)	187.882*** (3.075)	106.663*** (3.962)
S/X <sup>2</sup>	-59.002 (-1.213)	-2.968* (-1.662)	0.034 (1.599)	0.063 (1.548)	-0.024 (-0.987)	-0.056 (-1.190)	-257.479*** (-3.439)	-26.667*** (-3.179)
Days-to-Expiration	-0.782** (-2.292)	-0.030** (-2.303)	0.001*** (4.960)	0.001*** (5.167)	-0.000*** (-4.551)	-0.001*** (-4.772)	-0.247* (-1.697)	-0.102*** (-3.524)
Call	-5.274 (-0.654)	1.377* (1.936)	-0.017 (-1.224)	-0.021 (-1.295)	0.006 (0.371)	0.009 (0.491)	125.697*** (4.502)	23.777*** (4.031)
Constant	-209.182* (-1.853)	-4.265 (-0.893)	0.481*** (6.325)	0.542*** (5.376)	0.542*** (6.117)	0.482*** (3.923)	-394.201 (-1.102)	-18.915 (-0.636)
R <sup>2</sup>	0.034	0.029	0.099	0.125	0.099	0.107	0.014	0.007
N	14208	14208	14208	14208	14208	14208	14208	14208



Table 5 – Continued

	Order Volume		Fill Rate		Cancel Rate		Fill Speed (seconds)	
	OLS	Quantile (Median)	OLS	Tobit	OLS	Tobit	OLS	Quantile (Median)
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Post * Fee Change	-65.184*** (-5.469)	-3.266** (-1.963)	0.059*** (3.838)	0.065*** (3.966)	-0.046*** (-2.666)	-0.053*** (-2.761)	-150.997** (-2.384)	-46.660*** (-3.772)
Post	5.922 (0.997)	3.051*** (2.769)	-0.067*** (-4.856)	-0.074*** (-4.973)	0.069*** (4.254)	0.078*** (4.317)	4.677 (0.098)	3.199 (0.328)
Fee Change	80.641** (2.477)	2.141 (0.859)	-0.018 (-0.942)	-0.022 (-1.072)	0.012 (0.660)	0.016 (0.822)	24.366 (0.459)	11.429 (0.414)
Total Orders			-0.000*** (-3.614)	-0.000*** (-3.539)	0.000*** (3.742)	0.000*** (3.654)	-0.079*** (-4.333)	0.001** (2.021)
Limit Price	-0.713* (-1.846)	-0.022 (-1.260)	0.000 (0.167)	0.000 (0.260)	0.000 (0.127)	0.000 (0.022)	-0.299 (-0.560)	0.009 (0.190)
Order Size (# contracts)	-1.016*** (-2.655)	-0.013 (-0.796)	-0.000* (-1.693)	-0.000** (-2.010)	0.000 (0.830)	0.000 (1.302)	1.222** (2.578)	0.116 (0.886)
Underlying Size	65.246*** (4.699)	2.984** (2.439)	-0.027*** (-2.801)	-0.029*** (-2.827)	0.028*** (2.957)	0.031*** (3.004)	-45.579** (-2.410)	-2.697 (-0.827)
S/X	81.932 (0.691)	1.365 (0.327)	0.017 (0.334)	-0.025 (-0.366)	-0.059 (-0.865)	0.001 (0.009)	1197.948*** (3.556)	92.929*** (4.177)
S/X <sup>2</sup>	-38.309 (-0.867)	-1.311 (-0.835)	0.032* (1.988)	0.053** (2.446)	-0.028 (-1.376)	-0.061* (-1.777)	-250.286*** (-3.778)	-25.109*** (-3.657)
Days-to-Expiration	-0.853*** (-2.676)	-0.036** (-2.338)	0.001*** (4.693)	0.001*** (4.843)	-0.001*** (-4.386)	-0.001*** (-4.557)	-0.181 (-1.662)	-0.079*** (-3.080)
Call	-20.316*** (-4.049)	0.283 (0.243)	-0.002 (-0.192)	-0.004 (-0.323)	-0.010 (-0.861)	-0.009 (-0.683)	118.164*** (6.495)	18.799*** (3.038)
Constant	-152.136 (-1.385)	1.332 (0.354)	0.447*** (8.452)	0.493*** (8.319)	0.564*** (9.364)	0.504*** (6.240)	-321.959 (-1.125)	-14.953 (-0.579)
R <sup>2</sup>	0.038	0.034	0.114	0.137	0.117	0.123	0.015	0.007
N	26278	26278	26278	26278	26278	26278	26278	26278

**Table 6**  
**Pseudo-Event Study**

This table reports the results of estimating the following equation for both fee change firms and controls firms around the 40-day pseudo-event windows defined as the calendar year following the actual pricing model change for select option classes.

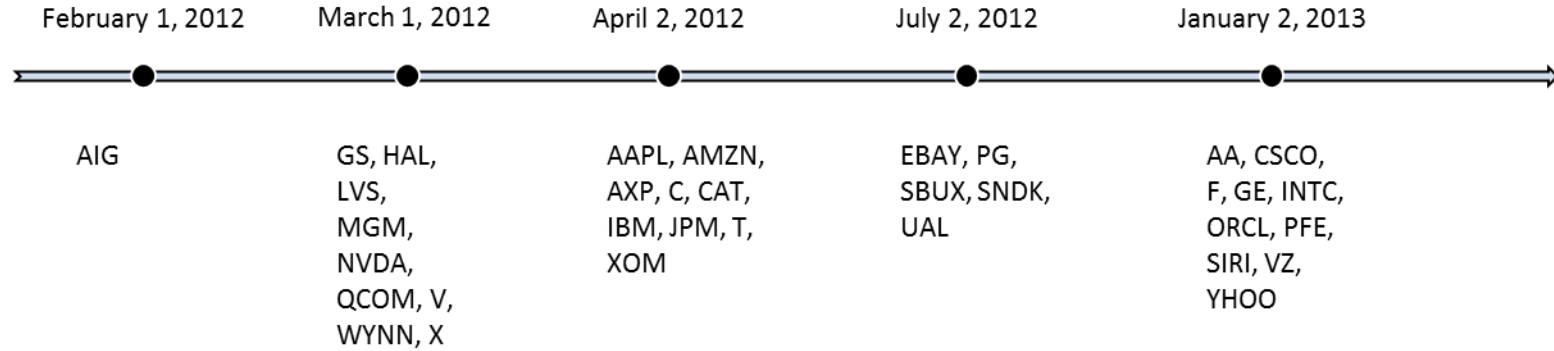
$$Order\ Execution\ Quality_{i,t}^j = \alpha + \beta_1 Post\ x\ Fee\ Change_{i,t} + \beta_2 Post_t + \beta_3 Fee\ Change_i + \beta_4 Total\ Orders_{i,t} + \beta_5 Limit\ Price_{i,t} + \beta_6 Order\ Size_{i,t} + \beta_7 Underlying\ Size_{i,t} + \beta_8 S/X_{i,t} + \beta_9 S/X^2_{i,t} + \beta_{10} Days\ Expiration_{i,t} + \beta_{11} Call_{i,t} + \epsilon_{i,t}$$

The variables are defined in the text. T-statistics are reported in parenthesis and are obtained from standard errors clustered at the firm level. \*\*\*, \*\*, and \* denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

	Order Volume		Fill Rate		Cancel Rate		Fill Speed (seconds)	
	OLS [7]	Quantile (Median) [8]	OLS [1]	Tobit [2]	OLS [3]	Tobit [4]	OLS [5]	Quantile (Median) [6]
Post * Fee Change	-161.935 (-1.522)	-0.686 (-0.154)	-0.004 (-0.151)	-0.005 (-0.175)	0.003 (0.121)	0.004 (0.147)	79.763 (1.496)	11.822 (1.149)
Post	-29.764* (-1.937)	-3.344** (-2.262)	0.019 (1.099)	0.019 (1.075)	-0.017 (-1.038)	-0.018 (-1.020)	-93.341* (-1.955)	-9.109 (-0.927)
Fee Change	170.957* (1.752)	3.583 (0.706)	-0.007 (-0.283)	-0.007 (-0.278)	0.010 (0.392)	0.010 (0.385)	-127.661** (-2.641)	-9.302 (-0.977)
Total Orders			-0.000*** (-2.921)	-0.000*** (-2.915)	0.000*** (2.971)	0.000*** (2.963)	-0.011*** (-5.654)	0.001 (1.120)
Limit Price	2.473*** (3.435)	0.000 (0.001)	0.000 (0.611)	0.000 (0.803)	-0.000 (-0.113)	-0.000 (-0.320)	-1.907*** (-3.154)	-0.024 (-0.880)
Order Size (# contracts)	-0.135 (-0.429)	0.000 (0.027)	-0.000*** (-4.145)	-0.000*** (-4.099)	0.000*** (4.205)	0.000*** (4.154)	0.778** (2.139)	0.027 (0.436)
Underlying Size	77.613*** (2.762)	4.640** (2.349)	-0.028*** (-2.689)	-0.028*** (-2.651)	0.028*** (2.865)	0.029*** (2.814)	-20.104 (-0.806)	1.244 (1.299)
S/X	601.381 (0.995)	9.170 (0.249)	-0.295 (-0.932)	-0.311 (-0.928)	0.369 (1.074)	0.401 (1.087)	-484.828 (-0.719)	-52.345 (-0.685)
S/X <sup>2</sup>	-214.545 (-1.003)	-5.795 (-0.392)	0.182 (1.499)	0.192 (1.496)	-0.216 (-1.643)	-0.234* (-1.648)	329.325 (1.114)	23.169 (0.676)
Days-to-Expiration	-0.546** (-2.322)	-0.053*** (-3.947)	0.001*** (5.472)	0.001*** (5.210)	-0.001*** (-5.205)	-0.001*** (-4.931)	0.097 (1.075)	-0.015** (-2.298)
Call	34.183 (1.532)	4.318*** (2.762)	-0.023*** (-3.833)	-0.023*** (-3.744)	0.021*** (3.548)	0.021*** (3.422)	35.823** (2.077)	3.280*** (3.624)
Constant	-675.769 (-1.324)	-3.853 (-0.130)	0.493** (2.044)	0.502** (1.982)	0.451* (1.758)	0.433 (1.592)	610.842 (1.521)	35.640 (0.778)
R <sup>2</sup>	0.015	0.010	0.086	0.605	0.085	0.431	0.009	0.001
N	12817	12817	12817	12817	12817	12817	12817	12817

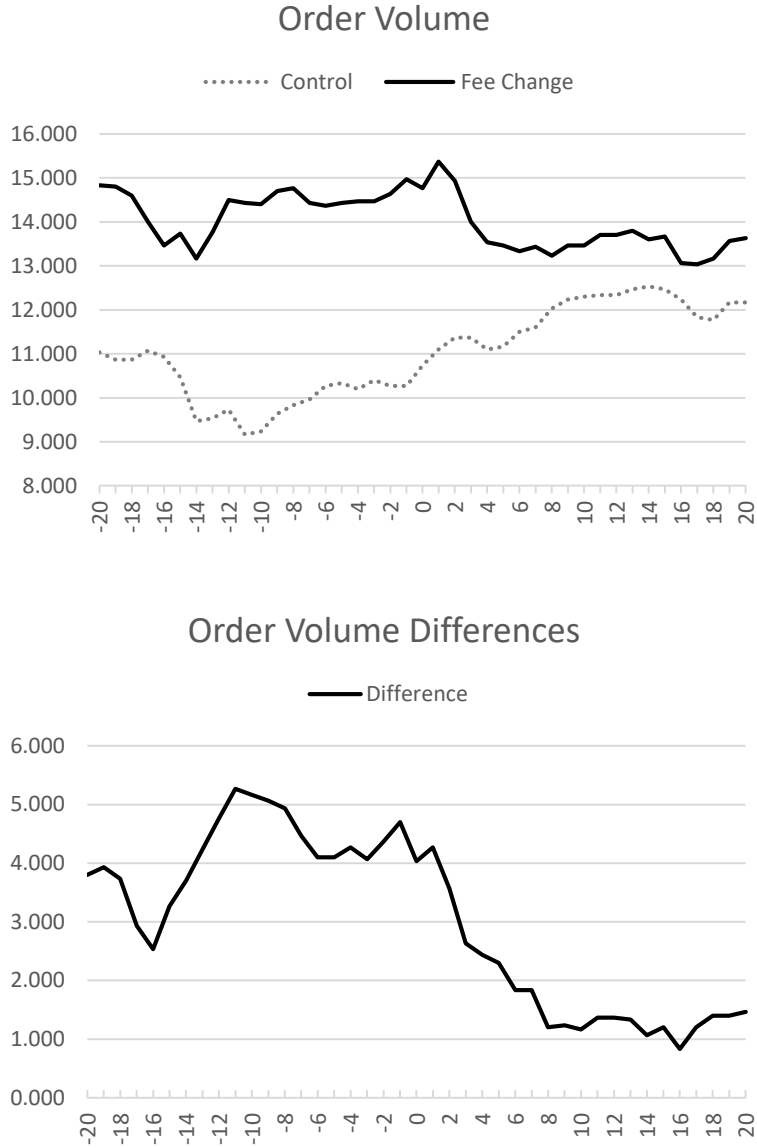
**Figure 1**  
**Timeline for Fee Change Option Classes**

This figure provides a timeline for the 5 separate dates on which select options classes transitioned from the maker-taker model to the PFOF model.



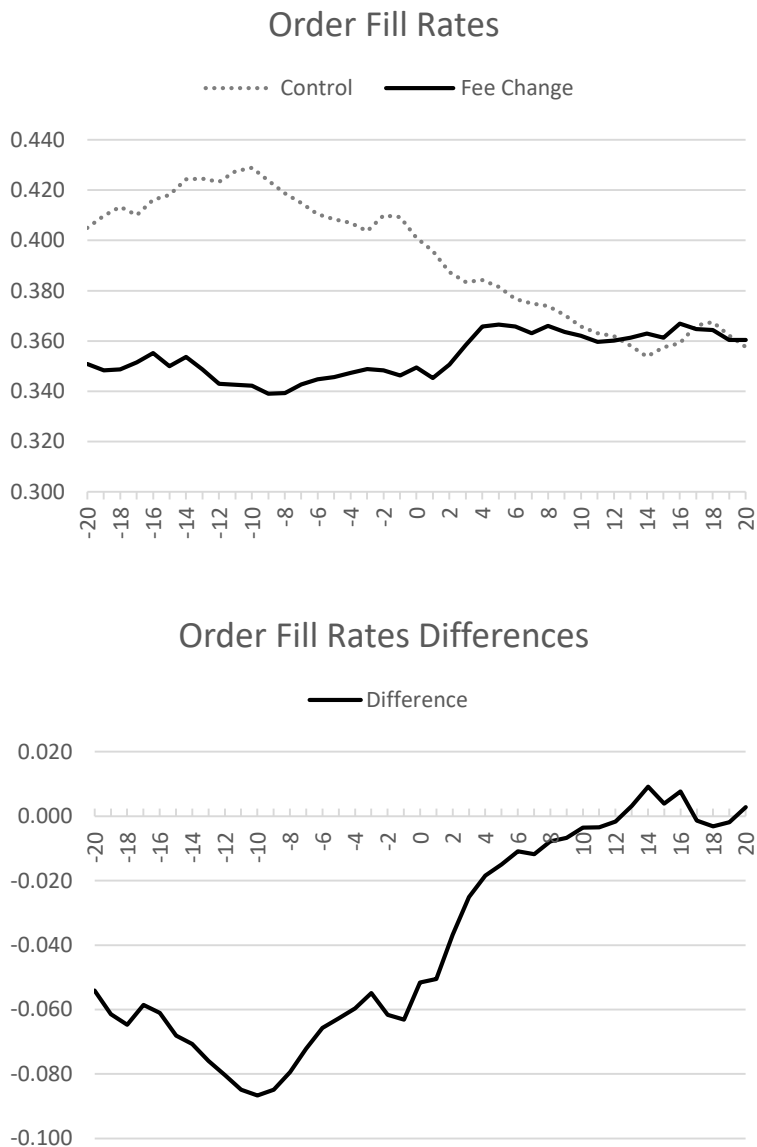
**Figure 2**  
**Order Volume (# Orders)**

Figure 2 plots 15-day moving averages of median order volume for options on fee change stocks and options on control stocks during the 2-month (40-day) event windows, including the event dates. The bottom panel plots the differences in order volume for options on fee change stocks and options on matched control stocks. Order volume is measured as the number of limit orders submitted per day by option series.



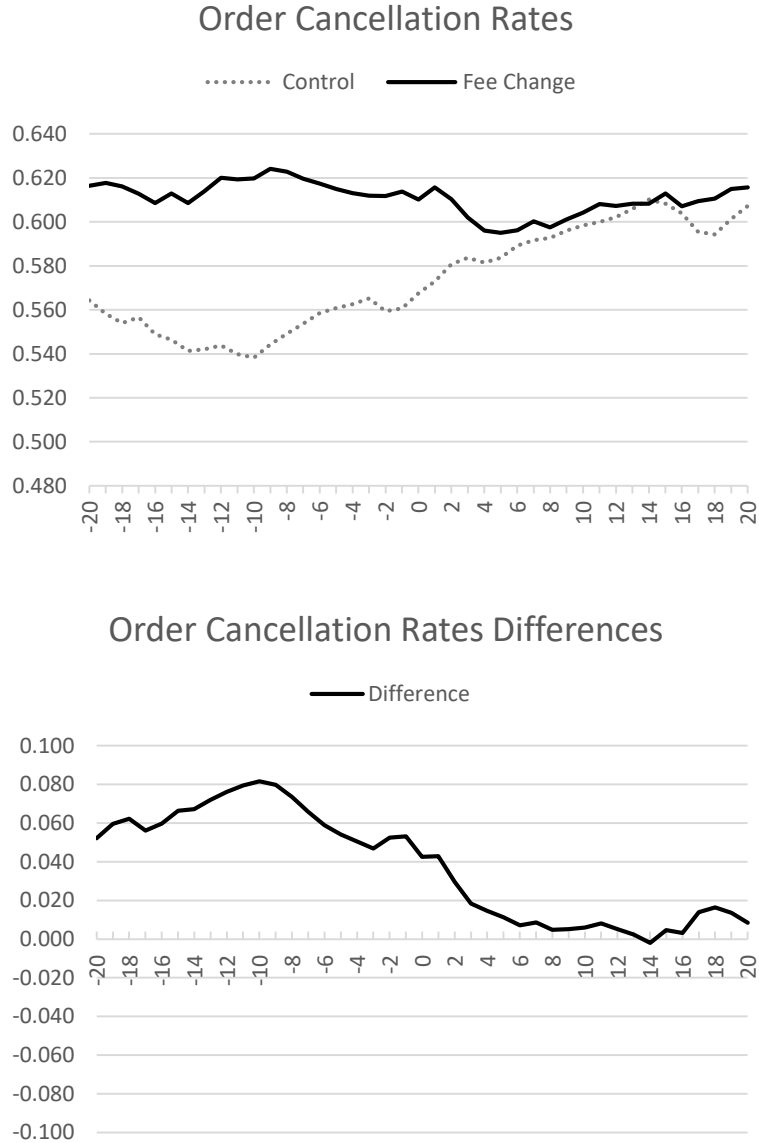
**Figure 3**  
**Limit Order Fill Rates**

Figure 3 plots 15-day moving averages of mean order fill rates for options on fee change stocks and options on control stocks during the 2-month (40-day) event windows. The bottom panel plots the differences in fill rates for options on fee change stocks and for options on matched non-fee change stocks. Order fill rates are measured as the number of orders filled divided by the total number of orders submitted.



**Figure 4**  
**Limit Order Cancellation Rates**

Figure 4 plots 15-day moving averages of mean order cancellation rates for options on fee change stocks and options on control stocks during the 2-month (40-day) event windows. The bottom panel plots the differences in order cancellation rates for options on fee change stocks and for options on matched control stocks. Order cancellation rates are measured as the number of orders canceled divided by the total number of orders submitted.



**Figure 5**  
**Limit Order Fill Speeds**

Figure 5 plots 15-day moving averages of median order fill speeds for options on fee change stocks and options on control stocks over the 2-month (40-day) event windows. The bottom panel plots the differences in fill speeds for options on fee change stocks and for options on matched control stocks. Fill speeds are measured as the passage of clocktime between limit order submission and complete fill.

