

# Do (Should) Brokers Route Limit Orders to Options Exchanges that Purchase Order Flow?

## Internet Appendix

### ***A. Access fees and rebates***

In this section, we provide a more detailed review of the exchange fees and rebates provided by the independent broker Investment Technologies Group (ITG). Specifically, we provide data on access fees and rebates for all market participants as of January 1, 2012, July 1, 2012, December 1, 2012, and January 2017. As noted by Lakonishok et al. (2006), Customer orders include those placed by customers of discount and full service brokers, BD orders are those placed by broker dealers, MM orders are those placed by market makers, Professional orders are those placed by professional traders, and proprietary orders include orders placed by employees of investment banks that are trading for the banks' own account. Fees and rebates are expressed in dollars per contract. PFOF (MT) indicates the fees and rebates apply to option classes trading under the PFOF (MT) model. These data are reported in Table A below. Importantly, we note that a more recent fee environment (January 2017) in equity options is similar to the one under examination in this study.

### ***B. Extended market share analysis***

In the market share analysis reported in the manuscript, we concentrate on trades at the NBB or the NBO when all relevant venues are quoting at the inside quote. In Table BI, we present the unconditional market share analysis. Panel A reveals that the PHLX's market share of regular, auto ex, spread, and straddle trades executed at the NBB or the NBO does not change when option classes are migrated from MT to PFOF while the CBOE's market share of these trades falls from 19.27% to 17.15%. Panel B reveals that the market share of regular, auto ex, spread, and straddle trades in control option classes rises on the PHLX and the NOM and falls on ARCA from the Pre to the Post period. We believe that these tests do not reveal the association between take fees and market share since order routers often do not have a choice as to where to route marketable customer orders (e.g., the only exchange at the best quote may be an exchange utilizing the MT model).

To better understand how the migration of option classes from the MT to the PFOF model on the PHLX impacts the routing of marketable customer orders when routers have a choice of venues, we follow Battalio, Corwin, and Jennings (2016) and examine the market share of trades executed when all relevant venues are at the inside quote. We believe these tests illustrate how take fees impact the routing of marketable customer orders in equity option markets. Our results suggest that at the margin, the PHLX's decision to stop charging brokers \$0.31 per contract to execute marketable customers and instead begin paying brokers for these orders caused the movement of marketable customer orders from the CBOE to the PHLX. If the PHLX had instead lowered its take fee for customer orders so that it positive but less than the ISE's take fee of \$0.15 per contract, we find it extremely unlikely that marketable customer order flow would have shifted from the CBOE (which pays brokers for their marketable customer orders) to a venue that charges brokers to execute their marketable customer orders.

Since intermarket sweep orders (ISOs) are key to how the MT and PFOF structures interact, we examine them separately. Unconditionally, we expect the PHLX market share of sweep trades to fall when option classes migrate to the PFOF model given the results in Anand et al. (2016). When all venues are at the inside quote, we expect order routers to preference exchanges with the lowest take fees. Table AI indicates that the PFOF venues generally have lower take fees for different market participants than the MT venues. As a result, we would expect the PHLX market share of sweep trades executed when all venues are at the inside quote to increase when option classes migrate to the PFOF model. The evidence presented in Table BII is consistent with this conjecture.

As spreads and straddles tend to be concentrated on PFOF exchanges, we examine them separately in our market share analysis. The results in Table BIII indicate that the PHLX's market share of spreads, straddles, buy writes, and combo trades does not change across the migration (pseudo-migration) of sample (control) option classes to the PFOF model. These results suggest that these types of orders did not make up a significant percentage of the orders purchased by the PHLX after it transitioned to the PFOF model.

### *C. Description of PHLX historical order data*

The NASDAQ OMX PHLX historical market data feed tracks both simple and complex orders submitted to the PHLX book. This includes nanosecond information on orders added and

changes made to orders on the PHLX. The PHLX reports a simple order message when a single order is received, or a change is made to an existing order. “Simple order” messages include the following fields: nanosecond time stamp, day-unique order id, market side (buy or sell), underlying security symbol, expiration date, explicit strike price, option type (call or put), original order volume, executable order volume (can increase or decrease as the size available for trading changes due to away exchange routing), order status (open, filled, or canceled), limit price, time in force (day order or good till canceled), and customer/firm identifier (customer, firm, market maker, broker/dealer, or professional). This dataset allows users to track an order from submission to either complete fill or cancellation. One limitation of the dataset is that it does not provide information on market maker quotations nor on partial executions.

In Panel A of Table C below, we provide details on the number of orders submitted by each trader type. We only report the orders on option/class day observations that meet our screening requirement of at least one complete order fill. We also only report the order flow for the 2-month window prior to the migration (or pseudo-migration) to PFOF. Customers submit the most marketable limit orders, while professionals and firms submit the most nonmarketable limit orders. In Panel B of Table C, we report the average daily order fill rates across migrating (control) option classes in the 2-month window prior to the migration (pseudo-migration). Here we can see that average order fill rates are highest for broker/dealers and customers and lowest for professionals. If we remove the one complete order fill screening requirement, we find drastic decreases in unconditional order fill rates for all trader types.

Table A. Snapshots of make take fees for different options market participants.

We present the make rebates and take fees generated by orders seeking to trade options in the Penny Pilot Program that are routed to exchanges by ITG in January 2012. Throughout 2012, the PHLX and the ISE use the PFOF model to arrange trades in certain option classes and the MT model to arrange trades in others. As noted by Lakonishok et al. (2006), Customer orders include those placed by customers of discount and full service brokers, BD orders are those placed by broker dealers, MM orders are those placed by market makers, Professional orders are those placed by professional traders, and proprietary orders include orders placed by employees of investment banks that are trading for the banks' own account. Fees and rebates are expressed in dollars per contract. PFOF (MT) indicates the fees and rebates apply to option classes trading under the PFOF (MT) model.

Panel A. January 2012.

		Customer	BD	MM	Professional	Proprietary
<b>PFOF</b>						
AMEX	Make	0.00	0.20	0.00	0.20	0.20
	Take	0.00	0.20	0.00	0.20	0.20
CBOE	Make	0.00	0.45	0.20	0.20	0.20
	Take	0.00	0.45	0.20	0.20	0.20
ISE	Make	0.00	0.20	0.00	0.20	0.20
	Take	0.00	0.20	0.00	0.20	0.20
MIO	Make	0.00	0.45			
	Take	0.00	0.45			
PHLX	Make	0.00	0.45	0.00	0.20	0.25
	Take	0.00	0.45	0.00	0.20	0.25
<b>MT</b>						
BOX	Make	0.29	0.62	0.62	0.42	0.62
	Take	-0.15	0.18	0.18	-0.02	0.18
ISE Select	Make	0.00		0.10	0.10	0.10
	Take	0.15		0.28	0.29	0.29
PHLX Select	Make	-0.26	0.05	0.00	-0.23	0.05
	Take	0.31	0.45	0.00	0.45	0.45
C2OX	Make	-0.37	-0.35	-0.40	-0.35	-0.35
	Take	0.44	0.45	0.45	0.45	0.45
BATS	Make	-0.30	-0.22	-0.22	-0.22	-0.22
	Take	0.44	0.44	0.44	0.44	0.44
NOM	Make	-0.26	-0.10	-0.30	-0.29	-0.10
	Take	0.45	0.45	0.45	0.45	0.45
ARCA	Make	-0.25	-0.10	-0.32		-0.10
	Take	0.45	0.45	0.45		0.45

Panel B. July 2012.

		Customer	BD	MM	Professional	Proprietary
<b>PFOF</b>						
AMEX	Make	0.00	0.28	0.20	0.28	0.20
	Take	0.00	0.28	0.20	0.28	0.20
CBOE	Make	0.00	0.45	0.20	0.30	0.20
	Take	0.00	0.45	0.20	0.30	0.20
ISE	Make	0.00	0.20	0.25	0.20	0.20
	Take	0.00	0.20	0.25	0.20	0.20
MIO	Make	0.00	0.45			
	Take	0.00	0.45			
PHLX	Make	0.00	0.45	0.00	0.25	0.40
	Take	0.00	0.45	0.00	0.25	0.40
<b>MT</b>						
BOX	Make	0.29	0.62	0.62	0.42	0.62
	Take	-0.15	0.18	0.18	-0.02	0.18
ISE Select	Make	0.00		0.10	0.10	0.10
	Take	0.15		0.28	0.29	0.29
PHLX Select	Make	-0.26	0.05	0.00	-0.23	0.05
	Take	0.39	0.45	0.00	0.45	0.45
C2OX	Make	-0.37	-0.35	-0.40	-0.35	-0.35
	Take	0.44	0.45	0.45	0.45	0.45
BATS	Make	-0.30	-0.22	-0.22	-0.22	-0.22
	Take	0.44	0.45	0.45	0.45	0.45
NOM	Make	-0.26	-0.10	-0.30	-0.29	-0.10
	Take	0.45	0.45	0.45	0.45	0.45
ARCA	Make	-0.25	-0.10	-0.32		-0.10
	Take	0.45	0.45	0.45		0.45

Panel C. December 1, 2012.

		Customer	BD	MM	Professional	Proprietary
<b>PFOF</b>						
AMEX	Make	0.00	0.28	0.20	0.28	0.20
	Take	0.00	0.28	0.20	0.32	0.20
CBOE	Make	0.00	0.45	0.20	0.30	0.20
	Take	0.00	0.45	0.20	0.30	0.20
ISE	Make	0.00	0.20	0.20	0.20	0.20
	Take	0.00	0.20	0.20	0.20	0.20
MIO	Make	0.00	0.45			
	Take	0.00	0.45			
PHLX	Make	0.00	0.45	0.00	0.25	0.40
	Take	0.00	0.45	0.00	0.25	0.40
<b>MT</b>						
BOX	Make	0.29	0.62	0.62	0.42	0.62
	Take	-0.15	0.18	0.18	-0.02	0.18
ISE Select	Make	0.00		0.10	0.10	0.10
	Take	0.15		0.32	0.33	0.33
PHLX Select	Make	-0.26	0.05	0.00	-0.23	0.05
	Take	0.43	0.45	0.00	0.45	0.45
C2OX	Make	-0.37	-0.35	-0.40	-0.35	-0.35
	Take	0.44	0.45	0.45	0.45	0.45
BATS	Make	-0.30	-0.22	-0.25	-0.25	-0.25
	Take	0.45	0.45	0.47	0.47	0.47
NOM	Make	-0.26	-0.10	-0.30	-0.29	-0.10
	Take	0.45	0.45	0.47	0.47	0.47
ARCA	Make	-0.25	-0.10	-0.32		-0.10
	Take	0.45	0.45	0.45		0.45

Panel D. January 1, 2017.

		Customer	BD	MM	Professional	Proprietary
<b>PFOF</b>						
AMEX	Make	0.00	0.50	0.25	0.50	0.42
	Take	0.00	0.50	0.25	0.50	0.42
CBOE <sup>1</sup>	Make	0.00	0.47	0.23	0.47	0.47
	Take	0.00	0.47	0.23	0.47	0.47
ISE <sup>1</sup>	Make	0.00		0.10	0.10	0.10
	Take	0.00		0.45	0.45	0.45
MIO	Make	0.00	0.47	0.23	0.47	
	Take	0.00	0.47	0.23	0.47	
PHLX <sup>1</sup>	Make	0.00	0.48	0.22	0.48	0.48
	Take	0.00	0.48	0.22	0.48	0.48
<b>MT</b>						
BOX	Make	0.05				
	Take	0.05				
BX	Make	0.39	0.46	0.39	0.46	0.46
	Take	0.00	0.46	0.46	0.46	0.46
EDGX	Make	-0.05	0.48	0.19	0.48	0.48
	Take	-0.05	0.48	0.19	0.48	0.48
GMNI	Make	-0.25		-0.30	-0.25	-0.25
	Take	0.45		0.49	0.49	0.49
MCRY	Make	-0.05		0.25	0.47	0.47
	Take	-0.05		0.20	0.47	0.47
C2OX	Make	-0.42	-0.40	-0.45	-0.40	-0.40
	Take	0.49	0.50	0.50	0.50	0.50
BATS	Make	-0.30	-0.22	-0.25	-0.25	-0.25
	Take	0.45	0.45	0.47	0.47	0.47
NOM	Make	-0.26	-0.10	-0.20	-0.20	-0.10
	Take	0.50	0.50	0.50	0.50	0.50
ARCA	Make	-0.25	-0.10	-0.28	-0.25	-0.10
	Take	0.49	0.50	0.50	0.50	0.50

Notes: Data are obtained from ITG and reflect the fees they expected to incur when routing options orders. <sup>1</sup>SIG PFOF of \$0.10/contract (\$0.05/contract) on orders for 200 or fewer (more than 200) contracts in penny pilot options and \$0.35/contract (\$0.20/contract) on orders for 200 or fewer (more than 200) contracts in non-penny pilot options.

Table BI. Unconditional market shares of regular, auto ex, spread, and straddle trades

**Panel A** reports across-class average market share of regular, auto ex, spread, and straddle trades executed at the NBB or the NBO in the 35 sample option classes that migrate from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	61,152	23.47%	19.27%	11.09%	9.11%	5.14%	14.74%	11.41%
Post	61,213	23.46%	17.15%	11.45%	9.37%	5.32%	15.59%	11.99%
Post-Pre		-0.01%	-2.12%***	0.36%	0.26%	0.18%	0.85%*	0.58%
% (Post – Pre) > 0		51.43%	17.14%	62.86%	57.14%	62.86%	77.14%	62.86%

**Panel B** reports across-class average market shares of regular, auto ex, spread, and straddle trades executed at the NBB or the NBO in the 35 control option classes before and after their matched option class migrates from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	17,743	23.46%	18.86%	10.56%	12.76%	5.76%	14.56%	7.68%
Post	18,914	23.22%	18.00%	10.64%	14.26%	5.95%	12.97%	8.67%
Post-Pre		-0.24%	-0.86%	0.08%	1.50%***	0.19%	-1.59%**	0.98%***
% (Post – Pre) > 0		51.43%	34.27%	51.43%	68.57%	51.43%	40.00%	74.29%



Table BII. Market shares of sweep trades

**Panel A** reports across-class average market shares of sweep trades executed at the NBB or the NBO in the 35 sample option classes that migrate from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	7,198	24.27%	8.35%	9.49%	12.93%	7.33%	19.14%	8.83%
Post	6,134	20.83%	8.83%	10.04%	9.75%	8.59%	20.76%	11.09%
Post – Pre		-3.44%***	0.48%	0.55%	-3.18%***	1.25%*	1.62%	2.26%***
% Post – Pre > 0		42.86	54.29%	54.29%	14.29%	65.71%	68.57%	80.00%

**Panel B** reports across-class average market shares of sweep trades executed at the NBB or the NBO in the 35 control option classes before and after their matched option class migrates from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	1,398	25.72%	9.72%	8.40%	12.00%	7.54%	18.81%	4.88%
Post	1,882	25.35%	11.08%	8.48%	12.84%	7.88%	13.83%	6.72%
Post – Pre		-0.37%	1.35%*	0.10%	0.84%	0.34%	-4.98%***	1.84%***
% Post – Pre > 0		51.43%	57.14%	54.29%	71.43%	54.29%	28.57%	85.71%

**Panel C** reports across-class average market shares of sweep trades executed at the NBB or the NBO when all relevant exchanges are at the best quote in the 35 sample option classes that migrate from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	1,202	45.28%	13.44%	5.76%	11.17%	2.12%	5.30%	0.79%
Post	764	30.57%	10.72%	6.76%	25.94%	3.13%	2.07%	1.34%
Post – Pre		-14.72%***	-2.72%**	1.00%**	14.78%***	1.02%	-3.23%**	0.55%**
%Post – Pre > 0		2.86	28.57%	54.29%	97.14%	60.00%	34.29%	74.29%

**Panel D** reports across-class average market shares of sweep trades executed at the NBB or the NBO when all relevant exchanges are at the best quote in the 22 control option classes before and after their matched option class migrates from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	259	26.57%	5.86%	9.88%	28.21%	1.42%	8.70%	0.78%
Post	390	18.46%	7.67%	9.79%	33.56%	2.06%	2.30%	0.96%
Post – Pre		-8.12%**	1.81%*	-0.09%	5.35%	0.64%	-6.40%**	0.18%
% Post – Pre > 0		31.82%	54.55%	54.5%	77.27%	45.45%	36.36%	45.5%

Table BIII. Market shares of spreads and straddles

**Panel A** reports across-class average market shares of spreads, straddles, buy writes, and combo trades executed at the NBB or the NBO in the 35 sample option classes that migrate from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	10,422	9.36%	29.26%	47.18%	7.95%	0.00%	3.78%	0.00%
Post	7,686	9.53%	26.14%	50.46%	7.02%	0.00%	3.48%	0.00%
Post – Pre		0.17%	-3.12%**	3.29%**	-0.93%	0.00%	-0.30%	0.00%
% Post – Pre > 0		48.57%	28.57%	74.29%	40.0%	n.a.	48.57%	n.a.

**Panel B** reports across-class average market shares of spreads, straddles, buy writes, and combo trades executed at the NBB or the NBO in the 35 control option classes before and after their matched option class migrates from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	1,959	5.18%	28.61%	50.39%	12.22%	0.00%	1.93%	0.00%
Post	2,099	6.72%	24.06%	52.49%	12.62%	0.00%	2.19%	0.00%
Post – Pre		1.54%**	-4.56***	2.10%	0.41%	0.00%	0.26%	0.00%
% Post – Pre > 0		62.86%	17.14%	51.43%	62.86%	n.a.	60.00%	n.a.

**Panel C** reports across-class average market shares of spreads, straddles, buy writes, and combo trades executed at the NBB or the NBO when all relevant exchanges are at the best quote in the 35 sample option classes that migrate from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	884	13.35%	26.54%	46.37%	6.64%	0.00%	4.84%	0.00%
Post	829	14.14%	21.81%	51.02%	5.69%	0.00%	3.98%	0.00%
Post – Pre		0.80%	-4.73***	4.65%**	-0.95%	0.00%	-0.86%	0.00%
% Post – Pre > 0		51.53%	22.86%	62.86%	40.00%	n.a.	54.29%	n.a.

**Panel D** reports across-class average market shares of spreads, straddles, buy writes, and combo trades executed at the NBB or the NBO when all relevant exchanges are at the best quote in the 22 control option classes before and after their matched option class migrates from the maker-taker model to the PFOF model.

	N (median)	AMEX	CBOE	ISE	PHLX	BATS	ARCA	NOM
Pre	178	9.49%	29.55%	49.73%	7.00%	0.00%	1.86%	0.00%
Post	355	16.29%	22.78%	48.38%	6.59%	0.00%	2.96%	0.00%
Post – Pre		6.80%*	-6.77***	-1.35%	-0.41%	0.00%	1.10%**	0.00%
% Post – Pre > 0		63.64%	27.27%	40.91%	54.55%	n.a.	54.55%	n.a.

Table C. Order flow and order fill rates by trader type

**Panel A** reports aggregated order flow by trader type for migrating option classes and control option classes in the pre-migration period.

	Migrate		Control	
	# of orders		# of orders	
	Marketable	Nonmarketable	Marketable	Nonmarketable
Broker/Dealer	1,504	14,740	209	5851
Customer	28,451	218,452	8,297	55,993
Firm	8,061	1,209,104	2,463	283,803
Market Maker	618	10,241	292	3066
Professional	8,058	2,331,927	1,427	362,477
Total	46,692	3,784,464	12,688	711,190

**Panel B** reports average order fill rates by trader type for migrating option classes and control option classes in the pre-migration period. For comparison purposes, we show the average order fill rates with and without requiring one order fill in a particular option class/day.

	Migrate		Control	
	Fill screen	No fill screen	Fill screen	No fill screen
Broker/Dealer	53.77%	23.98%	65.75%	34.21%
Customer	35.51%	31.91%	40.97%	30.93%
Firm	33.19%	18.85%	33.94%	20.01%
Market Maker	42.14%	20.56%	57.66%	25.28%
Professional	4.18%	1.23%	6.69%	1.00%