Online Appendix

EC.1. Supplementary discussion

EC.1.1. Parent order statistics in *Not Exposed* and *Exposed* samples

In this section, we examine parent order statistics for the *Not Exposed* and *Exposed* samples. Table EC.6 provides the order characteristics of each client in *Not Exposed* group and compares the average characteristics across two samples. We specifically examine the participation rate, the duration of the parent order, the stock price volatility while the parent order is being worked, the percentage of the parent orders' dollar volume executed in the BODP, and the percentage of the parent orders' dollar volume executed by an ELP. On average, the participation rate (duration) of the *Exposed* parent orders is 76 bps lower (66 minutes longer) than the orders that were not exposed to ELPs. There is no difference in volatility across the two sets of parent orders. Given that trading costs are generally increasing in participation rate, all else equal, these statistics suggest that the *Exposed* parent orders will have lower overall trading costs.

We observe that each client has quite different order characteristics. For example, client 6 has a large participation rate and relatively short duration, which may lead to higher execution costs at the parent order level. Conversely, client 2 has a relatively small participation rate but longer duration, which can lead to lower trading costs. In contrast to clients 4, 5 and 6, who execute between 7% and 15% of their child orders in our data provider's dark pool, clients 1, 2, and 3 have no exposure to the broker's dark pool. One takeaway from this heterogeneity is that there does not seem to be a common pattern across these six investors aside from the fact that they avoid ELPs.[23]

EC.1.2. Comparison of the data with other institutional trading data sets

In terms of order size and participation rate, our parent order execution data are very similar to other data sets employed in the broader microstructure literature. For example, Anand et al. (2011) find the average daily participation rate of the institutions in the Ancerno institutional order database is 2.1% of the total market volume between 1999 and 2008 (1.0% in 2008). Compared to the Ancerno data, our data set has information on the exact start- and end-time of the parent order execution (i.e., order duration), the interval volume during the execution period of the parent order (that helps us compute participation rate), the algorithm type (i.e., VWAP), and interval return.[24] More

[23] Although the investor identities are masked, the description field regarding the parent order identifier may signal the true identity of the investor. For three of these six clients, we observe that texts like "BNP," "SUSQ" and "FID" appear suggesting that these orders may be coming from BNP Paribas, Susquehanna International Group and Fidelity Investments, respectively. For the remaining clients, we observe "AMC," "AMMN" and "TXP" appearing in their parent order identifiers. Overall, this group of investors does not seem to be part of the broader ELP group. We thank Andy Puckett for suggesting this check.

[24] Hu et al. (2018) report that Ancerno data set has client identifiers only through 2011.

importantly, we have information on the executed child orders, e.g., the price, quantity and execution venue of the child order, which enables us to study the impact of interacting with ELPs in the dark.

Korajczyk and Murphy (2019) and van Kervel and Menkveld (2019) also employ institutional trading data (from Canada and Sweden, respectively) to examine the impact of high-frequency trading on parent order execution costs. Korajczyk and Murphy (2019) report an average trade size of $2.2 million with a participation rate of 2.5%. van Kervel and Menkveld (2019) examine roughly 5,000 parent orders (inferred from individual child order trades) from Sweden during a similar time period as our data and report an average trade size of $2.2 million corresponding to a participation rate of 3.6%. Overall, these similar statistics support the representativeness of our institutional trading data.

EC.2. Robustness tests

In this section, we assess the robustness of main finding on the positive correlation between execution costs and ELP exposure in four different tests: different proxies of ELP exposure, excluding the activity of the most active ELP, using a different benchmark price to compute overall trading costs, and controlling for the information content of the parent order.

EC.2.1. Different proxies of ELP exposure

Our current proxy of ELP exposure potentially understates the exposure to low-fill rate venues. To address this concern, we run our main regressions with two additional proxies: Dollar-based (e.g., *FracDolELP* would measure the dollar volume executed in ELP venues) and binary variables of trade exposure (e.g., *HasELP* would be 1 if there is a child order trade by an ELP and zero otherwise). In the low-fill-rate venues, the dollar volume of each single fill would be typically higher which can partially offset the exposure bias in the trade-based measure. Similarly, binary based measures could be useful to underweight the importance of the high-fill venues. Table EC.7 illustrates that these two different ELP proxies are also positively correlated with implementation shortfall. The coefficient on *HasELP* implies that if an execution were to fully substitute all exchange fills with ELP fills, then it would incur additional 6.49 bps in *IS*. Note that this is a very stringent condition. There are few parent orders that have zero exchange fills. The coefficient on *FracDolELP* has similar interpretation to *ELP Exposure* in Table 5.

EC.2.2. Does the most active ELP drive the findings?

Getco accounts for approximately 70% of the trades (60% of the dollar volume) that are executed by ELPs. To examine whether the results presented in Table 5 are driven by exposure of parent orders to Getco, we decompose our measure of ELP trading activity into two components: the percentage of child orders executed by Getco and the percentage of child orders executed by ELPs other than

Getco and re-estimate equation 7. We present the results in Table EC.8. As is the case when all ELP child executions are aggregated, we find that exposure to Getco and exposure to the other ELPs is associated with inflated trading costs for the parent order. This suggests child order executions by Getco are not driving our results.

EC.2.3. Different cost proxy: VWAP slippage

IS uses the NBBO midpoint prior to the execution of the first child order as a benchmark price to compute the execution cost measure. One popular ex-post benchmark for the average execution price is the volume-weighted average price (VWAP) during the parent order's trading interval. Madhavan (2002) argues that VWAP slippage may not be a reliable proxy of execution quality, as early aggressive trading would significantly affect the realized VWAP. Nevertheless, we examine the robustness of our findings using VWAP slippage as a measure of overall trading costs. Table EC.9 reports the main regression results using VWAP slippage and its fee-adjusted version. In both cases, the estimated coefficient on ELP Exposure is highly significant implying the robustness of our results with respect to a different proxy.

EC.2.4. Controlling for the information content of the parent order

One important concern in the OLS regression in equation 7 is that if the algorithm is routing informed orders to ELPs, then there would be a mechanical positive relationship between *IS* and ELP exposure. Our main regression includes urgency, order size and client fixed-effects to control for the private information of the client. If the broker is successful in identifying the information content of these orders in early stages of the regression and then intentionally routes the informed orders to ELPs, we may mechanically obtain positive correlation with overall trading costs and ELP fills. We run a robustness test to address this concern by controlling for *PPI* of the order as defined in 6.3. We include this proxy for informed trading in our main regression in equation 7. Table EC.10 reports the regression results. In both specifications, the estimated coefficient on ELP Exposure is still highly significant and positive highlighting the robustness of our results with respect to the potential strategic routing of informed orders to the ELPs.

EC.3. Evidence from Complete Trades of an Institutional Investor

In this section, we analyze a completely different data to emphasize that our main findings are not driven by a particular subset of institutional trade data set.

In response to a request made pursuant to the Colorado Open Records Act, the Colorado Public Employees' Retirement Association of Colorado (COPERA) provided trade execution data for stocks purchased or sold by COPERA's investment staff and any external asset managers who buy or sell

stock on the pension system's behalf.[25] As of December 31, 2016, the fair market value of COPERA's investments totaled $43,649,362,000.

We have child-order trade data from December 8, 2015 through December 31, 2017. We believe these data contain all domestic and international equity transactions made by COPERA. We focus on the domestic equity transactions. The data contain the ticker, the security name, the trade date, the child order execution price, order type, execution time, executing venue, executing broker, requested and executed trade size in shares.

There are a few advantages and disadvantages of this data set over the data set we have examined in the main body of the paper. With respect to the advantages, first, this data set includes all of the trades done by a single institutional client without any filters on the duration of the parent-order, stock universe, and fully executed status. The trades are executed by multiple brokers possibly using different algorithms over a recent time horizon providing an opportunity to examine our hypothesis in an out-of-sample data. There are also a few disadvantages. First, the time-stamps of the child-orders do not seem reliable and thus it is not possible to match them with the trades on TAQ. For this reason, we cannot classify a child-order trade as liquidity demanding or supplying. Second, we do not know the exact start- and end-time of the parent order execution. Third, only executed child-orders are provided in the data without explicitly stating the parent-order. Fourth, for some child-order trades, the executing venue field is blank. Fifth, some child-order entries are duplicated. Finally, we cannot see the algorithm type that is chosen by COPERA.

Given that parent-order information is missing, we first identify the parent-orders by classifying child-orders on the same day, on the same stock, having the same trading direction, the executing broker and the same requested trade size. There are 32,010 parent-orders initiated on common stocks with share code 10 or 11. Out of these, roughly 4,000 parent-orders do not have any information on their child-orders' execution venue. We use various sources on FIX-assigned codes and market participant identifiers to identify the venue of the child-orders as an exchange, dark pool, broker's own dark pool and an ELP. We were able to identify 99.7% of all child-orders with this methodology.

Table EC.11 provides the summary statistics of all parent-orders in the data set. Compared to our main data set, parent-orders are smaller in size and the median number of child-orders is 1. The average exposure to ELPs is 0.1% which is significantly smaller. Similarly, BODP share of the child-order is much smaller with 0.8%. In this data set, other DP and lit venue exposures are higher, with 5.5% and 93.6%, respectively.

Table EC.12 provides the summary statistics of parent-orders with only one single child order. We find that 78.9% of all parent-orders are executed in one child-order. The mean (median) order size

[25] In the spring of 2018, Wall Street Journal reporter Cezary Podkul made this FOIA request.

in this group is \$32,756 (\$2,212). Remarkably, we do not observe even a single fill by an ELP in this group providing further evidence that small orders are typically not routed to ELPs. These statistics clearly imply that ELPs do not reduce trading costs for small orders complementing our analysis for larger orders in the main data set. Instead, we find that in this set 98.8% of the orders are executed in the lit venues.

Table EC.13 provides the statistics of all parent-orders for a given broker. We have 14 brokers in total and approximately 64% of all parent orders are executed by Jefferies & Co. We observe that there is a wide heterogeneity of ELP exposure across brokers. 8 out of 14 brokers do not route any child-orders to ELPs. There are two brokers with 3% exposure and one broker with 1% exposure to ELPs. For the latter group, ELP exposure averages are in the same order of magnitude as in our main data set.

Since we do not know the exact start-time of the execution, we will use two benchmarks in the computation of the implementation shortfall: the open price and the first child-order transaction price. Let *ISOpen* (*ISFirstChild*) be the implementation shortfall using the open price (first child order price) as the benchmark. We run the following regressions with different sets of fixed effects to examine the correlation between parent-order execution costs and ELP exposure:

$$\begin{aligned} Cost_i = \alpha + \beta\, ELP\ Exposure_i + \theta_1\, BODP\ Exposure_i + \theta_2\, Other\ DP\ Exposure_i \\ + \sum_j \delta_j\, Control_{j,i} + \epsilon_i, \end{aligned} \tag{EC.1}$$

where C_i is either *ISOpen* or *ISFirstChild*.

Table EC.14 reports the regression results. In various specifications with different control variables and fixed effects, we find that *ELP Exposure* is always significant at 5% level. We also find that the estimated coefficients on *ELP Exposure* are comparable to our estimates from our main data set when the execution cost proxy is *ISFirstChild*. As reported in Table EC.15, we obtain very similar findings if we exclude parent-orders with only one child order which excludes 78.9% of the data set. Overall, our findings from this auxiliary data set implies the robustness of our findings with the main data set in which the existing filters may raise selection bias concerns.

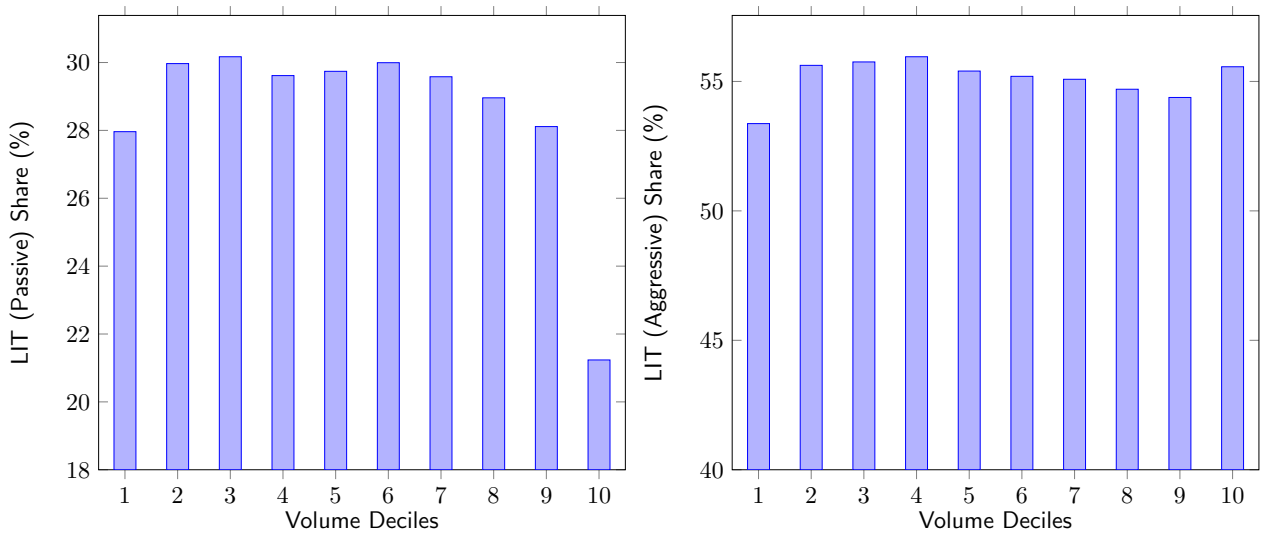

Figure EC.1 Share of passive and aggressive fills in executed volume deciles.

Notes: We plot the ratios of passive (left) versus aggressive (right) lit-venue executions in various deciles of executed volume.

Table EC.1 Fee assumptions (per share) for child order executions in each venue.

Notes: Negative numbers refer to rebates.

Venue	Type	Liquidity Providing Trades	Liquidity Demanding Trades
Archipelago Stock Exchange: ARCA	Make/Take Exch.	−$0.0025	$0.0030
Archipelago Stock Exchange: ARCX	Make/Take Exch.	−$0.0025	$0.0030
BZX Stock Exchange: BZX	Make/Take Exch.	−$0.0020	$0.0030
EDGX Stock Exchange: EDGX	Make/Take Exch.	−$0.0020	$0.0030
Nasdaq Stock Exchange: Nasdaq	Make/Take Exch.	−$0.0020	$0.0030
New York Stock Exchange: NYSE	Make/Take Exch.	−$0.0014	$0.0027
EDGA Stock Exchange: EDGA	Low Fee Exch.	$0.0003	$0.0003
Virtu Americas: GFLO	ELP	n.a.	$0.0000
Citadel: CDRG	ELP	n.a.	$0.0000
Trimark: TRIM	ELP	n.a.	$0.0000
Knight Securities: NITE	ELP	n.a.	$0.0000
D.E. Shaw: SHAW	ELP	n.a.	$0.0000
Two Sigma Securities: SOHO	ELP	n.a.	$0.0000
Sun Trading: FSOM	ELP	n.a.	$0.0000
BIDS ATS: BIDS	Other D.P.	$0.0000	$0.0000
Level ATS: EBXL	Other D.P.	$0.0000	$0.0000
Broker-owned dark pool: BODP	Broker's D.P.	$0.0000	$0.0000
Nasdaq BX Stock Exchange: BX	Inverted Exch.	$0.0020	−$0.0006
BYX Stock Exchange: BYX	Inverted Exch.	$0.0018	−$0.0008

Table EC.2 Time Trend in ELP executions

Notes: ELP Exposure is the percentage of a parent order's trades with ELPs. t is the relative number of days from January 3, 2011 expressed in number of years. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Inverse Price is the inverse of the arrival mid-quote price. Turnover is the ratio of the number of shares traded during the life of the parent order to the outstanding number of shares in thousands. LogMarketCap is the logarithm of the market capitalization of the executed stock. Standard errors are given in parentheses and are adjusted by clustering on stock.

	Dependent variable: ELP Exposure	
	(1)	(2)
t (years)	-0.006^{***}	-0.004^{**}
	(0.002)	(0.002)
Participation Rate		-0.06^{***}
		(0.02)
Volatility		-0.75^{***}
		(0.08)
Inverse Price		1.11^{***}
		(0.18)
Turnover		-0.001^{***}
		(0.0003)
LogMarketCap		0.01^{***}
		(0.002)
Observations	20,335	20,335
Adjusted R^2	0.001	0.12

Table EC.3 Summary statistics for parent orders submitted by clients who avoid ELPs and their matches

Notes: ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure is the percentage of a parent order's child executions that occur in the broker's own dark pool. PasExch Exposure is the percentage of a parent order's child executions that provide liquidity on a lit stock exchange. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Inverse Price is the inverse of the arrival mid-quote price. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Quoted Spread is the time-weighted percentage bid-ask spread over the parent order's life. Standard errors are adjusted by double-clustering on stock and day.

		Single Match			Double Match		
Statistic	No ELP	ELP	Difference	p-value	ELP	Difference	p-value
# of parent orders	915	915		1773			
ELP Exposure (%)	0.00	6.77	−6.77	<0.01	6.62	−6.62	<0.01
BODP Exposure (%)	3.39	4.50	−1.11	0.22	4.41	−1.02	0.19
Other DP Exposure (%)	0.42	0.27	0.15	0.09	0.29	0.13	0.13
PasExch Exposure (%)	35.7	33.6	2.10	0.03	33.5	2.2	0.01
Participation Rate (%)	2.57	1.71	0.86	0.01	1.77	0.80	0.02
Inverse Price	0.036	0.033	0.003	0.17	0.031	0.005	0.08
Volatility (%)	1.77	1.57	0.20	0.21	1.54	0.23	0.16
Quoted Spread (bps)	4.59	4.39	0.20	0.45	4.20	0.39	0.22

Table EC.4 Summary statistics for parent orders submitted by the switching client before and after the switch date

Notes: ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure is the percentage of a parent order's child executions that occur in the broker's own dark pool. PasExch Exposure is the percentage of a parent order's child executions that provide liquidity on a lit stock exchange. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Inverse Price is the inverse of the arrival mid-quote price. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Quoted Spread is the time-weighted percentage bid-ask spread over the parent order's life. We compute the z-scores by normalizing the raw variables with their daily means and standard deviations. Standard errors are adjusted by double-clustering on stock and day.

Statistic	Pre	Post	Difference	p-value
# of parent orders	40	111		
ELP Exposure (%)	6.19	0.00	6.19	<0.01
BODP Exposure (%)	4.22	4.13	0.09	0.95
PasExch Exposure	0.39	0.36	0.03	0.21
Participation Rate (%)	2.05	2.05	0.00	0.99
Inverse Price	0.026	0.030	0.004	0.50
Volatility (z-score)	-0.13	-0.13	0.00	0.99
Quoted Spread (z-score)	-0.03	0.06	-0.09	0.55

Table EC.5 Potential nonlinear relation between ELP exposure and the cost of the parent order.

Notes: Implementation Shortfall (*IS*) is computed as the normalized difference between the average child order execution price and the price of the asset prior to the start of the execution. Net Implementation Shortfall (*NetIS*) is adjusted for assumed fees and rebates. *IS* and *NetIS* are formally defined in Section 6.1. ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure (Other DP Exposure) is the percentage of a parent order's child executions that occur in the broker's own dark pool (in dark pools that our data provider does not own). PasExch Exposure is the percentage of a parent order's child executions that provide liquidity on a lit stock exchange. ζ is the median ELP exposure conditional on one ELP fill. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Inverse Price equals one divided by the arrival price. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Duration is the fraction of the trading day that the parent order is worked. Turnover is the ratio of the number of shares traded during the life of the parent order to the outstanding number of shares in thousands. Each regression includes stock, client and calendar day fixed-effects. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day.

	Dependent variable:	
	IS (bps)	*NetIS* (bps)
	(1)	(2)
ELP Exposure	93.89***	93.47***
	(21.98)	(21.98)
(ELP Exposure - ζ)$\mathbb{I}_{\{\text{ELP Exposure}>\zeta\}}$	−68.71***	−68.95***
	(26.21)	(26.21)
BODP Exposure	−6.18	−6.90*
	(4.13)	(4.13)
Other DP Exposure	−31.88	−32.43
	(28.46)	(28.46)
PasExch Exposure	6.83	5.81
	(5.15)	(5.15)
Participation Rate	55.29***	55.54***
	(19.46)	(19.47)
Inverse Price	−41.84	−34.81
	(67.00)	(66.72)
Volatility	51.65	52.26
	(305.94)	(305.99)
Duration	−3.97	−3.96
	(8.47)	(8.47)
Turnover	0.36	0.36
	(0.37)	(0.37)
Stock FE	Yes	Yes
Day FE	Yes	Yes
Client FE	Yes	Yes
N	20,335	20,335
Adjusted R^2	0.10	0.10

Table EC.6 Descriptive statistics for parent orders that avoid ELPs

Notes: Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Order size is the size of the parent order executed in shares and in %ADV over the previous month. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. BODP Exposure is the percentage of a parent order's child executions that occur in the broker's own dark pool. ELP Exposure is the percentage of a parent order's number of trades with ELPs. The table below presents averages for parent orders placed by each of the six clients that seemingly avoid sourcing ELP liquidity, the entire sample of parent orders placed by clients that appear to avoid sourcing ELP liquidity (*Not Exposed*), and the sample of parent orders placed by clients that allow their parent orders to interact with ELPs (*Exposed*).

	Client 1	Client 2	Client 3	Client 4	Client 5	Client 6	Not Exposed	Exposed	Diff
# of parent orders	280	228	62	40	179	165	954	19,379	−18,427
Participation rate (%)	1.82	0.84	0.95	1.02	2.03	7.50	2.52	1.76	0.76^{*}
Order size (shares)	58,966	12,829	2,892	7,908	14,108	87,279	38,605	25,296	13,338
Order size (% ADV)	2.50	1.47	0.20	0.85	1.64	11.13	3.37	2.81	0.56
Parent order duration	0.31	0.70	0.04	0.48	0.18	0.25	0.36	0.53	-0.18^{***}
Volatility (%)	1.81	1.38	1.84	1.89	2.53	1.40	1.78	1.49	0.28
BODP Exposure	0.00	0.00	0.00	12.46	9.22	5.90	3.27	9.87	-6.60^{***}
ELP Exposure	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.87	-5.87^{***}

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$

Table EC.7 Different proxies of ELP exposure

Notes: HasELP (HasBODP, HasODP) is a binary variable taking a value of 1 if the parent order execution has a child order fill executed by an ELP (BODP, ODP). FracDolELP (FracDolBODP, FracDolODP) is the fraction of the parent order executed by the ELPs (BODP, ODPs) in terms of dollar volume. We include all of control variables: participation rate, inverse price, volatility, turnover and duration. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day. Each regression includes stock, client and calendar day fixed-effects.

	Dependent variable: IS	
	(1)	(2)
HasELP	6.49***	
	(1.71)	
HasBODP	−0.59	
	(2.12)	
HasODP	1.67	
	(2.51)	
FracDolELP		47.42***
		(8.35)
FracDolML		−9.99***
		(3.59)
FracDolODP		−38.69**
		(19.40)
Stock FE	Yes	Yes
Date FE	Yes	Yes
Client FE	Yes	Yes
Controls	Yes	Yes
N	20,335	20,335
Adjusted R^2	0.10	0.10

Table EC.8 Multivariate relationship between implantation shortfall and exposure to Getco and the other ELPs.

Notes: IS and *NetIS* are formally defined in Section 6.1. Getco Exposure is the percentage of child executions by Getco. Other ELP Exposure is the percentage of child executions by ELPs other than Getco. BODP Exposure (Other DP Exposure) is the percentage of a parent order's child executions that occur in the broker's own dark pool (in a dark pool that is not owned by the data provider). PasExch Exposure is the percentage of a parent order's child executions that provide liquidity on a lit stock exchange. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Inverse Price equals one divided by the arrival price. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Duration is the fraction of the trading day that the parent order is worked. Turnover is the ratio of the number of shares traded during the life of the parent order to the outstanding number of shares in thousands. Each regression includes stock, client and calendar day fixed-effects. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day.

	Dependent variable:	
	IS (bps)	*NetIS* (bps)
	(1)	(2)
GETCO Exposure	34.57***	33.97***
	(8.86)	(8.85)
Other ELP Exposure	89.44***	88.86***
	(15.20)	(15.20)
BODP Exposure	−7.24*	−7.96**
	(4.03)	(4.03)
Other DP Exposure	−37.58	−38.16
	(28.30)	(28.30)
PasExch Exposure	6.93	5.91
	(5.15)	(5.15)
Participation Rate	54.47***	54.71***
	(19.43)	(19.44)
Inverse Price	−49.57	−42.57
	(66.26)	(65.99)
Volatility	47.60	48.21
	(305.84)	(305.89)
Duration	−4.01	−4.01
	(8.47)	(8.47)
Turnover	0.37	0.36
	(0.37)	(0.37)
Stock FE	Yes	Yes
Date FE	Yes	Yes
Client FE	Yes	Yes
N	20,335	20,335
Adjusted R^2	0.10	0.10

Table EC.9 Multivariate analysis of the relationship between VWAP slippage and ELP exposure.

Notes: VWAP Slippage is computed as the normalized difference between the average child order execution price and the volume-weighted average price observed in the market during the parent order's lifetime. Net VWAP Slippage is adjusted for assumed fees and rebates. Both variables are expressed in bps. ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure (Other DP Exposure) is the percentage of a parent order's child executions that occur in the broker's own dark pool (in dark pools that our data provider does not own). PasExch Exposure is the percentage of a parent order's child executions that provide liquidity on a lit stock exchange. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Inverse Price equals one divided by the arrival price. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Duration is the fraction of the trading day that the parent order is worked. Turnover is the ratio of the number of shares traded during the life of the parent order to the outstanding number of shares in thousands. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day. Each regression includes stock, client and calendar day fixed-effects.

	Dependent variable:	
	VWAP Slippage	Net VWAP Slippage
ELP Exposure	4.43^{***}	3.83^{***}
	(1.19)	(1.19)
BODP Exposure	-1.00^{*}	-1.72^{***}
	(0.52)	(0.52)
Other DP Exposure	9.79	9.22
	(7.51)	(7.54)
PasExch Exposure	-1.82^{**}	-2.84^{***}
	(0.77)	(0.77)
Participation Rate	3.08^{*}	3.32^{**}
	(1.64)	(1.64)
Inverse Price	15.63	22.63^{**}
	(10.01)	(9.77)
Volatility	140.48^{*}	141.11^{*}
	(80.73)	(80.72)
Duration	-0.29	-0.28
	(0.76)	(0.76)
Turnover	0.01	0.01
	(0.06)	(0.06)
Stock FE	Yes	Yes
Date FE	Yes	Yes
Client FE	Yes	Yes
N	20,335	20,335
Adjusted R^2	0.08	0.08

Table EC.10 Controlling for informed trading in the multivariate analysis of the relationship between trading costs and ELP exposure.

Notes: All of our cost measures and PPI at the parent order level are formally defined in Section 6.1 and 6.3. ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure (Other DP Exposure) is the percentage of a parent order's child executions that occur in the broker's own dark pool (in dark pools that our data provider does not own). PasExch Exposure is the percentage of a parent order's child executions that provide liquidity on a lit stock exchange. Participation Rate is measured as the ratio of the parent order's trading volume to the overall trading volume of the underlying stock over the period of time that the parent order is being worked. Inverse Price equals one divided by the arrival price. Volatility is measured as the volatility of the midpoint of the NBBO over the parent order's life. Duration is the fraction of the trading day that the parent order is worked. Turnover is the ratio of the number of shares traded during the life of the parent order to the outstanding number of shares in thousands. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day. Each regression includes stock, client and calendar day fixed-effects.

	Dependent variable:	
	IS (bps)	*NetIS* (bps)
	(1)	(2)
PPI	0.13^{***}	0.13^{***}
	(0.01)	(0.01)
ELP Exposure	35.37^{***}	34.77^{***}
	(6.77)	(6.77)
BODP Exposure	-7.35^{**}	-8.08^{**}
	(3.46)	(3.46)
Other DP Exposure	−23.10	−23.67
	(23.48)	(23.48)
PasExch Exposure	5.01	3.99
	(4.12)	(4.11)
Participation Rate	77.41^{***}	77.65^{***}
	(17.58)	(17.58)
Inverse Price	−9.12	−2.11
	(63.68)	(63.66)
Volatility	83.30	83.91
	(269.39)	(269.45)
Duration	−2.64	−2.64
	(7.81)	(7.81)
Turnover	0.34	0.34
	(0.28)	(0.28)
Stock FE	Yes	Yes
Date FE	Yes	Yes
Client FE	Yes	Yes
N	20,335	20,335
Adjusted R^2	0.26	0.26

Table EC.11 COPERA summary statistics: All parent orders

Notes: This table presents descriptive statistics for the 28,106 parent order executions placed by COPERA between December 2015 and December 2017.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Value of parent order ($ millions)	28,106	0.298	1.951	0.00000	0.001	0.050	91.396
Fraction of Daily Volume	28,106	0.004	0.020	0.00000	0.00001	0.001	0.775
# of child order executions	28,106	37.859	304.908	1	1	1	15,192
Fraction of ELP exposure	28,105	0.001	0.011	0.000	0.000	0.000	0.916
Fraction of BODP exposure	28,105	0.008	0.062	0.000	0.000	0.000	1.000
Fraction of ODP exposure	28,105	0.055	0.197	0.000	0.000	0.000	1.000
Fraction of LIT exposure	28,105	0.936	0.210	0.000	1.000	1.000	1.000

Table EC.12 COPERA summary statistics: Single child orders

Notes: This table presents descriptive statistics for the 22,178 parent orders with single child orders placed by COPERA between December 2015 and December 2017.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Value of parent order ($ millions)	22,178	0.033	0.172	0.00000	0.001	0.013	6.605
Fraction of Daily Volume	22,178	0.001	0.010	0.00000	0.00001	0.0001	0.775
# of child order executions	22,178	1	1	1	1	1	1
Fraction of ELP exposure	22,177	0	0	0	0	0	0
Fraction of BODP exposure	22,177	0.00005	0.007	0	0	0	1
Fraction of ODP exposure	22,177	0.012	0.107	0	0	0	1
Fraction of LIT exposure	22,177	0.988	0.107	0	1	1	1

Table EC.13 Broker-Level Summary Statistics of the COPERA data set

Notes: nParent is the number of parent orders. avgChild (minChild, maxChild) denotes the average (minimum, maximum) number of child orders for the broker's parent orders. avgELP (minELP, maxELP) denotes the average (minimum, maximum) ELP exposure for the broker's parent orders.

	Broker	nParent	minChild	maxChild	avgChild	minELP	maxELP	avgELP
1	BAIRD (ROBERT W.) & CO	320	1	7680	81.04	0.00	0.00	0.00
2	BARCLAYS CAPITAL INC	464	1	1706	85.41	0.00	0.43	0.01
3	CALYON SECURITIES	7	94	2884	673.29	0.00	0.00	0.00
4	CITIGROUP	1235	1	8132	33.98	0.00	0.00	0.00
5	DEUTSCHE BANK/ ALEX BROWN	6	277	9556	3185.83	0.00	0.00	0.00
6	GOLDMAN SACHS & CO	204	1	3766	286.65	0.00	0.27	0.03
7	JEFFERIES & CO	18110	1	9902	10.38	0.00	0.60	0.0003
8	JP MORGAN SECURITIES	513	1	11790	222.01	0.00	0.17	0.002
9	LIQUIDNET INC.	4908	1	15192	63.71	0.00	0.00	0.00
10	MERRILL LYNCH	6	91	728	286.83	0.00	0.18	0.03
11	MORGAN STANLEY DEAN WITTER	274	1	7224	284.83	0.00	0.00	0.00
12	RBC CAPITAL MARKETS	79	1	5610	222.89	0.00	0.00	0.00
13	SANFORD BERNSTEIN	878	1	5760	104.28	0.00	0.00	0.00
14	UBS SECURITIES	1111	1	7276	63.63	0.00	0.92	0.002

Table EC.14 Out-of-sample and different data set

Notes: ISOpen (*ISFirstChild*) is the implementation shortfall of the parent order using open price (first child-order price) as the benchmark. ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure (Other DP Exposure) is the percentage of a parent order's child executions that occur in the broker's own dark pool (in other dark pools than the routed broker). Fraction of Daily Volume is measured as the ratio of the parent order's trading volume to the overall daily trading volume of the underlying stock. Log (OpPrice) is the logarithm of the open price. Day Turnover is the ratio of the number of shares traded during the trading day of the parent order to the outstanding number of shares in thousands. Each regression includes stock fixed-effects. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day.

	Dependent variable:							
	ISFirstChild				*ISOpen*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ELP Exposure	64.36**	53.22**	64.45**	53.98**	193.85**	161.53**	194.78**	181.27**
	(26.83)	(24.26)	(26.76)	(24.02)	(93.51)	(81.12)	(94.00)	(81.28)
BODP Exposure	41.82	40.33	41.69	40.17	39.74	49.75	42.62	55.68
	(26.72)	(26.47)	(26.43)	(26.23)	(37.15)	(35.40)	(37.59)	(36.94)
Other DP Exposure	6.71**	4.08	6.61**	4.01	7.88	9.52	9.98	9.20
	(2.90)	(3.13)	(3.07)	(3.11)	(15.53)	(13.35)	(16.80)	(13.46)
Fraction of Daily Volume	87.06***	79.71***	87.85***	81.20***	183.13**	121.24**	176.42**	125.55*
	(33.51)	(28.43)	(33.23)	(28.39)	(74.64)	(59.94)	(76.20)	(63.93)
Log (OpPrice)			−0.16	0.93			4.96	86.05
			(0.92)	(3.50)			(5.60)	(52.84)
Day Turnover			17.92	58.47			−198.39	−114.10
			(36.08)	(40.53)			(216.61)	(189.67)
Observations	28,105	28,105	28,105	28,105	28,105	28,105	28,105	28,105
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Broker FE	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.10	0.27	0.10	0.27	0.03	0.09	0.03	0.09

Table EC.15 COPERA analysis with the exclusion of one-child parent-orders

Notes: ISOpen (*ISFirstChild*) is the implementation shortfall of the parent order using open price (first child-order price) as the benchmark. ELP Exposure is the percentage of a parent order's trades with ELPs. BODP Exposure (Other DP Exposure) is the percentage of a parent order's child executions that occur in the broker's own dark pool (in other dark pools than the routed broker). Fraction of Daily Volume is measured as the ratio of the parent order's trading volume to the overall daily trading volume of the underlying stock. Log (OpPrice) is the logarithm of the open price. Day Turnover is the ratio of the number of shares traded during the trading day of the parent order to the outstanding number of shares in thousands. Each regression includes stock fixed-effects. Standard errors are given in parentheses and are adjusted by double-clustering on stock and day.

	Dependent variable:							
	ISFirstChild				*ISOpen*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ELP Exposure	61.62**	49.63*	61.94**	53.61**	187.69**	151.40**	192.20**	148.90**
	(27.13)	(25.80)	(27.46)	(25.48)	(89.22)	(73.27)	(91.01)	(72.96)
BODP Exposure	41.64	28.43	41.05	27.30	47.43	42.07	52.90	40.32
	(28.48)	(18.35)	(27.09)	(17.60)	(37.66)	(26.67)	(38.45)	(26.53)
Other DP Exposure	7.33**	1.27	6.90	1.31	10.17	6.87	14.51	6.53
	(3.59)	(4.41)	(5.05)	(4.37)	(14.79)	(13.51)	(18.34)	(13.49)
Fraction of Daily Volume	108.66***	109.31***	113.41***	120.27***	94.09	88.18	82.22	87.56
	(38.52)	(27.52)	(37.70)	(27.24)	(71.68)	(79.52)	(68.60)	(75.07)
Log (OpPrice)			−0.36	0.21			8.65	−16.51
			(4.64)	(10.00)			(15.66)	(37.07)
Turnover			99.65	304.29*			−397.61	54.84
			(165.32)	(163.25)			(540.51)	(482.99)
Observations	5,928	5,928	5,928	5,928	5,928	5,928	5,928	5,928
Stock FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Broker FE	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.10	0.38	0.10	0.38	0.09	0.41	0.09	0.41