

ONLINE APPENDIX

Inverted Fee Structures, Tick Size, and Market Quality

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I. Additional tables

This section presents additional tables that complement results presented in the main text.

a. Fees

Table A.1 presents the base exchange fee schedule for all tapes.

b. Difference between subsamples

In this section, we revisit the results from Table 3 and Table 5 and test whether the differences in coefficients estimated in the two subsamples are different.

We first test for differences in Table 3. To do so, we interact each term in regression equations Eq. (1b) and (1a) with a tick constraint dummy:

$$\begin{aligned}
\text{Inverted Share}_{i,\tau} = & \alpha + \beta_1 \mathbf{1}_{[\text{trade-at}]_{i,\tau}} + \beta_2 \mathbf{1}_{[\text{trade}]_{i,\tau}} + \beta_3 \mathbf{1}_{[\text{quote}]_{i,\tau}} \\
& + \beta_4 \text{Inverted Share}_{i,\tau-1} \\
& + \beta_5 \mathbf{1}_{[\text{trade-at}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_6 \mathbf{1}_{[\text{trade}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_7 \mathbf{1}_{[\text{quote}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_8 \text{Dark Inverted}_{i,\tau-1} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \gamma_1 X_{i,\tau} + \gamma_2 X_{i,\tau} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_9 \mathbf{1}_{[\text{tick const.}]} + \epsilon_{i,\tau}
\end{aligned} \tag{A.1a}$$

$$\begin{aligned}
\text{Dark Share}_{i,\tau} = & \alpha + \beta_1 \mathbf{1}_{[\text{trade-at}]_{i,\tau}} + \beta_2 \mathbf{1}_{[\text{trade}]_{i,\tau}} + \beta_3 \mathbf{1}_{[\text{quote}]_{i,\tau}} \\
& + \beta_4 \text{Dark Share}_{i,\tau-1} \\
& + \beta_5 \mathbf{1}_{[\text{trade-at}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_6 \mathbf{1}_{[\text{trade}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_7 \mathbf{1}_{[\text{quote}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_8 \text{Dark Share}_{i,\tau-1} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \gamma_1 X_{i,\tau} + \gamma_2 X_{i,\tau} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_9 \mathbf{1}_{[\text{tick const.}]} + \epsilon_{i,\tau},
\end{aligned} \tag{A.1b}$$

Results presented in Table A.2 show that the coefficients are significantly different in the two samples for the quote rule and the lag dependent variable in both regressions and for the trade-at rule in the inverted share regression. This is consistent with our hypothesis that liquidity providers use inverted venues as a substitute to dark venues for sub-tick trading, which is more pronounced among stocks trading at a tighter spread.

Results from Table 5 suggest that improvements in pricing efficiency mainly come from the tick constrained group. To formally test this, we apply a similar test to examine the

differential impact of inverted trading on pricing efficiency between the tick constrained and unconstrained group. Specifically, we run the following IV-2SLS regression:

$$\begin{aligned}
Y_{i,\tau} = & \alpha + \beta_1 \widehat{\text{Inverted Share}}_{i,\tau} + \beta_2 \widehat{\text{Dark Share}}_{i,\tau} \\
& + \beta_3 \widehat{\text{Inverted Share}}_{i,\tau} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \beta_4 \widehat{\text{Dark Share}}_{i,\tau} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \delta_1 \mathbf{1}_{[\text{trade}]_{i,\tau}} + \delta_2 \mathbf{1}_{[\text{quote}]_{i,\tau}} \\
& + \delta_3 \mathbf{1}_{[\text{trade}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \delta_4 \mathbf{1}_{[\text{quote}]_{i,\tau}} \times \mathbf{1}_{[\text{tick const.}]} \\
& + \gamma_1 X_{i,\tau} + \gamma_2 X_{i,\tau} \times \mathbf{1}_{[\text{tick const.}]} + \eta_{i,\tau},
\end{aligned} \tag{A.2}$$

where $Y_{i,\tau}$ is a pricing efficiency measure. $\widehat{\text{Inverted Share}}_{i,\tau}$ and $\widehat{\text{Dark Share}}_{i,\tau}$ are the fitted market shares of inverted and dark venue trading from the first stage regressions with the tick constraint dummy interaction, which use the specifications defined in Eq. (A.1a) and (A.1b).

Results for pricing efficiency presented in Table A.3 indicate that improvements in pricing efficiency due to the inverted share are significantly greater in tick constrained stocks for the variance ratio and cross-correlation measures, while difference is not statistically significant for the autocorrelation measure. The improvement due to the dark share is greater in tick constrained stocks according to the cross-correlation measure only.

c. Variance ratios at different horizons

In this section, we revisit the results from Table 5 using variance ratios estimated at different horizons. The variance ratio in the main text is computed as:

$$|1 - VR| = \left| 1 - \frac{\sigma_{1min;i,\tau}^2}{4\sigma_{15sec;i,\tau}^2} \right|$$

where $\sigma_{15sec;i,\tau}^2$ and $\sigma_{1min;i,\tau}^2$ are daily variances of NBBO midpoint returns for stock i on day τ sampled at 15 seconds and one minute intervals, respectively. Table A.4 presents the results for the following ratios: $\sigma_{2min;i,\tau}^2/4\sigma_{30sec;i,\tau}^2$, $\sigma_{5min;i,\tau}^2/5\sigma_{1min;i,\tau}^2$ and $\sigma_{30min;i,\tau}^2/6\sigma_{5min;i,\tau}^2$. Results at these longer horizons are consistent with those presented in the main text.

d. Endogeneity of tick constraint

Result in the main text are presented for the full sample and tick constraint subsamples based on the average spread of each stock during the pre-pilot period. This average spread is somewhat endogenous, which can raise concerns about the validity of our results. A noisier but less problematic measure of pre-pilot tick constraint is the price of each stock. Because the pre-pilot minimum tick size is the same for all stock, lower priced stocks will have a larger relative tick size and thus be more likely to be tick constrained. We repeat our main tests of market quality for subsamples sorted on the stock price at the end of August 2016. Tables A.5 and A.6 presents the results. The subsample analysis results are consistent with results presented in the main text for all variables except for the cross-correlation.

e. Difference-in-difference approach

Results presented in Section 5.5.3 of the main text rely on a difference-in-difference approach. The analysis of inverted and dark market share in the main text is limited to the first stage regressions of the IV specification (Eq. (1b) and (1a)) in Table 3. We repeat the analysis using the difference-in-difference and triple-diff specifications (Eq. (6) and (7)) in Table A.7. Overall, the results are qualitatively similar to those presented in the main text.

f. Execution rate

The SEC Rule 605, adopted in 2000, requires market centers to publicly disclose a basket of market execution quality metrics, per stock, on a monthly basis. This data has been used in the literature to assess the impact of the Rule 605 (Zhao and Chung, 2007) and to study

some aspects of market quality (see, e.g., Goyenko et al., 2009, O’Hara and Ye, 2011).

We obtain the Rule 605 data for all lit venues from September to November 2016. Since Rule 605 data is published monthly and the Tick Size Pilot Program was phased in progressively over the course of October 2016, we focus our analysis on changes in execution rate for top-of-book orders (at-the-quote orders) between September and November.

We use the same difference approach used in Section 6.6.2 of the main text, but replace the dependent variable with Execution rate $_{i,v,\tau}$, the execution rate for stock i on venue v (inverted or non-inverted) on time τ , where τ is either September or November.

Results are presented in Table A.8. Both the quote rule and the trade-at rule increase the execution rate on inverted venues. Controlling for the tick constraint yields a positive coefficient for the trade-at rule on high tick constrained stocks, but the t -statistic of 1.44 falls short of the usual threshold for statistical significance. The trade-at rule also increases the execution rate on non-inverted venues, but the effect is of smaller magnitude.

g. Cancel-to-trade ratio

Table A.9 reestimates the regressions in Table 8 by replacing the dependent variable with the log of the cancel-to-trade ratio, using data from SEC MIDAS. We find that the quote rule significantly decreases the ratio on both inverted and non-inverted venues. The effect on non-inverted venues is larger for the high tick constraint subsample. The trade-at rule decreases the cancel-to-trade ratio only on inverted venues.

h. Trade-to-order ratio

Table A.10 reestimate the regressions in Table 8 without applying filters on the minimum number of trades, using data from SEC MIDAS. These filters, which exclude daily stock-exchange observations for which there are fewer than 20 trades, are used to avoid potential extreme values that could mechanically enhance our results. Unfiltered results are consistent with the filtered ones, but R^2 coefficients are smaller.

II. Trade-at prohibition exceptions

This section presents a verbatim report of the exceptions to the trade-at rule listed in the SEC plan published in the Federal Register, Vol. 80, No. 92 (May 2015). The original document was accessed on December 8, 2017 at the following URL: <https://www.gpo.gov/fdsys/pkg/FR-2015-05-13/pdf/2015-11425.pdf> .

1. The order is executed by a trading center that is displaying a quotation, via either a processor or an SRO quotation feed, at a price equal to the traded-at protected quotation but only up to the trading center's full displayed size. [Where the quotation is displayed through a national securities exchange, the execution at the size of the order must occur against the displayed size on that national securities exchange. Where the quotation is displayed through the Alternative Display Facility or another facility approved by the Commission that does not provide execution functionality, the execution at the size of the order must occur against the displayed size in accordance with the rules of the Alternative Display Facility or such approved facility];
2. The order is of Block Size;
3. The order is a Retail Investor Order executed with at least \$0.005 price improvement;
4. The order is executed when the trading center displaying the protected quotation that was traded at was experiencing a failure, material delay, or malfunction of its systems or equipment;
5. The order is executed as part of a transaction that was not a "regular way" contract;
6. The order is executed as part of a single-priced opening, reopening, or closing transaction by the trading center;
7. The order is executed when a protected bid was priced higher than a protected offer in the Pilot Security;

8. The order is identified as an Intermarket Sweep Order;
9. The order is executed by a trading center that simultaneously routed Trade-at Intermarket Sweep Orders to execute against the full displayed size of the protected quotation that was traded at;
10. The order is executed as part of a Negotiated Trade;
11. The order is executed when the trading center displaying the protected quotation that was traded at had displayed, within one second prior to execution of the transaction that constituted the trade-at, a best bid or best offer, as applicable, for the Pilot Security with a price that was inferior to the price of the trade-at transaction.
12. The order is executed by a trading center which, at the time of order receipt, the trading center had guaranteed an execution at no worse than a specified price (a “stopped order”), where:
 - (a) The stopped order was for the account of a customer;
 - (b) The customer agreed to the specified price on an order-by-order basis; and
 - (c) The price of the trade-at transaction was, for a stopped buy order, equal to the national best bid in the Pilot Security at the time of execution or, for a stopped sell order, equal to the national best offer in the Pilot Security at the time of execution; or
13. The order is for a fractional share of a Pilot Security, provided that such fractional share order was not the result of breaking an order for one or more whole shares of a Pilot Security into orders for fractional shares or was not otherwise effected to evade the requirements of the trade-at prohibition or any other provisions of the Plan.

III. TSP selection process

Eligible securities are those listed on NYSE, NYSE MKT or NASDAQ that have a market capitalization of \$5 millions or less, a stock price of at least \$2.00 and an average daily volume of 1 million shares or less.¹ Each security is assigned to one of the test groups or the control group following a stratified sampling procedure. These securities are first assigned to one of 27 strata based on their tercile ranking along three dimensions: market capitalization, stock price, and average trading volume. The cutoff values for each tercile are given in Table A.11.² Securities within each stratum are then randomly allocated to each group by preserving the within-stratum listing exchange representation. The resulting test groups and control group should, therefore, be representative of the full sample of eligible securities in terms of market capitalization, stock price, average daily volume and listing exchange.

Figure A.1 presents the within-group distributions of stock characteristics for securities in our sample. Overall, the distributions of securities characteristics are very similar over many dimensions.

IV. Instrumental variables approach

In this section, we discuss potential issues with the instrumental variables approach used for our main result (see, e.g., Roberts and Whited, 2013, Jiang, 2017). Specifically, we repeat our main tests using uninstrumented OLS regressions, discuss the exclusion restriction and discuss the use of lagged variables.

¹See the Exhibit A for a technical description of eligibility criteria and the stratified sampling procedure: <https://www.sec.gov/rules/sro/nms/2015/34-74892-exa.pdf>, accessed December 28, 2016.

²Two strata contain no securities and are ignored. Four strata contain fewer than 10 securities, so these securities are reassigned to another stratum. In total, 21 strata are used for the stratified sampling procedure.

a. Uninstrumented regressions

We first reestimate our main regressions using uninstrumented OLS regressions instead of IV-2SLS. Table A.12 and A.13 present the uninstrumented analogs of Tables 5 and 6, respectively. For comparison, Table A.14 presents the ratio between each IV-2SLS coefficient and the corresponding OLS coefficient. While the direction of the potential bias is not evident in our setup, we note that all coefficients of interest from the instrumented OLS regressions have the same sign as those in our IV-2SLS regressions and that almost all magnitude differences are within a single digit factor. This suggests that our results are not artificially inflated by a bad specification, as is often the case with instrumental variables (Jiang, 2017).

b. Exclusion restriction and the “trade-at” rule

While it is not possible to test for the exclusion restriction directly, we argue that the “trade-at” rule is unlikely to affect our measures of market quality directly. We believe that our proposed channel, i.e., that market participants alter their trading strategies and routing choices because of the rule, is of first-order importance. We also note that results from the difference-in-difference regression presented in Table 7 of the net policy section in the main text show that the trade-at rule has little to no direct impact on our market quality measures.

c. Lagged instruments

Using lagged variables as instruments can be problematic in certain circumstances. Roberts and Whited (2013) note that the use of lagged variables should be motivated by the structure of the question under study, but does not offer specific guidance on the circumstances under which it is appropriate or not to use this approach. More recently, Bellemare et al. (2017) investigate more formally the concerns over the use of lagged explanatory variables as instruments.

We make three critical assumptions regarding our data generating process to justify the use of lagged variables.³ First, we assume that the causal effect of inverted and dark trading share on our market quality metrics is contemporaneous. Second, we assume that observed trading share has a causal effect on future trading share, i.e., that investors consider historical trading patterns when determining where to route their orders. Finally, we assume that there is no such causal relation between observed market quality measures and their future realization, i.e., that the persistence in those measures can be explained solely by the persistence in our instrumented and other explanatory variables. Bellemare et al. (2017) show that the use of lagged instrumental variables is appropriate under these assumptions.

V. “Post” dummy for control stocks

The difference-in-difference approach used in the main text relies on the use of the $\mathbf{1}_{[\text{post}]_{i,\tau}}$ dummy variable. For pilot stocks in groups one, two or three, $\mathbf{1}_{[\text{post}]_{i,\tau}}$ is equal to one if the pilot rule for stock i is activated at time τ , and zero otherwise. Control stocks, however, do not get activated. For the difference-in-difference approach to be valid, $\mathbf{1}_{[\text{post}]_{i,\tau}}$ should reflect the counter-factual, i.e., the date each stock would have been activated had it been subject to rule changes. Given that stocks were randomly allocated to each pilot group and the control group using a rigorous stratified sampling procedure, each control stock would have had an equal chance of being activated on any of the pilot activation dates.

We thus rely on the empirical distribution of activation dates for the pilot program. Using the details presented in Section 2.2.2 of the main text, we find that out of 1200 pilot stocks, 10 (0.83%) were scheduled to be activated in October 3, 190 (15.83%) on October 10, 605 (50.42%) on October 17, 95 (7.92%) on October 24 and 300 (25%) on October 31.

For control stocks, the activation date is randomly set to one of the five possible dates with

³These are in addition to the assumption that justifies the use of instrumental variables in the first place, namely that there is reverse causality between our market quality metrics and instrumented variables, i.e., that market quality affects the trading venue choice. We also assume that there is no unobserved confounding factor.

probabilities matching the empirical distribution for pilot stocks. For example, each control stock is assigned October 3 with 0.83% probability, October 10 with 15.83% probability, and so on.

References

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- Roberts, M. R., Whited, T. M., 2013. Endogeneity in empirical corporate finance. In: Constantinides, G. M., Harris, M., Stulz, R. M. (eds.), *Handbook of the Economics of Finance*, North Holland, Amsterdam, 493–572.
- Zhao, X., Chung, K. H., 2007. Information disclosure and market quality: The effect of SEC Rule 605 on trading costs. *Journal of Financial and Quantitative Analysis* 42, 657–682.

Figure A.1. Stock Characteristics

This Figure shows the distribution of characteristics for securities assigned to the three pilot test groups and the control group. Panels A to D show the histograms, in log, of the market capitalization (A), stock price (B), average daily volume (C) and average daily dollar volume (D). Panels E to G show the proportion of stocks within each group that are index members (E), listed on different exchanges (F) or assigned to each market cap-stock price-daily volume strata (G).

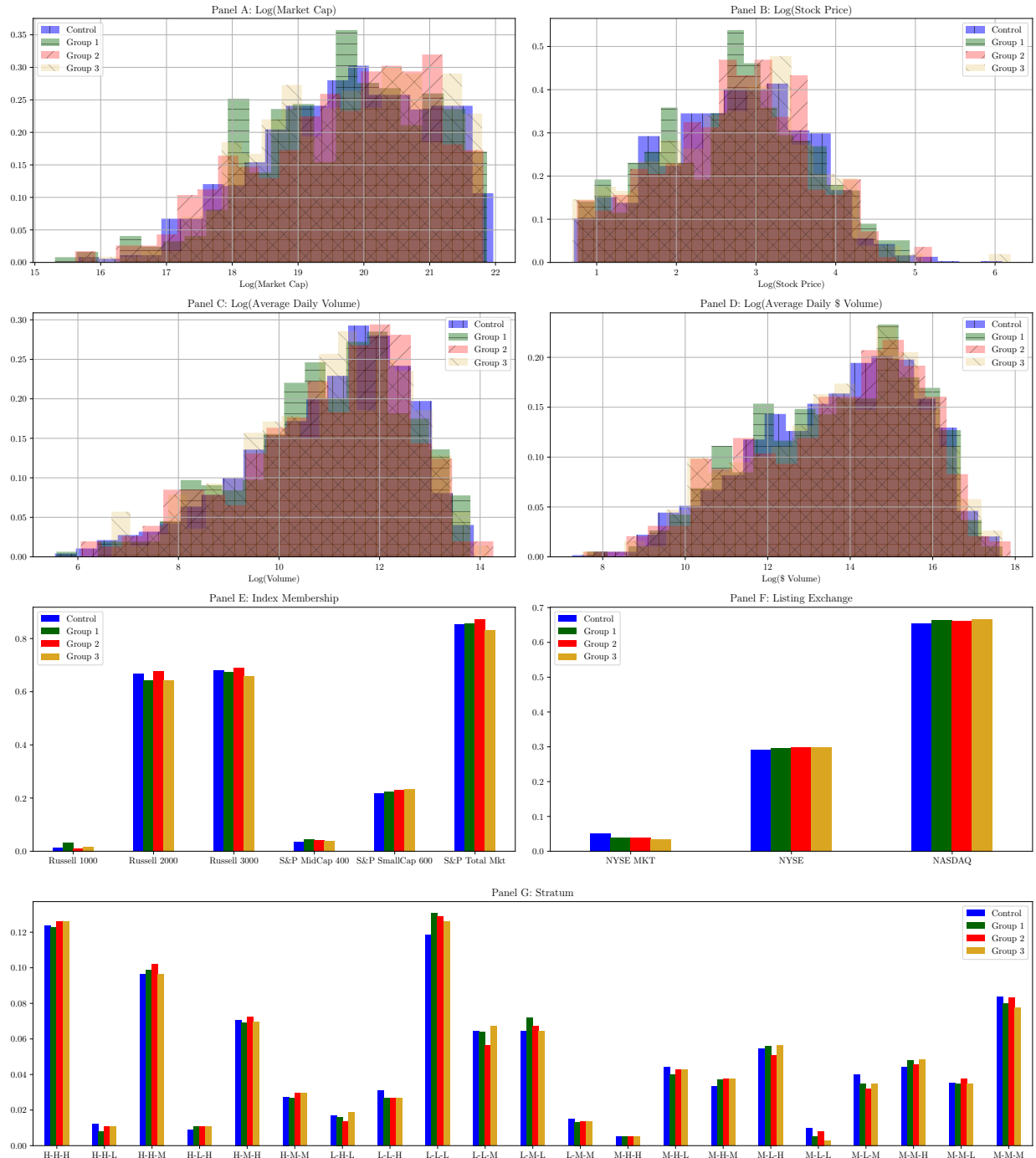


Table A.1
Fee Schedule

This table presents the standard exchange fee schedule for stocks priced above \$1 as at 21 December 2016. Parentheses indicate a rebate. The three inverted venues are BATS-Y, EDGA and NASDAQ BX. Tapes A, B and C refer to stocks listed on NYSE, NYSE MKT and NASDAQ, respectively. Data is from each venue's respective website. The fees apply to Tape A, B and C unless indicated otherwise. NYSE MKT does not trade Tape A stocks. NYSE only trades Tape A stocks.

| Venue | Adding Liquidity | Removing Liquidity |
|------------|------------------------|--------------------|
| BATS-Y | \$0.0018 | (\$0.0010) |
| BATS-Z | (\$0.0020) | \$0.0030 |
| | (\$0.0025) | |
| CHX | (\$0.0020) | \$0.0030 |
| EDGA | \$0.0005 | (\$0.0002) |
| EDGX | (\$0.0020) | \$0.0029 |
| IEX | \$0.0000 | \$0.0000 |
| NASDAQ BX | \$0.0020 | (\$0.0006) |
| NASDAQ PSX | (\$0.0023) | \$0.0030 |
| NASDAQ | Tape A & B: (\$0.0020) | \$0.0030 |
| | Tape C: (\$0.0015) | |
| NSX | \$0.0000 | \$0.0030 |
| NYSE | (\$0.0014) | \$0.00275 |
| NYSE ARCA | (\$0.0020) | \$0.0030 |
| NYSE MKT | Tape B: (\$0.0016) | Tape B: \$0.0028 |
| | Tape C: (\$0.0025) | Tape C: \$0.0030 |

Table A.2
Market Share by Tick Constraint

This table reports coefficients from OLS regressions of inverted venues and dark venues market share of dollar-volume continuous trading, both in %, on rule dummies ($\mathbf{1}_{[\text{trade-at}]}$, $\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), lags of the dependent variables, controls, and interactions with a tick constraint dummy. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap (Log(Size)), the inverse of the share price (1/Price), pilot group fixed effects, index membership fixed effects, industry fixed effects, and date fixed effects. $\mathbf{1}_{[\text{tick const.}]}$ is a dummy variable equal to one if the stock has above-median tick constraint and zero otherwise. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group.

| | Inverted Share | | Dark Share | |
|---|---------------------|---------------------|-----------------------|-----------------------|
| | (1) | (2) | (3) | (4) |
| $\mathbf{1}_{[\text{trade-at}]}$ | 2.882*** (10.59) | 1.865*** (7.14) | -9.338*** (-23.57) | -8.706*** (-14.82) |
| $\mathbf{1}_{[\text{trade-at}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 1.892*** (5.48) | | -0.640 (-0.91) |
| $\mathbf{1}_{[\text{trade}]}$ | -0.114 (-0.94) | -0.041 (-0.23) | -0.402 (-1.34) | -0.645 (-1.26) |
| $\mathbf{1}_{[\text{trade}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | -0.084 (-0.35) | | 0.538 (0.86) |
| $\mathbf{1}_{[\text{quote}]}$ | 3.518*** (29.48) | 2.970*** (21.04) | 2.671*** (9.78) | 1.450*** (3.14) |
| $\mathbf{1}_{[\text{quote}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 1.183*** (5.75) | | 2.015*** (3.87) |
| Inverted Share ($t - 1$) | 0.411*** (41.18) | 0.350*** (31.81) | | |
| Inverted Share ($t - 1$) \times $\mathbf{1}_{[\text{tick const.}]}$ | | 0.083*** (6.19) | | |
| Dark Share ($t - 1$) | | | 0.245*** (38.76) | 0.193*** (25.59) |
| Dark Share ($t - 1$) \times $\mathbf{1}_{[\text{tick const.}]}$ | | | | 0.141*** (12.93) |
| Controls | Yes | Yes | Yes | Yes |
| Pilot Group F.E. | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes |
| Date F.E. | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.518 | 0.528 | 0.336 | 0.342 |
| N | 152,303 | 152,303 | 152,303 | 152,303 |

Table A.3
Pricing Efficiency by Tick Constraint

This table reports coefficients from IV-2SLS regressions of price efficiency measures on inverted venues market share and dark venues market share, both in decimals, rule dummies ($\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), controls, and interactions with a tick constraint dummy. The price efficiency measures are the absolute difference between one and the variance ratio ($|1 - VR|$), the 15-seconds midpoint return auto-correlation (AC (15 sec)) and the 15-seconds midpoint return market cross-correlation (CC (15 sec)). Instrumented variables inverted venues market share and dark venues market share are estimated in the first stage by regressing on the dependent variables of the second stage, using the trade-at rule dummy ($\mathbf{1}_{[\text{trade-at}]}$) and one lag of the instrumented variable as instruments. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap ($\text{Log}(\text{Size})$), the inverse of the share price ($1/\text{Price}$), pilot group fixed effects, index membership fixed effects, industry fixed effects, and date fixed effects. $\mathbf{1}_{[\text{tick const.}]}$ is a dummy variable equal to one if the stock has above-median tick constraint and zero otherwise. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | $ 1 - VR $ | | AC (15 sec) | | CC (15 sec) | |
|--|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Inverted Share | -0.099*** (-3.34) | -0.024 (-0.49) | -0.035** (-2.46) | -0.019 (-0.77) | -0.037*** (-3.18) | 0.014 (1.03) |
| Inverted Share $\times \mathbf{1}_{[\text{tick const.}]}$ | | -0.143** (-2.21) | | -0.037 (-1.24) | | -0.097*** (-4.72) |
| Dark Share | -0.108*** (-6.71) | -0.121*** (-4.98) | -0.061*** (-7.12) | -0.072*** (-5.13) | -0.024*** (-4.70) | -0.004 (-0.82) |
| Dark Share $\times \mathbf{1}_{[\text{tick const.}]}$ | | 0.045 (1.49) | | 0.027 (1.63) | | -0.053*** (-6.00) |
| $\mathbf{1}_{[\text{trade}]}$ | 0.003 (0.73) | 0.004 (0.69) | 0.002 (1.17) | 0.003 (0.83) | -0.002 (-1.43) | -0.001 (-0.65) |
| $\mathbf{1}_{[\text{trade}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.001 (0.13) | | 0.000 (0.07) | | -0.003 (-1.18) |
| $\mathbf{1}_{[\text{quote}]}$ | -0.001 (-0.18) | -0.017*** (-3.43) | -0.006*** (-3.26) | -0.013*** (-4.61) | -0.009*** (-5.72) | -0.002 (-1.37) |
| $\mathbf{1}_{[\text{quote}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.033*** (4.85) | | 0.014*** (3.67) | | -0.013*** (-4.51) |
| $\mathbf{1}_{[\text{tick const.}]}$ | | 0.047 (1.06) | | 0.037 (1.44) | | -0.018 (-0.79) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Pilot Group F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Date F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.011 | 0.018 | 0.016 | 0.022 | 0.371 | 0.407 |
| N | 152,303 | 152,303 | 152,303 | 152,303 | 152,172 | 152,172 |

Table A.4
Variance Ratio

This table reports coefficients from IV-2SLS regressions of price efficiency measures on inverted venues market share and dark venues market share, both in decimals, rule dummies ($\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), and controls. The price efficiency measures are the absolute difference between one and the variance ratio ($|1 - VR|$) computed at different horizons. Instrumented variables inverted venues market share and dark venues market share are estimated in the first stage by regressing on the dependent variables of the second stage, using the trade-at rule dummy ($\mathbf{1}_{[\text{trade-at}]}$) and one lag of the instrumented variable as instruments. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap ($\text{Log}(\text{Size})$), the inverse of the share price ($1/\text{Price}$), pilot group fixed effects, index membership fixed effects, industry fixed effects, and date fixed effects. Results are presented for the full sample, and for two subsamples of stocks with below and above median tick constraint. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | Full Sample | | | Low Tick Constraint | | | High Tick Constraint | | |
|-------------------------------|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | 2m/30s (1) | 5m/1m (2) | 30m/5m (3) | 2m/30s (4) | 5m/1m (5) | 30m/5m (6) | 2m/30s (7) | 5m/1m (8) | 30m/5m (9) |
| Inverted Share | -0.082** (-2.62) | -0.125*** (-4.11) | -0.229*** (-4.81) | 0.006 (0.11) | -0.086 (-1.66) | -0.125* (-1.89) | -0.122*** (-3.17) | -0.102*** (-3.05) | -0.218*** (-3.26) |
| Dark Share | -0.127*** (-7.59) | -0.133*** (-7.81) | -0.045** (-2.26) | -0.144*** (-5.58) | -0.130*** (-5.07) | -0.020 (-0.65) | -0.071*** (-3.73) | -0.083*** (-4.48) | -0.014 (-0.45) |
| $\mathbf{1}_{[\text{trade}]}$ | 0.000 (0.03) | 0.001 (0.31) | -0.003 (-0.47) | 0.003 (0.62) | -0.001 (-0.16) | -0.007 (-0.95) | 0.000 (0.08) | 0.006 (1.30) | 0.003 (0.40) |
| $\mathbf{1}_{[\text{quote}]}$ | 0.004 (0.98) | 0.007 (1.57) | 0.003 (0.49) | -0.017*** (-3.07) | -0.007 (-1.16) | -0.004 (-0.59) | 0.021*** (4.08) | 0.015*** (2.71) | 0.003 (0.31) |
| VIX | 0.005*** (16.02) | 0.004*** (9.82) | 0.006*** (10.66) | 0.004*** (7.78) | 0.004*** (6.26) | 0.007*** (8.93) | 0.005*** (11.46) | 0.002*** (4.39) | 0.004*** (4.80) |
| $\text{Log}(\text{Size})$ | -0.013*** (-10.18) | -0.012*** (-8.13) | -0.011*** (-6.15) | -0.010*** (-4.73) | -0.010*** (-4.42) | -0.011*** (-4.62) | -0.011*** (-7.11) | -0.008*** (-5.26) | -0.009*** (-3.94) |
| $1/\text{Price}$ | -0.022** (-2.25) | -0.024* (-1.99) | -0.042*** (-3.71) | 0.060*** (3.00) | 0.012 (0.63) | -0.046* (-1.85) | -0.022** (-2.33) | -0.007 (-0.71) | -0.018 (-1.65) |
| Pilot Group F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Date F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.011 | 0.007 | 0.006 | 0.012 | 0.009 | 0.005 | 0.011 | 0.006 | 0.007 |
| N | 152,303 | 152,303 | 152,259 | 73,884 | 73,884 | 73,865 | 78,416 | 78,416 | 78,391 |

Table A.5
Pricing Efficiency Split on pre-TSP Price

This table reports coefficients from IV-2SLS regressions of price efficiency measures on inverted venues market share and dark venues market share, both in decimals, rule dummies ($\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), and controls. The price efficiency measures are the absolute difference between one and the variance ratio ($|1 - VR|$), the 15-seconds midpoint return auto-correlation (AC (15 sec)) and the 15-seconds midpoint return market cross-correlation (CC (15 sec)). Instrumented variables inverted venues market share and dark venues market share are estimated in the first stage by regressing on the dependent variables of the second stage, using the trade-at rule dummy ($\mathbf{1}_{[\text{trade-at}]}$) and one lag of the instrumented variable as instruments. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap (Log(Size)), the inverse of the share price (1/Price), pilot group fixed effects, index membership fixed effects, industry fixed effects, and date fixed effects. Results are presented for the full sample, and for two subsamples of stocks with below and above median price as of end of August 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | Full Sample | | | Low Price | | | High Price | | |
|-------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | $ 1 - VR $ (1) | AC (15 sec) (2) | CC (15 sec) (3) | $ 1 - VR $ (4) | AC (15 sec) (5) | CC (15 sec) (6) | $ 1 - VR $ (7) | AC (15 sec) (8) | CC (15 sec) (9) |
| Inverted Share | -0.099*** (-3.34) | -0.035** (-2.46) | -0.037*** (-3.18) | -0.192*** (-4.73) | -0.088*** (-4.75) | -0.010 (-0.71) | 0.050 (1.09) | 0.027 (1.12) | -0.058*** (-3.39) |
| Dark Share | -0.108*** (-6.71) | -0.061*** (-7.12) | -0.024*** (-4.70) | -0.127*** (-6.06) | -0.066*** (-6.56) | -0.019*** (-3.30) | -0.065*** (-2.71) | -0.050*** (-3.61) | -0.042*** (-5.09) |
| $\mathbf{1}_{[\text{trade}]}$ | 0.003 (0.73) | 0.002 (1.17) | -0.002 (-1.43) | 0.005 (0.98) | 0.005* (1.92) | -0.003 (-1.36) | 0.001 (0.13) | -0.000 (-0.06) | -0.003 (-1.28) |
| $\mathbf{1}_{[\text{quote}]}$ | -0.001 (-0.18) | -0.006*** (-3.26) | -0.009*** (-5.72) | 0.008 (1.66) | -0.002 (-0.83) | -0.011*** (-4.94) | -0.014** (-2.61) | -0.011*** (-3.89) | -0.007*** (-3.33) |
| VIX | 0.004*** (13.63) | 0.002*** (12.46) | -0.002*** (-7.15) | 0.005*** (10.23) | 0.003*** (11.24) | -0.001*** (-5.38) | 0.004*** (9.28) | 0.002*** (7.64) | -0.003*** (-7.98) |
| Log(Size) | -0.008*** (-6.81) | -0.004*** (-5.74) | 0.016*** (17.48) | -0.008*** (-4.91) | -0.003*** (-3.75) | 0.010*** (10.77) | -0.012*** (-5.88) | -0.006*** (-5.25) | 0.025*** (17.35) |
| 1/Price | -0.014 (-1.61) | -0.015** (-2.59) | 0.013*** (3.32) | 0.004 (0.56) | -0.005 (-1.24) | -0.006* (-1.92) | -0.415*** (-4.58) | -0.142*** (-2.93) | 0.325*** (5.44) |
| Pilot Group F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Date F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.011 | 0.016 | 0.371 | 0.011 | 0.011 | 0.286 | 0.018 | 0.029 | 0.357 |
| N | 152,303 | 152,303 | 152,172 | 75,281 | 75,281 | 75,164 | 76,952 | 76,952 | 76,938 |

Table A.6
Liquidity Split on pre-TSP Price

This table reports coefficients from IV-2SLS regressions of liquidity measures on inverted venues market share and dark venues market share, both in decimals, rule dummies ($\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), and controls. The liquidity measures are the relative spread, the effective spread, the 1-minute realized spread and the 1-minute price impact. Instrumented variables inverted venues market share and dark venues market share are estimated in the first stage by regressing on the dependent variables of the second stage, using the trade-at rule dummy ($\mathbf{1}_{[\text{trade-at}]}$) and one lag of the instrumented variable as instruments. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap ($\text{Log}(\text{Size})$), the inverse of the share price ($1/\text{Price}$), pilot group fixed effects, index membership fixed effects, industry fixed effects, and date fixed effects. Results are presented for the full sample, and for two subsamples of stocks with below and above median tick constraint. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | Full Sample | | | | Low Price | | | | High Price | | | |
|-------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | Rel. Spd. (1) | Eff. Spd. (2) | Real. Spd. (3) | Prc. Impact (4) | Rel. Spd. (5) | Eff. Spd. (6) | Real. Spd. (7) | Prc. Impact (8) | Rel. Spd. (9) | Eff. Spd. (10) | Real. Spd. (11) | Prc. Impact (12) |
| Inverted Share | -5.687*** (-10.33) | -3.066*** (-11.16) | -2.438*** (-11.44) | -0.643*** (-6.39) | -3.960*** (-6.05) | -2.042*** (-5.75) | -1.880*** (-6.62) | -0.241* (-1.69) | -5.254*** (-6.27) | -2.817*** (-6.72) | -2.033*** (-6.15) | -0.761*** (-5.73) |
| Dark Share | -0.698*** (-2.77) | -0.293** (-2.19) | 0.020 (0.17) | -0.360*** (-6.09) | -0.579 (-1.60) | -0.207 (-1.06) | 0.044 (0.27) | -0.341*** (-4.01) | 0.016 (0.05) | 0.056 (0.35) | 0.333** (2.04) | -0.273*** (-3.68) |
| $\mathbf{1}_{[\text{trade}]}$ | 0.096** (2.41) | 0.048* (1.93) | 0.040** (2.10) | 0.002 (0.17) | 0.108* (1.80) | 0.031 (0.77) | 0.023 (0.72) | -0.004 (-0.20) | 0.101** (2.42) | 0.071*** (3.38) | 0.063*** (3.92) | 0.009 (0.96) |
| $\mathbf{1}_{[\text{quote}]}$ | 0.558*** (11.07) | 0.362*** (13.06) | 0.254*** (11.33) | 0.113*** (10.28) | 0.593*** (8.41) | 0.426*** (9.82) | 0.305*** (8.67) | 0.133*** (7.36) | 0.371*** (5.67) | 0.212*** (6.89) | 0.137*** (5.52) | 0.074*** (6.94) |
| VIX | 0.174*** (21.61) | 0.096*** (20.25) | 0.057*** (15.04) | 0.038*** (22.76) | 0.204*** (15.90) | 0.114*** (15.10) | 0.068*** (11.23) | 0.044*** (17.42) | 0.182*** (14.29) | 0.098*** (13.70) | 0.062*** (10.61) | 0.036*** (16.01) |
| $\text{Log}(\text{Size})$ | -0.523*** (-19.33) | -0.301*** (-19.48) | -0.189*** (-16.18) | -0.107*** (-20.24) | -0.676*** (-13.67) | -0.397*** (-14.13) | -0.253*** (-11.79) | -0.136*** (-14.84) | -0.546*** (-13.75) | -0.302*** (-14.00) | -0.200*** (-11.84) | -0.101*** (-15.33) |
| $1/\text{Price}$ | -0.492** (-2.22) | 0.273* (1.81) | -0.031 (-0.28) | 0.320*** (5.57) | 0.144 (0.57) | 0.629*** (3.18) | 0.290** (2.15) | 0.361*** (4.82) | -11.963*** (-7.41) | -5.765*** (-6.48) | -4.440*** (-6.62) | -1.277*** (-4.78) |
| Pilot Group F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Date F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.337 | 0.371 | 0.222 | 0.184 | 0.323 | 0.353 | 0.205 | 0.148 | 0.357 | 0.358 | 0.250 | 0.159 |
| N | 152,303 | 151,961 | 151,961 | 151,961 | 75,281 | 75,037 | 75,037 | 75,037 | 76,952 | 76,854 | 76,854 | 76,854 |

Table A.7
Difference-in-Difference Market Share

This table reports coefficients from OLS regressions of inverted venues and dark venues market share of dollar-volume continuous trading, both in %. $\mathbf{1}_{[\text{s.t. trade-at}]}$, $\mathbf{1}_{[\text{s.t. trade}]}$, $\mathbf{1}_{[\text{s.t. quote}]}$ are dummy variables equal to one if the stock is subject to the rule at one point in the sample and zero otherwise. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. $\mathbf{1}_{[\text{tick const.}]}$ is a dummy variable equal to one if the stock has above-median tick constraint and zero otherwise. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. $\mathbf{1}_{[\text{post}]}$ is a dummy variable equal to one if the stock is in the post-treatment period and zero otherwise. Controls include the daily VIX level, the log of the stock issue market cap (Log(Size)), the inverse of the share price (1/Price), index membership fixed effects, and industry fixed effects. *t*-statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016 to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | Inverted Share | | Dark Share | |
|--|---------------------|---------------------|------------------------|------------------------|
| | (1) | (2) | (3) | (4) |
| $\mathbf{1}_{[\text{s.t. trade-at}]} \times \mathbf{1}_{[\text{post}]}$ | 4.547*** (14.05) | 2.562*** (7.00) | -12.231*** (-25.27) | -10.479*** (-15.09) |
| $\mathbf{1}_{[\text{s.t. trade}]} \times \mathbf{1}_{[\text{post}]}$ | -0.200 (-0.96) | -0.044 (-0.16) | -0.498 (-1.25) | -0.774 (-1.23) |
| $\mathbf{1}_{[\text{s.t. quote}]} \times \mathbf{1}_{[\text{post}]}$ | 6.013*** (33.67) | 4.651*** (21.94) | 3.467*** (9.43) | 1.838*** (3.19) |
| $\mathbf{1}_{[\text{s.t. trade-at}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 3.701*** (7.50) | | -3.576*** (-4.01) |
| $\mathbf{1}_{[\text{s.t. trade}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | -0.207 (-0.55) | | 0.653 (0.81) |
| $\mathbf{1}_{[\text{s.t. quote}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 2.663*** (8.98) | | 3.167*** (4.60) |
| Controls | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.412 | 0.432 | 0.289 | 0.291 |
| <i>N</i> | 154,613 | 154,613 | 154,613 | 154,613 |

Table A.8
Execution Rate

This table reports coefficients from OLS regressions of execution rate for top-of-book orders, in %. $\mathbf{1}_{[\text{s.t. trade-at}]}$, $\mathbf{1}_{[\text{s.t. trade}]}$, $\mathbf{1}_{[\text{s.t. quote}]}$ are dummy variables equal to one if the stock is subject to the rule at one point in the sample and zero otherwise. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. $\mathbf{1}_{[\text{tick const.}]}$ is a dummy variable equal to one if the stock has above-median tick constraint and zero otherwise. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. $\mathbf{1}_{[\text{post}]}$ is a dummy variable equal to one if the stock is in the post-treatment period and zero otherwise. Dependent variables are at the stock-venue-day level and results are presented for inverted fee venues and for non-inverted venues separately. Controls include the log of the stock issue market cap ($\text{Log}(\text{Size})$), the inverse of the share price ($1/\text{Price}$), venue fixed effects, index membership fixed effects, and industry fixed effects. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September and November 2016, and include stocks from the Tick Size Pilot Program groups and control group.

| | Inverted | | Non-inverted | |
|--|--------------------|-------------------|-------------------|-------------------|
| | (1) | (2) | (3) | (4) |
| $\mathbf{1}_{[\text{s.t. trade-at}]} \times \mathbf{1}_{[\text{post}]}$ | 1.431*** (4.23) | 0.932* (1.82) | 0.447* (1.70) | 0.768* (1.88) |
| $\mathbf{1}_{[\text{s.t. trade}]} \times \mathbf{1}_{[\text{post}]}$ | -0.645* (-1.88) | -0.769 (-1.49) | 0.053 (0.20) | 0.297 (0.74) |
| $\mathbf{1}_{[\text{s.t. quote}]} \times \mathbf{1}_{[\text{post}]}$ | 0.736*** (2.60) | 0.809* (1.82) | -0.337 (-1.58) | -0.020 (-0.06) |
| $\mathbf{1}_{[\text{s.t. trade-at}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.976 (1.44) | | -0.530 (-1.01) |
| $\mathbf{1}_{[\text{s.t. trade}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.229 (0.33) | | -0.554 (-1.06) |
| $\mathbf{1}_{[\text{s.t. quote}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | -0.169 (-0.30) | | -0.650 (-1.52) |
| Controls | Yes | Yes | Yes | Yes |
| Venue F.E. | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.105 | 0.108 | 0.374 | 0.380 |
| N | 13,237 | 13,237 | 25,459 | 25,459 |

Table A.9
Cancel-to-Trade Ratio

This table reports coefficients from OLS regressions of log cancel-to-trade ratio, in %. The trade-to-order ratio is defined as trade volume divided by order volume. $\mathbf{1}_{[\text{s.t. trade-at}]}$, $\mathbf{1}_{[\text{s.t. trade}]}$, $\mathbf{1}_{[\text{s.t. quote}]}$ are dummy variables equal to one if the stock is subject to the rule at one point in the sample and zero otherwise. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. $\mathbf{1}_{[\text{tick const.}]}$ is a dummy variable equal to one if the stock has above-median tick constraint and zero otherwise. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. $\mathbf{1}_{[\text{post}]}$ is a dummy variable equal to one if the stock is in the post-treatment period and zero otherwise. Dependent variables are at the stock-venue-day level and results are presented for inverted fee venues and for non-inverted venues separately. Controls include the daily VIX level, the log of the stock issue market cap (Log(Size)), the inverse of the share price (1/Price), venue fixed effects, index membership fixed effects, and industry fixed effects. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group.

| | Inverted | | Non-inverted | |
|--|----------------------|----------------------|----------------------|-----------------------|
| | (1) | (2) | (3) | (4) |
| $\mathbf{1}_{[\text{s.t. trade-at}]} \times \mathbf{1}_{[\text{post}]}$ | -0.102** (-2.64) | -0.072 (-1.30) | 0.006 (0.20) | 0.015 (0.46) |
| $\mathbf{1}_{[\text{s.t. trade}]} \times \mathbf{1}_{[\text{post}]}$ | -0.033 (-1.01) | -0.038 (-0.83) | -0.026 (-0.98) | -0.013 (-0.47) |
| $\mathbf{1}_{[\text{s.t. quote}]} \times \mathbf{1}_{[\text{post}]}$ | -0.278*** (-8.71) | -0.282*** (-6.68) | -0.200*** (-8.81) | -0.349*** (-14.60) |
| $\mathbf{1}_{[\text{s.t. trade-at}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | -0.066 (-1.04) | | -0.016 (-0.37) |
| $\mathbf{1}_{[\text{s.t. trade}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.020 (0.33) | | -0.017 (-0.39) |
| $\mathbf{1}_{[\text{s.t. quote}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | -0.033 (-0.67) | | 0.233*** (6.85) |
| Controls | Yes | Yes | Yes | Yes |
| Venue F.E. | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.262 | 0.327 | 0.391 | 0.410 |
| N | 223,621 | 223,621 | 443,169 | 443,169 |

Table A.10
Trade-to-Order Ratio - No Filter

This table reports coefficients from OLS regressions of unfiltered trade-to-order ratio, in %. The trade-to-order ratio is defined as trade volume divided by order volume. $\mathbf{1}_{[s.t. \text{ trade-at}]}$, $\mathbf{1}_{[s.t. \text{ trade}]}$, $\mathbf{1}_{[s.t. \text{ quote}]}$ are dummy variables equal to one if the stock is subject to the rule at one point in the sample and zero otherwise. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. $\mathbf{1}_{[\text{tick const.}]}$ is a dummy variable equal to one if the stock has above-median tick constraint and zero otherwise. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. $\mathbf{1}_{[\text{post}]}$ is a dummy variable equal to one if the stock is in the post-treatment period and zero otherwise. Dependent variables are at the stock-venue-day level and results are presented for inverted fee venues and for non-inverted venues separately. Controls include the daily VIX level, the log of the stock issue market cap (Log(Size)), the inverse of the share price (1/Price), venue fixed effects, index membership fixed effects, and industry fixed effects. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016, to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. No filter is applied based on the number of trades or orders.

| | Inverted | | Non-inverted | |
|---|--------------------|--------------------|--------------------|----------------------|
| | (1) | (2) | (3) | (4) |
| $\mathbf{1}_{[s.t. \text{ trade-at}]} \times \mathbf{1}_{[\text{post}]}$ | 1.020*** (5.94) | 0.623*** (3.69) | 0.513*** (3.85) | 0.603*** (3.64) |
| $\mathbf{1}_{[s.t. \text{ trade}]} \times \mathbf{1}_{[\text{post}]}$ | 0.279* (1.73) | 0.251* (1.80) | 0.160 (1.57) | 0.134 (0.98) |
| $\mathbf{1}_{[s.t. \text{ quote}]} \times \mathbf{1}_{[\text{post}]}$ | -0.127 (-0.89) | 0.125 (1.04) | 0.287*** (3.18) | 0.706*** (6.62) |
| $\mathbf{1}_{[s.t. \text{ trade-at}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.780** (2.39) | | -0.162 (-0.76) |
| $\mathbf{1}_{[s.t. \text{ trade}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | 0.040 (0.13) | | 0.037 (0.21) |
| $\mathbf{1}_{[s.t. \text{ quote}]} \times \mathbf{1}_{[\text{post}]} \times \mathbf{1}_{[\text{tick const.}]}$ | | -0.501* (-1.86) | | -0.774*** (-5.23) |
| Controls | Yes | Yes | Yes | Yes |
| Venue F.E. | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.093 | 0.120 | 0.155 | 0.162 |
| N | 385,113 | 385,113 | 758,527 | 758,527 |

Table A.11
Group Stratum Categories

This table presents the cutoff values of the categories used for the stratified sampling group assignment. Each stock is classified as having low, medium or high: market capitalization on the last day of the measurement period (in \$ millions), share price based on the measurement period VWAP, and volume based on the consolidated average daily volume during the measurement period. The measurement period is the three-calendar-month period ending at least 30 days prior to the effective date of the Tick Size Pilot program.

| | Market Cap | Share Price | Avg. Daily Volume |
|--------|-----------------|-------------------|----------------------|
| Low | < \$200M | < \$10.09 | < \$53,055 |
| Medium | \$200M – \$745M | \$10.09 – \$23.96 | \$53,055 – \$225,967 |
| High | > \$745M | > \$23.96 | > \$225,967 |

Table A.12
Pricing Efficiency

This table reports coefficients from OLS regressions of price efficiency measures on inverted venues market share and dark venues market share, both in decimals, rule dummies ($\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), and controls. These regressions are the uninstrumented versions of IV-2SLS regressions presented in Table 5. The price efficiency measures are the absolute difference between one and the variance ratio ($|1 - VR|$), the 15-seconds midpoint return auto-correlation (AC (15 sec)) and the 15-seconds midpoint return market cross-correlation (CC (15 sec)). The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap (Log(Size)), the inverse of the share price (1/Price), index membership fixed effects, and industry fixed effects. Results are presented for the full sample, and for two sub-samples of stocks with below and above median tick constraint. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016 to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | Full Sample | | | Low Tick Constraint | | | High Tick Constraint | | |
|-------------------------------|-------------------|----------------------|-----------------------|---------------------|----------------------|-----------------------|----------------------|----------------------|-----------------------|
| | $ 1 - VR $ (1) | AC (15 sec) (2) | CC (15 sec) (3) | $ 1 - VR $ (4) | AC (15 sec) (5) | CC (15 sec) (6) | $ 1 - VR $ (7) | AC (15 sec) (8) | CC (15 sec) (9) |
| Inverted Share | | -0.019*** (-2.95) | -0.002 (-0.30) | | -0.010 (-1.12) | 0.013*** (2.68) | | -0.030*** (-3.95) | -0.013* (-1.70) |
| Dark Share | | -0.019*** (-9.13) | -0.010*** (-7.85) | | -0.020*** (-7.59) | -0.003*** (-2.83) | | -0.015*** (-5.22) | -0.025*** (-9.45) |
| $\mathbf{1}_{[\text{trade}]}$ | | 0.004** (2.48) | -0.002 (-1.35) | | 0.005* (1.87) | -0.001 (-0.54) | | 0.004* (1.86) | -0.004* (-1.80) |
| $\mathbf{1}_{[\text{quote}]}$ | | -0.008*** (-4.93) | -0.012*** (-8.23) | | -0.014*** (-5.14) | -0.002 (-1.52) | | -0.002 (-1.16) | -0.021*** (-9.64) |
| VIX | | 0.004*** (13.42) | -0.006*** (-15.88) | | 0.002*** (5.70) | -0.006*** (-13.48) | | 0.004*** (11.40) | -0.006*** (-11.98) |
| Log(Size) | | -0.003*** (-4.71) | 0.016*** (17.82) | | 0.000 (0.24) | 0.014*** (13.96) | | -0.004*** (-5.64) | 0.016*** (14.91) |
| 1/Price | | -0.021*** (-3.79) | 0.011*** (2.67) | | 0.002 (0.18) | 0.039*** (5.83) | | -0.017*** (-2.80) | -0.013** (-2.37) |
| Pilot Group F.E. | | Yes | Yes | | Yes | Yes | | Yes | Yes |
| Index F.E. | | Yes | Yes | | Yes | Yes | | Yes | Yes |
| Industry F.E. | | Yes | Yes | | Yes | Yes | | Yes | Yes |
| Date F.E. | | Yes | Yes | | Yes | Yes | | Yes | Yes |
| Adjusted R^2 | | 0.017 | 0.373 | | 0.018 | 0.356 | | 0.016 | 0.399 |
| N | | 154,613 | 154,480 | | 75,028 | 74,943 | | 79,580 | 79,532 |

Table A.13
Liquidity

This table reports coefficients from OLS regressions of liquidity measures on inverted venues market share and dark venues market share, both in decimals, rule dummies ($\mathbf{1}_{[\text{trade}]}$, and $\mathbf{1}_{[\text{quote}]}$), and controls. The liquidity measures are the relative spread, the effective spread, the 1-minute realized spread and the 1-minute price impact. These regressions are the uninstrumented versions of IV-2SLS regressions presented in Table 6. The trade-at rule applies to group three only, the trade rule applies to groups two and three, and the quote rule applies to all pilot tests groups. Controls include the daily VIX level, the log of the stock issue market cap ($\text{Log}(\text{Size})$), the inverse of the share price ($1/\text{Price}$), pilot group fixed effects, index membership fixed effects, industry fixed effects, and date fixed effects. Results are presented for the full sample, and for two sub-samples of stocks with below and above median tick constraint. The level of tick constraint is measured as the inverse of the time-weighted average spread during the pre-pilot period of September 2016. t -statistics from robust standard errors clustered by date and stock are presented in parenthesis and *, ** and, *** indicate statistical significance at the 10%, 5%, and 1% level respectively. The sample period is September 1, 2016 to December 13, 2016, and include stocks from the Tick Size Pilot Program groups and control group. See the text for details on variable construction.

| | Full Sample | | | | Low Tick Constraint | | | | High Tick Constraint | | | |
|-------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|-----------------------|
| | Rel. Spd. (1) | Eff. Spd. (2) | Real. Spd. (3) | Prc. Impact (4) | Rel. Spd. (5) | Eff. Spd. (6) | Real. Spd. (7) | Prc. Impact (8) | Rel. Spd. (9) | Eff. Spd. (10) | Real. Spd. (11) | Prc. Impact (12) |
| Inverted Share | -2.172*** (-9.25) | -1.127*** (-9.31) | -0.392*** (-4.03) | -0.721*** (-16.30) | -1.808*** (-5.40) | -0.866*** (-4.89) | -0.102 (-0.71) | -0.759*** (-11.83) | -1.163*** (-7.70) | -0.820*** (-9.63) | -0.239*** (-3.98) | -0.576*** (-12.39) |
| Dark Share | 0.014 (0.23) | 0.002 (0.05) | 0.475*** (13.21) | -0.462*** (-26.54) | 0.236*** (2.95) | 0.123** (2.59) | 0.639*** (13.87) | -0.502*** (-22.73) | -0.167*** (-3.41) | -0.118*** (-3.07) | 0.262*** (8.90) | -0.378*** (-15.05) |
| $\mathbf{1}_{[\text{trade}]}$ | 0.067* (1.80) | 0.024 (1.02) | 0.025 (1.37) | -0.003 (-0.27) | 0.073 (1.23) | 0.049 (1.52) | 0.047* (1.69) | -0.001 (-0.06) | 0.039 (1.02) | -0.008 (-0.29) | -0.006 (-0.32) | -0.002 (-0.21) |
| $\mathbf{1}_{[\text{quote}]}$ | 0.327*** (9.20) | 0.238*** (10.89) | 0.119*** (6.96) | 0.120*** (12.50) | 0.071 (1.29) | 0.064** (2.13) | 0.026 (1.01) | 0.041*** (2.99) | 0.489*** (14.48) | 0.377*** (14.90) | 0.195*** (10.99) | 0.183*** (16.93) |
| VIX | 0.274*** (21.24) | 0.158*** (21.34) | 0.096*** (17.13) | 0.060*** (24.42) | 0.291*** (14.27) | 0.166*** (14.39) | 0.099*** (11.34) | 0.062*** (17.48) | 0.090*** (6.92) | 0.059*** (5.94) | 0.023*** (3.74) | 0.036*** (8.79) |
| $\text{Log}(\text{Size})$ | -0.562*** (-20.45) | -0.325*** (-21.06) | -0.212*** (-18.07) | -0.109*** (-21.16) | -0.598*** (-13.69) | -0.341*** (-14.12) | -0.225*** (-12.19) | -0.109*** (-14.26) | -0.185*** (-6.77) | -0.120*** (-5.80) | -0.055*** (-4.31) | -0.064*** (-7.59) |
| $1/\text{Price}$ | -0.690*** (-3.16) | 0.172 (1.16) | -0.155 (-1.45) | 0.336*** (5.36) | 1.489** (2.42) | 1.560*** (4.18) | 0.857*** (2.92) | 0.667*** (6.56) | 1.423*** (3.55) | 1.255*** (4.08) | 0.711*** (3.79) | 0.552*** (4.42) |
| Pilot Group F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Index F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Date F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted R^2 | 0.337 | 0.369 | 0.228 | 0.207 | 0.325 | 0.355 | 0.222 | 0.179 | 0.491 | 0.572 | 0.329 | 0.319 |
| N | 154,613 | 154,262 | 154,262 | 154,262 | 75,028 | 74,694 | 74,694 | 74,694 | 79,580 | 79,563 | 79,563 | 79,563 |

Table A.14
IV/OLS Ratios

This table reports coefficients from IV-2SLS and OLS regressions of market quality measures and the ratio of the two coefficients. Coefficients are from Tables 5, A.12, 6 and A.13. Refer to these tables for details on the regression specifications.

| Market Quality | Sample | Variables Measure | Coef. IV | | Coef. OLS | | Ratio | |
|--------------------|----------------------|-------------------|------------|----------------|------------|----------------|------------|----------------|
| | | | Dark Share | Inverted Share | Dark Share | Inverted Share | Dark Share | Inverted Share |
| Pricing Efficiency | Full Sample | $ 1 - VR $ | -0.11 | -0.10 | -0.03 | -0.05 | 3.41 | 2.14 |
| | | AC (15 sec) | -0.06 | -0.04 | -0.02 | -0.02 | 3.22 | 1.90 |
| | | CC (15 sec) | -0.02 | -0.04 | -0.01 | -0.00 | 2.44 | 24.70 |
| | High Tick Constraint | $ 1 - VR $ | -0.08 | -0.17 | -0.03 | -0.09 | 2.58 | 1.91 |
| | | AC (15 sec) | -0.05 | -0.06 | -0.02 | -0.03 | 2.95 | 1.86 |
| | | CC (15 sec) | -0.06 | -0.08 | -0.03 | -0.01 | 2.25 | 6.21 |
| | Low Tick Constraint | $ 1 - VR $ | -0.12 | -0.02 | -0.03 | -0.01 | 4.09 | 1.95 |
| | | AC (15 sec) | -0.07 | -0.02 | -0.02 | -0.01 | 3.62 | 1.88 |
| | | CC (15 sec) | -0.00 | 0.01 | -0.00 | 0.01 | 1.44 | 1.10 |
| Liquidity | Full Sample | Eff. Spd. | -0.29 | -3.07 | 0.00 | -1.13 | -170.97 | 2.72 |
| | | Prc. Impact | -0.36 | -0.64 | -0.46 | -0.72 | 0.78 | 0.89 |
| | | Real. Spd. | 0.02 | -2.44 | 0.47 | -0.39 | 0.04 | 6.21 |
| | | Rel. Spd. | -0.70 | -5.69 | 0.01 | -2.17 | -48.69 | 2.62 |
| | High Tick Constraint | Eff. Spd. | -0.35 | -1.74 | -0.12 | -0.82 | 3.01 | 2.13 |
| | | Prc. Impact | -0.25 | -0.39 | -0.38 | -0.58 | 0.67 | 0.68 |
| | | Real. Spd. | -0.08 | -1.32 | 0.26 | -0.24 | -0.29 | 5.55 |
| | | Rel. Spd. | -0.76 | -2.71 | -0.17 | -1.16 | 4.55 | 2.33 |
| | Low Tick Constraint | Eff. Spd. | 0.06 | -3.33 | 0.12 | -0.87 | 0.52 | 3.85 |
| | | Prc. Impact | -0.41 | -0.70 | -0.50 | -0.76 | 0.82 | 0.92 |
| | | Real. Spd. | 0.36 | -2.69 | 0.64 | -0.10 | 0.57 | 26.41 |
| | | Rel. Spd. | 0.07 | -6.10 | 0.24 | -1.81 | 0.30 | 3.38 |