Internet Appendix

"Tick Size, Competition for Liquidity Provision, and Price Discovery: Evidence from the U.S. Treasury Market"

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Table A1: Latency Threshold Analysis: How Fast Are Fast Traders?

	Security					Weighted
Latency Threshold	2-year	3-year	5-year	7-year	10-year	Average
Panel A: Correlation between PTFs' and Fast Traders' Trading Activity						
1 ms	0.386	0.454	0.547	0.479	0.26	0.421
5 ms	0.386	0.462	0.558	0.473	0.233	0.417
10 ms	0.386	0.46	0.563	0.462	0.227	0.416
25 ms	0.377	0.455	0.554	0.421	0.217	0.404
50 ms	0.359	0.438	0.536	0.372	0.205	0.385
100 ms	0.342	0.424	0.51	0.33	0.19	0.363
Panel B: Correlation between PTFs' and Slow Traders' Trading Activity						
1 ms	0.123	0.229	0.135	-0.131	-0.123	0.046
5 ms	0.061	0.183	0.051	-0.202	-0.132	-0.007
10 ms	0.025	0.156	-0.011	-0.221	-0.147	-0.043
25 ms	-0.014	0.122	-0.038	-0.194	-0.154	-0.062
50 ms	0.019	0.147	-0.012	-0.128	-0.152	-0.037
100 ms	0.066	0.181	0.047	-0.049	-0.129	0.008

This table reports the correlation in daily trading activity shares between PTFs and traders classified into fast traders (Panel A) and slow traders (Panel B) for the indicated Treasury note and latency threshold in milliseconds (ms) from April 1, 2019 to December 31, 2020. PTFs' trading activity is computed as the fraction of trading volume on electronic IDB platforms accounted for by PTFs as calculated from FINRA TRACE data and provided to us by Fleming et al. (2021). Fast traders' trading activity is computed as the fraction of trades on BrokerTec occurring within the indicated latency threshold from a market signal (change in the best bid-ask midpoint). Slow traders' trading activity is computed as the fraction of trades on BrokerTec occurring after the indicated latency threshold (but still within one second) from a market signal. The last column reports the average correlation across securities weighted by their average daily trading volume over the same period.

Table A2: Sensitivity Analysis of Latency Threshold

	Slow Traders		Fast Traders	
Latency Threshold	$FirstLO$	$SprTight$	$FirstLO$	$SprTight$
Panel A: Cash Tick Size Reduction				
1 ms	0.068	0.048^{*}	-0.106^{*}	-0.119^{**}
	(0.008)	(0.004)	(0.011)	(0.008)
5 ms	0.047	0.043^{**}	-0.086^{*}	-0.114^{**}
	(0.006)	(0.002)	(0.009)	(0.005)
25 ms	0.031^{*}	0.039^{*}	-0.070^{**}	-0.110^{**}
	(0.004)	(0.004)	(0.006)	(0.007)
50 ms	0.028^{*}	0.036^{*}	-0.067^{*}	-0.108^{**}
	(0.003)	(0.004)	(0.006)	(0.007)
100 ms	0.024^{*}	0.032^{**}	-0.063^{**}	-0.104^{**}
	(0.002)	(0.003)	(0.005)	(0.006)
Panel B: Futures Tick Size Reduction				
1 ms	-0.068^{**}	-0.023	0.087^{**}	0.012
	(0.004)	(0.015)	(0.004)	(0.020)
5 ms	-0.051^{**}	-0.032	0.070^{**}	0.020
	(0.003)	(0.011)	(0.004)	(0.017)
25 ms	-0.032^{**}	-0.041	0.051^{**}	0.030
	(0.002)	(0.009)	(0.004)	(0.015)
50 ms	-0.029^{**}	-0.047	0.048^{**}	0.035
	(0.002)	(0.009)	(0.004)	(0.015)
100 ms	-0.026^{**}	-0.045	0.045^{**}	0.033
	(0.002)	(0.009)	(0.004)	(0.014)

This table presents the sensitivity analysis of the results in Table 4 by latency threshold in milliseconds (ms). The regression model is $Y_{i,t} = \alpha_i + \gamma_t + \beta Post_t \times Treatment_i + \epsilon_{i,t}$, where Y is the outcome variable of interest, $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, $Post$ is an indicator variable equal to 1 for the period following the tick size change, i provides security indexing, t provides day indexing, and α_i and γ_t are security and day fixed effects, respectively. The table reports the estimate for β, with the corresponding standard error in parentheses. Slow and fast traders are identified by the latency of response to market signals, with the cutoff threshold as indicated in the first column. $FirstLO$ is the fraction of the first limit order reaching the book submitted by a given trader type following a market price change. $SprTight$ is the fraction of time a given trader type is the first to restore the bid-ask spread to one tick. Variables are measured at the daily frequency using data from the BrokerTec platform over New York trading hours (7:30 to 17:00 Eastern time). The sample includes 2-, 3-, 5-, 7-, and 10-year notes. For regressions around the cash tick size reduction in Panel A, the sample period is from September 24, 2018 to January 11, 2019, with the $Post$ period starting on November 19, 2018. For regressions around the futures tick size reduction in Panel B, the sample period is from November 19, 2018 to March 9, 2019, with the $Post$ period starting from January 14, 2019. Standard errors are clustered by security. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

Table A3: Placebo Analysis: Effects on Market Quality

	Cash Tick Size Reduction		Futures Tick Size Reduction	
Outcome Variable	Coef	Adj R^2	Coef	Adj R^2
Panel A: Trading Activity and Transaction Costs				
BAS	0.003	0.194	−0.023	0.267
BAS_L	0.007	0.360	−0.098	0.589
$OneTick$	0.000	0.203	0.007	0.329
$LogTVol$	−0.004	0.812	0.116	0.875
$LogTFreq$	−0.035	0.826	0.035	0.915
$TSize$	0.315	0.308	0.015	0.513
Panel B: Price Efficiency				
$NonZeroBA$	0.000	0.790	−0.052	0.924
$NonZeroT$	0.004	0.713	−0.061	0.885
RV	0.000	0.699	−0.485	0.727
$PErr$	0.009	0.277	−0.006	0.283
Panel C: Liquidity Supply at Select Price Tiers				
$LogD1$	0.084	0.646	−0.062	0.863
$LogD5$	0.114	0.702	0.021	0.892
$LogDT$	0.083	0.660	−0.062	0.819
Panel C: Liquidity Supply at Fixed Price Distances				
$LogD1A$	0.084	0.646	−0.062	0.863
$LogD2A$	0.081	0.681	0.001	0.885
$LogD3A$	0.084	0.680	0.012	0.889
$LogD4A$	0.099	0.690	0.018	0.891
$LogD5A$	0.114	0.702	0.021	0.892
Observations	380		375	

This table reports placebo tests on the effects of fake tick size reduction events on market quality. We estimate the regression model $Y_{i,t} = \alpha_i + \gamma_t + \beta Post_t \times Treatment_i + \epsilon_{i,t}$, where Y is the outcome variable of interest (shown in column 1 and defined in Table 1), $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, $Post$ is an indicator variable equal to 1 for the period following the placebo tick size change, i provides security indexing, t provides day indexing, and α_i and γ_t are security and day fixed effects, respectively. Columns "Coef" show the estimates of β. Columns "Adj. R^2" report the adjusted R^2 of each regression for a given outcome variable. The placebo date for the cash tick size reduction is Monday, November 20, 2017, and the sample period for the placebo regressions is from September 25, 2017 to January 12, 2018, with the $Post$ period starting on November 20, 2017. The placebo date for the futures tick size reduction is Monday, January 15, 2018, and the sample period for the placebo regressions is from November 20, 2017 to March 9, 2018, with the $Post$ period starting on January 15, 2018. Standard errors are clustered by security. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). *$p < .1$; **$p < .05$; ***$p < .01$.

Table A4: Placebo Analysis: Effects on Competition for Liquidity Provision and Price Discovery

	Cash Tick Size Reduction		Futures Tick Size Reduction	
Outcome Variable	Coef	Adj R^2	Coef	Adj R^2
Panel A: Liquidity Provision by Fast and Slow Traders				
$FirstLO - Slow$	0.010	0.122	−0.009	0.169
$FirstLO - Fast$	−0.048	0.152	0.023	0.137
$SprTight - Slow$	−0.021	0.144	0.002	0.315
$SprTight - Fast$	0.032	0.065	−0.006	0.115
Observations	380		375	
Panel B: Contribution to Price Discovery				
$IS : 1s$	−0.035	0.228	−0.004	0.243
$VarRW : 1s$	−0.000	0.412	−0.000	0.465
Observations	228		225	

This table reports placebo tests on the effects of fake tick size reduction events on liquidity provision by fast and slow traders and price discovery. We estimate the regression model $Y_{i,t} = \alpha_i + \gamma_t + \beta Post_t \times Treatment_i + \epsilon_{i,t}$, where Y is the outcome variable of interest (shown in column 1 and defined in Table 1), $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, $Post$ is an indicator variable equal to 1 for the period following the placebo tick size change, i provides security indexing, t provides day indexing, and α_i and γ_t are security and day fixed effects, respectively. Columns "Coef" show the estimates of β. Columns "Adj. R^2" report the adjusted R^2 of each regression for a given outcome variable. The placebo date for the cash tick size reduction is Monday, November 20, 2017, and the sample period for the placebo regressions is from September 25, 2017 to January 12, 2018, with the $Post$ period starting on November 20, 2017. The placebo date for the futures tick size reduction is Monday, January 15, 2018, and the sample period for the placebo regressions is from November 20, 2017 to March 9, 2018, with the $Post$ period starting on January 15, 2018. Standard errors are clustered by security. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). *$p < .1$; **$p < .05$; ***$p < .01$.

Table A5: Alternative Regression Model: Effects on Market Quality

	Cash Tick Size Reduction		Futures Tick Size Reduction	
Outcome Variable	Coef	Adj R^2	Coef	Adj R^2
Panel A: Trading Activity and Transaction Costs				
BAS	-0.974^{***}	0.914	0.006	0.351
BAS_L	-0.946^{**}	0.693	0.194	0.632
$Pct1Tick$	-0.047^{**}	0.622	0.002	0.425
$TV(\$B)$	0.392	0.386	-0.138	0.496
$Tfreq$	0.613^{**}	0.462	-0.010	0.497
$AVSZ$	-1.586^{**}	0.645	-0.850	0.364
Panel B: Price Efficiency				
$NonZeroBA$	0.208^{**}	0.557	0.041	0.580
$NonZeroT$	0.147	0.497	0.023	0.617
$RV(\%ann.)$	-0.065	0.276	0.140	0.359
$\lvert AR30\rvert$	-0.062	0.125	-0.013	0.086
$VR_{10s,1m}$	-0.165	0.176	-0.078	0.193
$PErr$	-0.024^{**}	0.187	-0.005	0.144
Panel C: Liquidity Supply at Select Price Tiers				
$D1$	-0.795^{**}	0.859	-0.641	0.680
$D5$	-0.385^{**}	0.875	-0.406	0.761
DT	-0.209^{*}	0.868	-0.155	0.776
Panel C: Liquidity Supply at Fixed Price Distances				
$D1A$	0.384^{**}	0.764	-0.540	0.711
$D2A$	0.294^{**}	0.809	-0.435	0.728
$D3A$	0.214^{*}	0.824	-0.375	0.742
$D4A$	0.171^{*}	0.837	-0.326	0.763
$D5A$	0.132	0.844	-0.288	0.774
Observations	370		370	

This table reports the effects of tick size reduction on various market quality metrics. The regression model is $Y_{i,t} = \alpha_i + \beta_1 Post_t + \beta_2 Post_t \times Treatment_i + \theta' Z_{i,t} + \epsilon_{i,t}$, where Y is the outcome variable of interest (shown in the first column and defined in Table 1). $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, and $Post$ is an indicator variable equal to 1 for the period after the relevant tick size reduction. α_i is security fixed effects. $Z_{i,t}$ include variables to control for security-specific variation over time due to aggregate bond market volatility (the $MOVE$ index) and Treasury market liquidity (measured by the average total market depth $MKTDEPTH$ and aggregate trading volume $MKTVOL$ across all on-the-run securities traded on BrokerTec), day-of-week dummies, a dummy for early market close days, and a holiday dummy for the holiday period (December 24, 2018 – December 31, 2018). Columns "Coef" show the estimates of β. Columns "Adj. R^2" report the adjusted R^2 of each regression for a given outcome variable. Variables are measured at the daily frequency using data from the BrokerTec platform over New York trading hours (7:30 to 17:00 Eastern time). The sample includes 2-, 3-, 5-, 7-, and 10-year notes. For regressions around the cash tick size reduction, the sample period is from September 24, 2018 to January 11, 2019, with the $Post$ period starting on November 19, 2018. For regressions around the futures tick size reduction, the sample period is from November 19, 2018 to March 9, 2019, with the $Post$ period starting from January 14, 2019. Standard errors are clustered by security. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

Table A6: Alternative Regression Model: Effects on Competition for Liquidity Provision

	Slow Traders		Fast Traders	
Latency Threshold	$FirstLO$	$SprTight$	$FirstLO$	$SprTight$
	Panel A: Cash Tick Size Reduction			
1 ms	0.098^{**}	0.072	-0.141^{**}	-0.107
	(0.005)	(0.009)	(0.005)	(0.014)
5 ms	0.075^{**}	0.075^{*}	-0.118^{**}	-0.110^{*}
	(0.004)	(0.006)	(0.005)	(0.011)
10 ms	0.066^{**}	0.077^{*}	-0.109^{**}	-0.106
	(0.003)	(0.007)	(0.004)	(0.012)
25 ms	0.051^{**}	0.079^{*}	-0.094^{**}	-0.114
	(0.002)	(0.007)	(0.003)	(0.012)
50 ms	0.048^{**}	0.080^{*}	-0.090^{**}	-0.114
	(0.002)	(0.007)	(0.003)	(0.011)
100 ms	0.042^{**}	0.072^{**}	-0.085^{**}	-0.106^{*}
	(0.002)	(0.004)	(0.002)	(0.008)
	Panel B: Futures Tick Size Reduction			
1 ms	-0.084	-0.003	0.109	-0.033
	(0.001)	(0.001)	(0.001)	(0.002)
5 ms	-0.056	-0.028	0.081	-0.008
	(0.000)	(0.001)	(0.001)	(0.002)
10 ms	-0.046	-0.037	0.071	-0.006
	(0.000)	(0.001)	(0.001)	(0.003)
25 ms	-0.035	-0.046	0.060	0.010
	(0.000)	(0.001)	(0.001)	(0.003)
50 ms	-0.030	-0.050	0.055	0.014
	(0.000)	(0.001)	(0.001)	(0.003)
100 ms	-0.024	-0.040	0.049	0.004^{**}
	(0.000)	(0.001)	(0.001)	(0.002)

This table reports the effects of tick size reduction on the competition for liquidity provision between fast and slow traders. The regression model is $Y_{i,t} = \alpha_i + \beta_1 Post_t + \beta_2 Post_t \times Treatment_i + \theta' Z_{i,t} + \epsilon_{i,t}$, where Y is the outcome variable of interest. $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, and $Post$ is an indicator variable equal to 1 for the period after the relevant tick size reduction. α_i is security fixed effects. $Z_{i,t}$ include variables to control for security-specific variation over time due to aggregate bond market volatility (the $MOVE$ index) and Treasury market liquidity (measured by the average total market depth $MKTDEPTH$ and aggregate trading volume $MKTVOL$ across all on-the-run securities traded on BrokerTec), day-of-week dummies, a dummy for early market close days, and a holiday dummy for the holiday period (December 24, 2018 – December 31, 2018). Slow and fast traders are identified by the latency of response to market signals, with the cutoff threshold in milliseconds (ms) as indicated in the first column. $FirstLO$ is the fraction of the first limit order reaching the book submitted by a given trader type following a market price change. $SprTight$ is the fraction of time a given trader type is the first to restore the bid-ask spread to one tick. Variables are measured at the daily frequency using data from the BrokerTec platform over New York trading hours (7:30 to 17:00 Eastern time). The sample includes 2-, 3-, 5-, 7-, and 10-year notes. For regressions around the cash tick size reduction in Panel A, the sample period is from September 24, 2018 to January 11, 2019, with the $Post$ period starting on November 19, 2018. For regressions around the futures tick size reduction in Panel B, the sample period is from November 19, 2018 to March 9, 2019, with the $Post$ period starting from January 14, 2019. Standard errors are clustered by security. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

Table A7: Alternative Regression Model: Effects on Price Discovery

	Cash Tick Size Reduction		Futures Tick Size Reduction	
Sampling Frequency	IS_Cash	$VarRW$	IS_Cash	$VarRW$
1 second	0.186^{*}	0.770	-0.177	0.739
	(0.014)	(0.731)	(0.003)	(0.292)
10 seconds	0.208^{*}	0.018	-0.270	0.902
	(0.014)	(0.675)	(0.004)	(0.356)
30 seconds	0.150^{*}	0.286	-0.234	1.013
	(0.006)	(0.556)	(0.006)	(0.409)
1 minute	0.062	-0.367	-0.186	1.162
	(0.018)	(0.262)	(0.004)	(0.465)
5 minutes	0.013	1.572	0.078	0.885
	(0.007)	(0.490)	(0.003)	(0.407)
10 minutes	0.042	13.310	0.013	-3.068
	(0.008)	(17.909)	(0.005)	(5.579)

This table shows the effects of tick size on price informativeness of the cash market relative to the futures market at various return sampling frequencies. The regression model is
$Y_{i,t} = \alpha_i + \beta_1 Post_t + \beta_2 Post_t \times Treatment_i + \theta' Z_{i,t} + \epsilon_{i,t}$, where Y is the outcome variable of interest. $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, and $Post$ is an indicator variable equal to 1 for the period after the relevant tick size reduction. α_i is security fixed effects. $Z_{i,t}$ include variables to control for security-specific variation over time due to aggregate bond market volatility (the $MOVE$ index) and Treasury market liquidity (measured by the average total market depth $MKTDEPTH$ and aggregate trading volume $MKTVOL$ across all on-the-run securities traded on BrokerTec), day-of-week dummies, a dummy for early market close days, and a holiday dummy for the holiday period (December 24, 2018 – December 31, 2018). The dependent variable is the information share of the cash market based on midpoint returns at a given sampling frequency. Information shares are computed from a VECM(5) estimated separately for each day using cash and futures prices sampled at each given horizon for the 2-, 5-, 7-, and 10-year maturities (with the 7-year note paired with the 10-year Treasury note futures and the 10-year note paired with the ultra 10-year Treasury note futures). Cash data are from the BrokerTec platform and futures data are from the CME. The sample includes 2-, 3-, 5-, 7-, and 10-year notes. For regressions around the cash tick size reduction, the sample period is from September 24, 2018 to January 11, 2019, with the $Post$ period starting on November 19, 2018. For regressions around the futures tick size reduction, the sample period is from November 19, 2018 to March 9, 2019, with the $Post$ period starting from January 14, 2019. Standard errors are clustered by security and reported in parentheses. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

Table A8: Alternative Regression Model: Effects on Treasury Futures Market

	Cash Tick Size Reduction		Futures Tick Size Reduction	
Outcome Variable	Coef	Adj R^2	Coef	Adj R^2
		Panel A: Trading Activity and Transaction Costs		
BAS	0.013	0.382	-0.951^{***}	0.984
$Pct1Tick$	-0.010	0.397	-0.061	0.509
$TV(\$B)$	0.355	0.543	-0.091	0.619
$Tfreq$	0.243	0.414	0.169	0.507
$AVSZ$	18.262	0.763	-5.481	0.800
		Panel B: Price Efficiency		
$NonZeroBA$	0.040	0.402	0.167^{**}	0.701
$RV(\%ann.)$	0.286	0.349	-0.260	0.516
$\lvert AR30\rvert$	-0.011	0.020	-0.028	0.035
$VR_{10s,1m}$	-0.037	0.049	-0.087	0.071
		Panel C: Liquidity Supply		
$D1$	-0.850^{*}	0.846	-0.888	0.858
$D5$	-0.389^{*}	0.842	-0.665	0.871
$D1A$	-0.855^{*}	0.846	0.168	0.853
$D2A$	-0.615^{*}	0.846	0.091	0.852
$D3A$	-0.500^{*}	0.844	0.081	0.850
$D4A$	-0.436^{*}	0.843	0.093	0.849
$D5A$	-0.392^{*}	0.842	0.098	0.849

This table reports the effects of tick size reduction on various market quality metrics in the futures market. The regression model is $Y_{i,t} = \alpha_i + \beta_1 Post_t + \beta_2 Post_t \times Treatment_i + \theta' Z_{i,t} + \epsilon_{i,t}$, where Y is the outcome variable of interest. $Treatment$ is an indicator variable equal to 1 for the 2-year note and 0 otherwise, and $Post$ is an indicator variable equal to 1 for the period after the relevant tick size reduction. α_i is security fixed effects. $Z_{i,t}$ include variables to control for security-specific variation over time due to aggregate bond market volatility (the $MOVE$ index) and Treasury market liquidity (measured by the average total market depth $MKTDEPTH$ and aggregate trading volume $MKTVOL$ across all on-the-run securities traded on BrokerTec), day-of-week dummies, a dummy for early market close days, and a holiday dummy for the holiday period (December 24, 2018 – December 31, 2018). Columns "Coef" show the estimates of β. Columns "Adj. R^2" report the adjusted R^2 of each regression for a given outcome variable. The sample includes 2-, 5-, 10-year, and ultra 10-year Treasury note futures. Variables are measured at the daily frequency using data from the CME over New York trading hours (7:30 to 17:00 Eastern time). For regressions around the cash tick size reduction, the sample period is from September 24, 2018 to January 11, 2019, with the $Post$ period starting on November 19, 2018. For regressions around the futures tick size reduction, the sample period is from November 19, 2018 to March 9, 2019, with the $Post$ period starting from January 14, 2019. Standard errors are clustered by security. Statistical significance is based on wild cluster bootstrap p-values (with 9999 reps and using six-point weight distribution). $^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$.

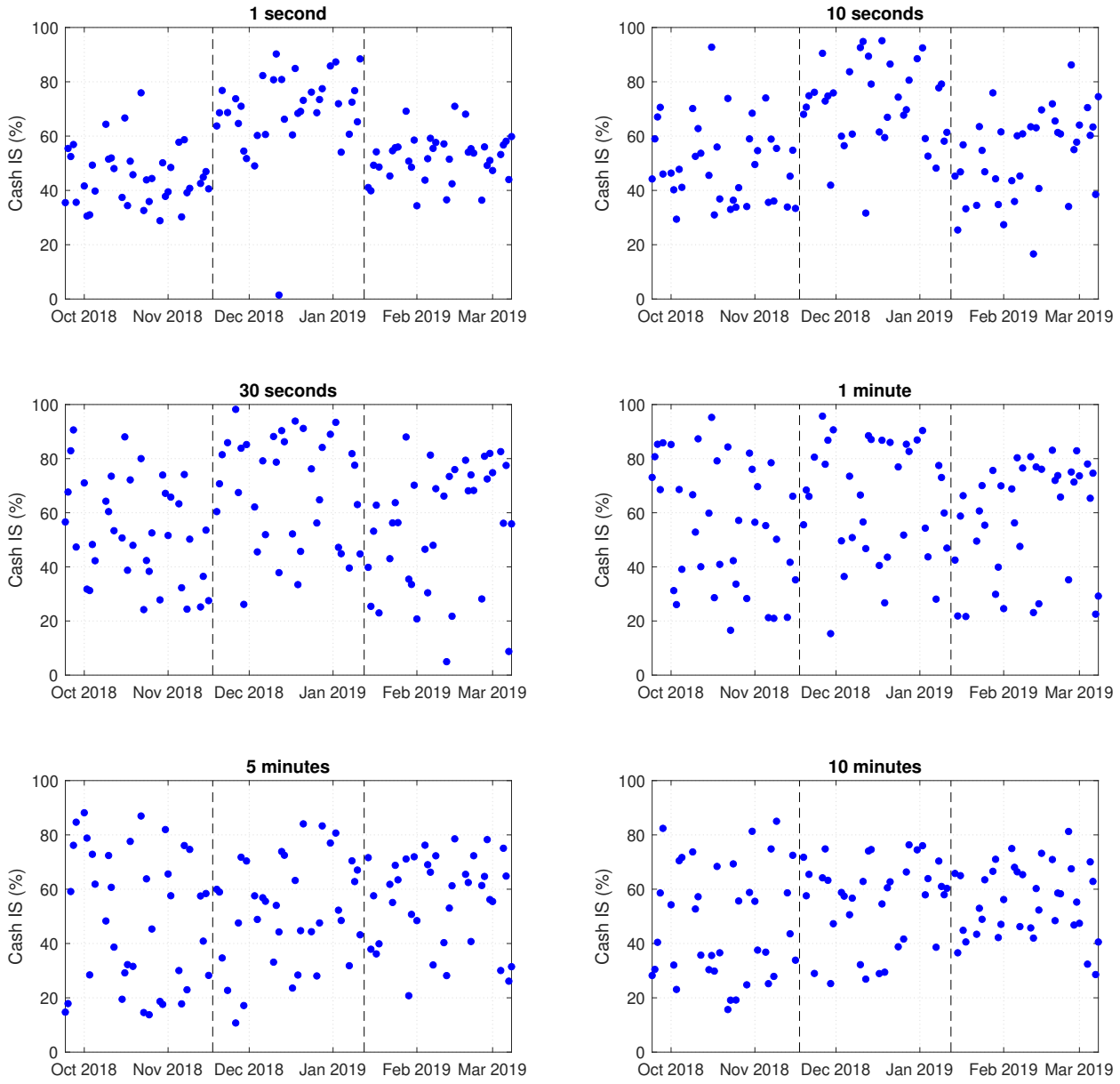

Figure A1: Information Share of Cash Market At Different Sampling Frequencies.
This figure shows the information share of the cash market for the 2-year note across different return sampling frequencies. The information share is the fraction of the efficient return variance explained by the price variation in the cash market. Efficient return variance and information share are computed from a VECM (5) of cash and futures prices sampled at a given frequency. Data for cash instruments are from BrokerTec. Data for futures instruments are from the CME. The sample period is from September 24, 2018 to March 8, 2019. Model estimation is based on data over New York trading hours (7:30 to 17:00 Eastern time). The left vertical line separates the cash market's pre-change period (through November 16, 2018) and its post-change period (starting November 19, 2018). The right vertical line separates the futures market's pre-change period (through January 11, 2019) and its post-change period (starting January 14, 2019).