

Internet Appendix

“Price and Size Discovery in Financial Markets:
Evidence from the U.S. Treasury Securities Market”

By: Michael J. Fleming and Giang Nguyen

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Table IA1: Treasury Auction Statistics

	<u>2-Year</u>	<u>3-Year</u>	<u>5-Year</u>	<u>7-Year</u>	<u>10-Year</u>	<u>30-Year</u>
Issue Size (\$ Billion)	32.52	30.73	31.68	29.79	20.28	13.88
Purchases at Auction (%):						
Dealers and Brokers	55.68	53.56	48.43	42.60	47.01	47.12
Investment Funds	17.58	20.27	26.01	32.29	27.73	36.25
Foreign and International	19.19	21.74	19.58	21.31	20.08	10.91
Federal Reserve System	5.55	3.51	4.76	2.97	4.47	4.36
Depository Institutions	0.40	0.46	0.67	0.43	0.36	0.73
Pension/Retirement Funds and Insurance Cos.	0.06	0.09	0.11	0.13	0.07	0.35
Individuals	1.15	0.21	0.28	0.09	0.19	0.12
Other	0.38	0.15	0.17	0.18	0.08	0.16

This table reports average issue size (in billions of dollars) and average purchases at auction by investor class (as a percent of issue size) for auctions of nominal coupon Treasury securities over the 2006-2016 period, based on data from Office of Debt Management, Department of Treasury.

Table IA2: Permanent Price Impact of Segmented Order Flow

	Workup Trades								
	Lit Trades			Same Side			Other Side		
	Mean	90% Range		Mean	90% Range		Mean	90% Range	
	$\times 10^{-3}$								
Panel A: Duration-adjusted price impact per unitary shock in order flow									
2-Year	1.44*	[0.29	4.05]	1.61*	[0.35	4.14]	-1.21	[-3.58	0.51]
3-Year	2.78*	[0.54	8.04]	3.09*	[0.68	7.85]	-1.62	[-4.89	0.90]
5-Year	3.59*	[1.08	9.03]	2.12*	[0.94	4.06]	-1.11*	[-2.55	-0.02]
7-Year	6.57*	[2.14	15.73]	5.87*	[2.21	12.61]	-2.54	[-7.75	1.66]
10-Year	4.57*	[1.60	10.92]	2.77*	[1.34	5.10]	-1.56*	[-3.38	-0.09]
30-Year	21.73*	[9.24	43.04]	4.44	[-1.58	12.82]	-2.64	[-11.84	3.79]
Panel B: Duration-adjusted price impact of average transaction									
2-Year	23.67*	[4.78	66.41]	34.07*	[7.46	87.60]	-9.45	[-28.05	4.03]
3-Year	22.81*	[4.43	65.99]	36.39*	[7.97	92.40]	-7.08	[-21.33	3.92]
5-Year	22.71*	[6.85	57.13]	20.49*	[9.13	39.21]	-6.09*	[-14.00	-0.10]
7-Year	25.32*	[8.24	60.66]	34.05*	[12.82	73.17]	-7.66	[-23.32	5.00]
10-Year	25.82*	[9.03	61.67]	22.81*	[11.07	42.00]	-6.98*	[-15.15	-0.41]
30-Year	38.51*	[16.37	76.28]	8.82	[-3.14	25.45]	-3.71	[-16.64	5.33]

This table reports the permanent price impact of order flow, derived from a VAR(5) model of pre-workup trade flow, return, workup trade flow initiated from the same side, and workup trade flow initiated from the other side. Panel A reports duration-adjusted price impact estimates per unitary shock in each order flow variable. Panel B reports duration-adjusted price impact estimates for an average-sized transaction with workup. Estimation is based on BrokerTec data for on-the-run nominal coupon Treasury securities over the 2006-2016 period. Daily duration data are from the CRSP Daily Treasuries database. Observations outside the [7:00-17:30] time window are excluded. The model is estimated separately for each day. The mean and 90% range (5th and 95th percentiles) are computed from the time series of daily price impact estimates. Statistical significance at the 5% level (one-sided) is marked with an asterisk (*).

Table IA3: Tests of Difference in Price Impacts Among Order Flow Types

	Lit vs. Same-side Workup	Same-side vs. Other-side Workup		
	t-stat	t-stat	Same-side: % Positive	Other-side: % Negative
2-Year	-9.95	7.89	0.99	0.86
3-Year	-4.84	18.59	1.00	0.87
5-Year	36.02	48.95	1.00	0.95
7-Year	8.22	30.78	1.00	0.88
10-Year	36.18	37.51	1.00	0.96
30-Year	77.99	9.72	0.90	0.75

This table reports the results of tests for the difference in price impacts among order flow types. Column (1) shows the t-statistic for the difference in price impact of lit versus same-side workup order flow. Column (2) shows the t-statistic for the difference in the magnitude of price impact of same-side versus other-side workup order flow. Column (3) shows the percentage of positive price impact estimates for same-side workup trades. Column (4) shows the percentage of negative price impact estimates for other-side workup trades. Price impact estimates are derived from a VAR(4) model of pre-workup trade flow, return, workup trade flow initiated from the same side, and workup trade flow initiated from the other side. The model is estimated separately for each day for each security, based on BrokerTec data over the 2006-2016 period.

Table IA4: Price Discovery of Level Factor of Treasury Benchmark Yield Curve

	Statistic	Pre-workup	Workup (same side)	Workup (other side)	Total
2-Year	Mean	0.513	1.076	0.162	1.751
	StdErr	(0.006)	(0.014)	(0.005)	(0.019)
3-Year	Mean	0.723	1.521	0.123	2.367
	StdErr	(0.009)	(0.015)	(0.002)	(0.021)
5-Year	Mean	2.204	2.564	0.308	5.077
	StdErr	(0.015)	(0.018)	(0.008)	(0.027)
7-Year	Mean	1.359	1.381	0.207	2.946
	StdErr	(0.013)	(0.013)	(0.004)	(0.023)
10-Year	Mean	2.548	2.305	0.253	5.106
	StdErr	(0.014)	(0.013)	(0.005)	(0.020)
30-Year	Mean	2.487	0.777	0.158	3.422
	StdErr	(0.022)	(0.010)	(0.003)	(0.032)
Total	Mean	9.834	9.625	1.211	20.669
	StdErr	(0.044)	(0.052)	(0.017)	(0.097)

This table reports the contributions of order flow variables (in percentage points) to the variance of the level factor of the Treasury benchmark yield curve, derived from a VAR(5) model of pre-workup trade flow, same-side workup trade flow, other-side workup trade flow, and four yield curve factors extracted from one-second returns of six nominal on-the-run coupon Treasury securities. Estimation is based on BrokerTec data over the period from February 27, 2009 to the end of 2016 (1953 days in total). The model is estimated and information shares are computed separately for each trading day. Observations outside the [7:00-17:30] time window are excluded.

Table IA5: Price Discovery of Level Factor of Treasury Benchmark Yield Curve on Macroeconomic and FOMC Announcement Days

	2-Year	3-Year	5-Year	7-Year	10-Year	30-Year
Panel A: Aggregate trade information share						
Intercept	1.737***	2.352***	5.194***	3.041***	5.202***	3.531***
FOMC	-0.093	-0.321***	-0.927***	-0.553***	-0.927***	-0.396**
Macro	0.046	0.084	-0.132**	-0.109*	-0.127**	-0.123
Macro x High Belief Dispersion	-0.209	-0.615***	-0.603***	-0.884***	-0.246	-1.260***
Macro x Low Belief Dispersion	0.254**	0.346**	0.558***	0.570***	0.290**	0.936***
Panel B: Information share ratio of workup trades to all trades						
Intercept	0.686***	0.685***	0.565***	0.540***	0.504***	0.263***
FOMC	-0.010	-0.014	-0.007	-0.029**	0.012	-0.014
Macro	0.006	0.008	-0.006	-0.002	-0.007	-0.003
Macro x High Belief Dispersion	-0.013	-0.042**	-0.076***	-0.051***	-0.030**	-0.040***
Macro x Low Belief Dispersion	0.002	0.013	0.040**	0.002	0.050***	0.024**

This table reports the regression of trade information share (Panel A) and the ratio of information share of workup trades to that of all trades (Panel B) on macroeconomic and FOMC announcement dummies. Dispersion of beliefs among market participants with respect to each macroeconomic announcement is computed as described in the text. High Belief Dispersion (Low Belief Dispersion) is a dummy for announcements with dispersion level in the top (bottom) 5% of its distribution. The information shares considered here are the contributions of order flow variables (in percentage points) to the variance of the level factor of the Treasury benchmark yield curve, derived from a VAR(5) model of pre-workup trade flow, same-side workup trade flow, other-side workup trade flow, and four yield curve factors extracted from one-second returns of six nominal on-the-run coupon Treasury securities. Estimation is based on BrokerTec data over the period from February 27, 2009 to the end of 2016 (1953 days in total). The model is estimated and information shares are computed separately for each trading day. Observations outside the [7:00-17:30] time window are excluded.

Table IA6: Price Discovery of Short-term Slope Factor of Treasury Benchmark Yield Curve

	Statistic	Pre-workup	Workup (same side)	Workup (other side)	Total
2-Year	Mean	1.149	1.734	0.414	3.297
	StdErr	(0.019)	(0.026)	(0.018)	(0.045)
3-Year	Mean	1.197	1.663	0.164	3.025
	StdErr	(0.013)	(0.020)	(0.004)	(0.029)
5-Year	Mean	0.125	0.106	0.050	0.282
	StdErr	(0.002)	(0.002)	(0.001)	(0.004)
7-Year	Mean	0.071	0.063	0.043	0.177
	StdErr	(0.003)	(0.001)	(0.001)	(0.004)
10-Year	Mean	0.076	0.082	0.042	0.200
	StdErr	(0.001)	(0.001)	(0.001)	(0.002)
30-Year	Mean	0.058	0.045	0.029	0.132
	StdErr	(0.001)	(0.001)	(0.001)	(0.002)
Total	Mean	2.677	3.695	0.742	7.113
	StdErr	(0.025)	(0.037)	(0.020)	(0.063)

This table reports the contributions of order flow variables (in percentage points) to the variance of the short-term slope factor of the Treasury benchmark yield curve, derived from a VAR(5) model of pre-workup trade flow, same-side workup trade flow, other-side workup trade flow, and four yield curve factors extracted from one-second returns of six nominal on-the-run coupon Treasury securities. Estimation is based on BrokerTec data over the period from February 27, 2009 to the end of 2016 (1953 days in total). The model is estimated and information shares are computed separately for each trading day. Observations outside the [7:00-17:30] time window are excluded.

Table IA7: Price Discovery of Medium-term Slope Factor of Treasury Benchmark Yield Curve

	Statistic	Pre-workup	Workup (same side)	Workup (other side)	Total
2-Year	Mean	0.033	0.045	0.034	0.113
	StdErr	(0.001)	(0.001)	(0.001)	(0.002)
3-Year	Mean	0.039	0.059	0.035	0.132
	StdErr	(0.001)	(0.001)	(0.001)	(0.002)
5-Year	Mean	0.842	0.589	0.097	1.527
	StdErr	(0.008)	(0.008)	(0.003)	(0.014)
7-Year	Mean	0.637	0.634	0.087	1.358
	StdErr	(0.007)	(0.009)	(0.002)	(0.013)
10-Year	Mean	0.057	0.059	0.041	0.156
	StdErr	(0.001)	(0.001)	(0.001)	(0.003)
30-Year	Mean	0.040	0.037	0.030	0.106
	StdErr	(0.001)	(0.001)	(0.001)	(0.001)
Total	Mean	1.647	1.423	0.323	3.393
	StdErr	(0.012)	(0.015)	(0.005)	(0.023)

This table reports the contributions of order flow variables (in percentage points) to the variance of the medium-term slope factor of the Treasury benchmark yield curve, derived from a VAR(5) model of pre-workup trade flow, same-side workup trade flow, other-side workup trade flow, and four yield curve factors extracted from one-second returns of six nominal on-the-run coupon Treasury securities. Estimation is based on BrokerTec data over the period from February 27, 2009 to the end of 2016 (1953 days in total). The model is estimated and information shares are computed separately for each trading day. Observations outside the [7:00-17:30] time window are excluded.

Table IA8: Price Discovery of Long-term Slope Factor of Treasury Benchmark Yield Curve

	Statistic	Pre-workup	Workup (same side)	Workup (other side)	Total
2-Year	Mean	0.028	0.036	0.036	0.099
	StdErr	(0.001)	(0.001)	(0.002)	(0.003)
3-Year	Mean	0.029	0.039	0.032	0.100
	StdErr	(0.001)	(0.001)	(0.001)	(0.002)
5-Year	Mean	0.069	0.069	0.040	0.178
	StdErr	(0.002)	(0.001)	(0.001)	(0.003)
7-Year	Mean	0.057	0.055	0.041	0.153
	StdErr	(0.002)	(0.001)	(0.001)	(0.003)
10-Year	Mean	0.617	0.441	0.109	1.166
	StdErr	(0.011)	(0.005)	(0.002)	(0.013)
30-Year	Mean	2.164	0.251	0.168	2.583
	StdErr	(0.017)	(0.004)	(0.003)	(0.022)
Total	Mean	2.964	0.890	0.424	4.278
	StdErr	(0.014)	(0.007)	(0.004)	(0.018)

This table reports the contributions of order flow variables (in percentage points) to the variance of the long-term slope factor of the Treasury benchmark yield curve, derived from a VAR(5) model of pre-workup trade flow, same-side workup trade flow, other-side workup trade flow, and four yield curve factors extracted from one-second returns of six nominal on-the-run coupon Treasury securities. Estimation is based on BrokerTec data over the period from February 27, 2009 to the end of 2016 (1953 days in total). The model is estimated and information shares are computed separately for each trading day. Observations outside the [7:00-17:30] time window are excluded.