Randomized Double Auctions
Gains from Trade, Trader Roles, and Price Discovery

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Online Supplementary Materials S2 and S3

S2 Supplementary Tables and Figures

S3 Additional Analyses of Trader Behavior

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S2: Supplementary Tables and Figures

Table 15: Price convergence estimation, tobit regression

	Dependent variable: Transaction Price		
	All data	Symmetric treatment	Asymmetric treatment
Midpoint of trader values range – origin	0.677***	0.686***	0.652***
	(0.050)	(0.065)	(0.075)
Previous closing price – origin	0.167***	0.150***	0.205***
	(0.040)	(0.055)	(0.047)
Positive equilibrium price – asymptote	0.937***	0.941***	0.931***
	(0.017)	(0.023)	(0.024)
Zero equilibrium price – asymptote	0.769	-0.529	4.987
	(2.178)	(2.610)	(3.864)
Root mean squared error	33.358***	33.646***	32.626***
	(1.048)	(1.177)	(2.331)
Number of obs.	2,772	1,961	811

Notes: The table reports estimates of equation 1, which calibrates how prices evolve within each trading period. Separate regressions were estimated when pooling all sessions, symmetric treatment only, and asymmetric treatment only. In symmetric treatment, all participants have the same random yield distributions. In asymmetric treatment, half of the traders receive the lower half of yield draws and are typically net buyers, while the other half receives the higher yield draws and are typically net sellers. The estimated relationship shows how the first transaction price (the origin) relates to (i) the midpoint between lowest opportunity cost and highest marginal willingness to pay and (ii) the previous period closing price, and how well prices tend to converge (the asymptote) toward the equilibrium price. "Zero Equilibrium Price" is an indicator variable that allows for a discontinuity in the asymptote price when the equilibrium price is zero. Robust standard errors clustered on session are in parentheses. */**/*** indicate significance at the 10/5/1 percent levels.

Table 16: Units traded in comparison to theoretical equilibrium.

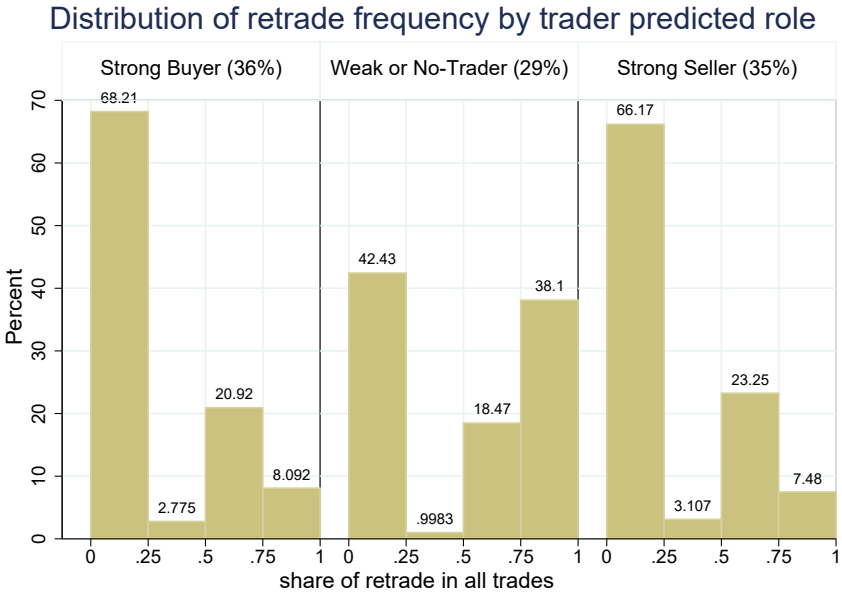
	Dependent variable: Units Traded				
	(1)	(2)	(3)	(4)	(5)
Predicted Q_L	0.449***		0.556***		
	(0.194)		(0.161)		
Predicted Q_U		0.532***	0.574***		
		(0.167)	(0.164)		
$\frac{Q_L+Q_U}{2}$				1.139***	1.167*
				(0.250)	(0.481)
Zero Eqm. Price					2.104*
					(0.985)
Eqm. Price					-0.001
					(0.008)
Low GFT					-2.531**
					(1.362)
Potential GFT					-0.0004
					(0.003)
Period					-0.0005
					(0.071)
Constant	9.095***	6.352***	2.847*	2.820	2.715
	(1.706)	(1.330)	(1.670)	(1.643)	(2.501)
No. of observations	260	260	260	260	260
R-squared	0.048	0.163	0.235	0.235	0.255
Adjusted R-squared	0.044	0.159	0.229	0.232	0.238

Notes: The table reports regressions of units traded in each period against predicted volume and other characteristics. Predicted Q_L is the lowest number of trades needed to achieve equilibrium and full efficiency. Predicted Q_U is the highest number of trades with full efficiency, which can be much larger than Q_L. The average of Q_L and Q_U predicts actual units traded about as well as possible. Other independent variables considered are: an indicator variable for zero equilibrium price; equilibrium price; an indicator for low potential gains from trade (<100); potential gains from trade; and the chronological period number in the session. Robust standard errors, with clusters by session, are reported in parentheses. Indicated significance levels: *p<0.1; **p<0.05; ***p<0.01. Results are broadly similar with session and yield-sequence fixed effects, except Q_L loses statistical significance.

Table 17: Transaction surplus, by treatment

		Transaction surplus			
Treatment	Variable	Positive	Zero	Negative	Total
All	seller gain, $	24.89	3.46	-47.21	9.43
	buyer gain, $	47.83	-3.46	-16.64	23.38
	frequency, %	55.38	32.74	11.89	100
	Number of obs.	1,668	986	358	3,012
Symmetric, no experience periods 1-10	seller gain, $	22.16	4.36	-47.17	6.37
	buyer gain, $	49.32	-4.36	-14.56	22.86
	frequency, %	53.49	31.93	14.58	100
	Number of obs.	774	462	211	1,447
Symmetric, no experience periods 11-20	seller gain, $	29.47	2.93	-43.41	14.64
	buyer gain, $	45.46	-2.93	-21.59	23.45
	frequency, %	57.46	34.92	7.63	100
	Number of obs.	339	206	45	590
Symmetric, experienced periods 1-10	seller gain, $	32.28	-2.57	-10	12.71
	buyer gain, $	34.13	2.57	-40	15.41
	frequency, %	44.44	52.78	2.78	100
	Number of obs.	32	38	2	72
Asymmetric, no experience periods 1-10	seller gain, $	24.43	3.36	-50.07	8.97
	buyer gain, $	49.24	-3.36	-15.62	24.92
	frequency, %	56.52	31.7	11.78	100
	Number of obs.	451	253	94	798
Asymmetric, experienced periods 1-10	seller gain, $	32.35	1.44	14.83	23.4
	buyer gain, $	40.22	-1.44	-60.67	23.74
	frequency, %	68.57	25.71	5.71	100
	Number of obs.	72	27	6	105

*Seller and buyer gains are in experimental dollars, averaged for each transaction surplus category



Notes: The figure illustrates a sharp contrast in re-trading frequencies between predicted strong buyers and sellers on one side, and predicted weak and no-traders on the other. For the overwhelming majority of predicted strong buyers and sellers, the share of re-trades in all trades is less than 25%. In contrast, in contrast, while for more than half of predicted weak and no-traders, the share of re-trades in all trades is 50% or higher.

Figure 4: Percent re-trade by trader role

Table 18: Frequency of individuals trading towards the equilibrium, by treatment

Treatment	Time interval		Strong trade to eqm			Weak trade to eqm		
			Buy	Sell	All	Buy	Sell	All
Total		frequency	0.44	0.62	0.53	0.89	0.86	0.88
		total no of obs.	3012	3012	6024	3012	3012	6024
Symmetric, no experience	periods 1-10	frequency	0.42	0.58	0.5	0.88	0.85	0.86
		total no of obs.	1447	1447	2894	1447	1447	2894
Symmetric, no experience	periods 11-20	frequency	0.45	0.62	0.54	0.92	0.89	0.9
		total no of obs.	590	590	1180	590	590	1180
Symmetric, experienced	periods 1-10	frequency	0.32	0.5	0.41	0.96	0.99	0.97
		total no of obs.	72	72	144	72	72	144
Asymmetric, no experience	periods 1-10	frequency	0.46	0.64	0.55	0.88	0.85	0.86
		total no of obs.	798	798	1596	798	798	1596
Asymmetric, experienced	periods 1-10	frequency	0.48	0.97	0.72	0.9	0.95	0.92
		total no of obs.	105	105	210	105	105	210

S3: Additional Analyses of Trader Behavior

Trading towards equilibrium and buyer and seller earnings by transaction How often do traders buy or sell in the direction predicted by equilibrium? How often do they profit and lose? Are these characteristics the same for buyers and sellers?

Table 18 displays how often individual traders trade "strongly" towards the equilibrium (buy when their quantity is strictly below the equilibrium prediction, and sell when it is strictly above); and trade "weakly" towards, i.e., not counter the equilibrium prediction (do not sell when their quantity is below the lower bound allowed in equilibrium and do not buy when their quantity is above the upper bound). Traders trade strongly towards the equilibrium only 53% of the times, but they trade weakly towards the equilibrium 88% of the times; these numbers closely match the frequencies of positive surplus trades (55%), and non-negative (positive and zero) surplus trades (88%), as given earlier in Table 17. One observation is a striking difference between buying and selling: buyers trade strongly toward equilibrium in only 44% of trades while sellers trade strongly toward equilibrium in 62% of trades. The data show that this difference persists in treatments with both symmetric and asymmetric yield assignments, i.e., irrespective of whether or not each trader tends to maintain the same predicted buyer or predicted sellers role across periods. The difference between buying and selling is statistically significant: a multinomial logit regression estimating the probability a trader trades towards equilibrium, shown in Table 19, confirms that buyers are

significantly less likely than sellers to trade towards the equilibrium. Indeed, buyers make positive profits in 60.86% of trades, and lose in 35.09% of their trades, while sellers profit in 79.35% trades and lose in 16.47% of trades.

This pattern may arise due to the nonlinear valuation schedule (refer back to Table 1 in the main text) which tends to benefit the buyer side of the market: the average per-transaction buyer earnings are 23.38 experimental dollars, while the average seller earnings are only 9.43 experimental dollars (Table 17). Further, buyers lose less in losing transactions than sellers do (a loss of 16.64 experimental dollars for buyers and 47.21 for sellers). At the same time, buyers gain much more in profitable transactions than sellers (an average gain of 47.83 for buyers and 24.89 for sellers). Perhaps sellers behave more cautiously since they have lower potential gains, and thereby trade at a loss less frequently than buyers, whereas buyers, having more ample potential gains from trade, may be lulled into a complacency that leads to error and lower than possible gains. Apparent losses may also result from speculation: buying (or selling) at a loss followed by selling (or buying) with a gain. We evaluate trader gains from re-trading and possible speculation in the main paper.

A multinomial logit estimating the odds of trader gain and loss, also displayed in Table 19, indicates that these odds are similarly associated with characteristics that predict gainful trade and trade toward equilibrium (compare Table 19 and Table 10 in the main text). We find that experience reduces the odds of trader loss and trading against equilibrium; traders in asymmetric treatment are also less likely to make a loss. Further, trader loss and trading against equilibrium occur more often in later transactions within a period, and, not surprisingly, the odds of trading against equilibrium and of trader loss increase as prices deviate from equilibrium predictions.

Summary 1 *Just over a half of individual trading decisions are strong trades towards the equilibrium, but almost 90% of decisions are weakly consistent with equilibrium prediction. Traders in the asymmetric yield treatment are less likely to trade with a loss than traders in the symmetric yield treatment. Traders are more likely to trade strongly towards equilibrium and less likely to trade at a loss when selling, then when buying. However, on average, traders gain more when buying than when selling.*

Determinants of trader normalized earnings by period We use regression analyses to consider how individual and market-level characteristics and trader behavior are associated with normalized period-level trader earnings (the difference between predicted and actual earnings in the market). Market-level characteristics include potential gains from trade, equilibrium price level (at or above zero), "no marginal trades" indicator for markets with zero equilibrium quantity spread ($Q_U - Q_L$),[1] as well as period number, and indicators for asymmetric treatment and experienced sessions. Individual characteristics include trader role, predicted earnings (allowing for a differentiated effect between predicted buyers and sellers), and the (lowest) equilibrium number of net trades. Behavioral variables characterize

[1]We use other traders' average equilibrium earnings as a proxy for market-level gains from trade, to reduce the correlation of this characteristic with trader's own predicted earnings; employing market-level gains from trade instead produces qualitatively identical results. Likewise, using "no marginal trades" indicator avoids high correlation of the equilibrium quantity spread with zero equilibrium price, another explanatory variable included in the regressions.

Table 19: Determinants of probability of trade towards equilibrium and trader gain, logit estimation

Dependent variable:	*Direction of Trade*		*Trader Gain*	
	Against Equilibrium		Negative gain	
asymmetric yields	-0.24	(0.17)	-0.20**	(0.08)
experience	-0.93***	(0.24)	-0.40***	(0.08)
buying	1.45***	(0.21)	1.12***	(0.16)
potential market GFT per trader	-0.01***	(0.00)	-0.01***	(0.00)
zero equilibrium price	-0.99***	(0.33)	0.24*	(0.13)
absolute price deviation from eqm	0.02***	(0.00)	0.01***	(0.00)
trade order	0.12***	(0.01)	0.08***	(0.02)
period	-0.14***	(0.04)	-0.03*	(0.02)
period squared	0.00*	(0.00)	0.00	(0.00)
constant	-2.49***	(0.36)	-1.64***	(0.22)
	Within Eqm Bounds		Zero gain	
asymmetric yields	-0.07	(0.07)	0.66	(0.44)
experience	-0.22	(0.14)	0.47	(0.56)
buying	0.88***	(0.18)	0.23**	(0.09)
potential market GFT per trader	-0.01***	(0.00)	-0.00	(0.00)
zero equilibrium price	2.04***	(0.10)	-1.43***	(0.33)
absolute price deviation from eqm	-0.00	(0.00)	-0.01*	(0.01)
trade order	0.08***	(0.02)	0.09***	(0.03)
period	0.10**	(0.04)	-0.01	(0.09)
period squared	-0.01**	(0.00)	0.00	(0.00)
constant	-1.53***	(0.22)	-3.11***	(0.60)
(base outcome)	Towards equilibrium		Positive gain	
Yield fixed effects	Y		Y	
Number of observations	6024		6024	
Pseudo R-squared	0.2554		0.1056	

Standard errors clustered on session. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

actual net trading and share of re-trading. For net trading, we consider the excess or shortfalls in net trades relative to equilibrium, and predicted loss from under- and over-trading, i.e., the number of extra and insufficient trades evaluated at the equilibrium price. The regression analyses are conducted on all trader-period observations pooled, and separately for traders with zero, medium, and high equilibrium earnings.

Regression results, presented in Table 20, suggest that market, individual and behavioral characteristics are all significantly associated with trader earnings relative to equilibrium. Individual earnings get closer to equilibrium with higher predicted number of net trades, but traders with positive predicted earnings under-earn a significant share of what they would in equilibrium. Moreover, sellers fall short on earnings significantly more than buyers: the coefficient on seller equilibrium earnings is -0.86, which is significantly below the corresponding coefficient of -0.47 on buyer earnings ($p < 0.01$). Separate estimations by predicted earnings categories demonstrate that this earnings gap between buyers and sellers persists across both medium and high predicted earners. We further find that all traders are less short on earnings in markets with higher potential gains from trade, and most traders gain more in markets with positive equilibrium prices. The absence of equilibrium quantity spread in the market (i.e., no marginal trades) has a negligible effect on individual earnings overall, but this is due to high differences across trader categories: the effect is negative and significant ($p < 0.01$) for medium predicted earners, while it is positive and significant ($p < 0.05$) for high predicted earners. Note that a positive equilibrium quantity spread is conducive to re-trading, which we found to particularly benefit medium-range earners (Table 12 in the main text). In addition, experienced zero-earners earn significantly more, and traders earn more in later periods.[2]

Turning to trader behavior, the number of net trades short of equilibrium have a negative and highly significant effect on earnings ($p < 0.01$), while net trade excess is only significant for medium-earners. The value of missing net trades, evaluated at the equilibrium price, is also significantly associated with earnings shortages, based on the pooled regression. Not surprisingly, net trades excesses and shortages particularly harm positive predicted earners, and do not harm zero-earners.

The coefficient on re-trading is positive and significant overall ($p < 0.05$) and for medium predicted earners ($p < 0.01$). This finding concurs with our earlier observation that medium earners benefit from environments with positive equilibrium quantity spread that is conducive to speculation and near-equilibrium pricing. For zero-earners, the effect of re-trading is positive on average but insignificant, likely due highly variable rewards of pure speculative trading. In contrast to other earning categories, the high predicted earners are estimated to have, on average, (insignificantly) lower earnings if they engage in re-trading. It could be that high predicted earners use re-trading in an attempt to (partially) correct large trading errors, or are less careful when speculating than lower earners. Recall that high expected earners fall much shorter of their potential earnings as compared to other traders, possibly having been lulled into complacency after an initial windfall.

[2]An insignificant coefficient on the asymmetric treatment indicator is likely due to trader heterogeneity. On average, traders in the symmetric treatment fell short of equilibrium earnings by 10 experimental dollars, compared to 7 experimental dollars in the asymmetric treatment. While the difference is insignificant on the individual level, it translates into significantly higher market efficiency of the asymmetric treatment on the aggregate level, as documented in our analysis in the maint ext.

Table 20: Determinants of trader normalized earnings

		Dependent variable: Normalized earning			
		Trader category by predicted earnings			
		All traders	Zero	Medium ≤ 50	High ≥ 75
Trader characteristics	predicted no-trader	4.29	-4.29		
		(5.91)	(5.75)		
	predicted seller	-5.05	7.12	-10.89	-29.28
		(5.31)	(4.55)	(14.67)	(37.39)
	buyer equilibrium earnings	-0.47***		-0.94***	-0.34
		(0.10)		(0.35)	(0.25)
	seller equilibrium earnings	-0.86***		-1.64***	-0.56***
		(0.05)		(0.25)	(0.08)
	# net trades in equilibrium	20.39***	1.60	47.89***	29.29**
		(4.48)	(3.86)	(7.74)	(14.66)
Trader behavior	net trades excess	-7.67	-5.29	-26.25**	-65.29
		(5.43)	(6.14)	(11.82)	(42.09)
	net trades shortage	-26.37***	-4.50	-36.58***	-46.34***
		(5.55)	(4.60)	(6.56)	(15.90)
	price of extra trades	-0.12	-0.16	0.00	0.68
		(0.15)	(0.22)	(0.26)	(0.44)
	price of missing trades	-0.16***		0.07	-0.11
		(0.05)		(0.08)	(0.10)
	share retrade	9.46**	5.10	20.59***	-12.97
		(3.72)	(3.93)	(7.11)	(19.31)
Market characteristics	other traders average GFT	0.38***	0.39***	0.57***	0.05
		(0.04)	(0.09)	(0.09)	(0.21)
	equilibrium price above zero	5.41*	-4.89	36.49***	22.32
		(2.86)	(5.32)	(8.24)	(18.34)
	no marginal trades	-0.65	-6.91	-23.06***	22.58**
		(2.54)	(10.93)	(7.30)	(8.79)
	asymmetric yields	2.08	-3.04	-0.75	10.09
		(4.93)	(5.32)	(6.82)	(16.16)
	experienced traders	9.24	18.90***	12.35	-9.34
		(5.84)	(6.14)	(8.92)	(20.18)
	period	1.41***	1.84	0.09	0.24
		(0.54)	(1.44)	(1.10)	(2.60)
	period squared	-0.05*	-0.06	-0.00	-0.01
		(0.03)	(0.10)	(0.05)	(0.11)
	constant	-28.31***	-13.08**	-64.70***	-48.98
		(6.46)	(5.47)	(11.98)	(37.91)
Number of observations		2,333	859	938	536
Adjusted R-squared		0.204	0.043	0.132	0.168

All regressions include yield sequence fixed effects. 1000 bootstrap replications based on 21 clusters on session. */**/*** indicate significance at the 10/5/1 percent level.

Summary 2 *Trader earnings are closer to equilibrium in markets with higher potential gains from trade and in markets with positive equilibrium prices. Predicted sellers fall short on earnings significantly more than predicted buyers. Traders earn closer to equilibrium when they are predicted to make more trades, and earn less if they make either too few or too many net trades compared to equilibrium. The share of re-trading has a positive but modest in magnitude effect on trader earnings overall, with medium-earners gaining the most from re-trading.*