Experiments in High-Frequency Trading: Testing the Frequent Batch Auction

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One-slide Summary

- **Motivation:** What is a good design for financial markets in the presence of HFT? Does the CDA/CLOB (the most widely used market format) exhibit important flaws? If so, what are the alternative market formats? Do those really perform better than the CDA?
- **This paper:** A laboratory study that compares the CDA against a (newly) proposed Frequent Batch Auction (FBA).
- **Results:** The FBA outperforms the CDA. FBA exhibits:
  1. less **predatory** trading behavior
  2. lower investments in **communication** technology (less wasteful).
  3. lower transaction costs (**spread**)
  4. lower **volatility** (in market spreads and liquidity)
  5. higher market **stability**

Motivation: A piece of the HFT Debate

- The CDA/CLOB has a **design flaw** (Budish et al. 2015).
- Huge **Rewards** for traders that can react to information a nanosecond **faster** than others and exploit stale orders.
- This generates an **arms race** around expensive faster communication technology.
- The outcome: a **massive prisoner's dilemma**
- Are there other market rules that undo the negative incentives built-in the CDA? Yes: **FBA**, IEX, Flow markets, etc.
- Existing data cannot resolve the debate, as data come from a single exchange format.
- Experimentation is therefore required to generate evidence on the relative performance of market alternatives.

Experiment Environment BCS: Exogenous Processes

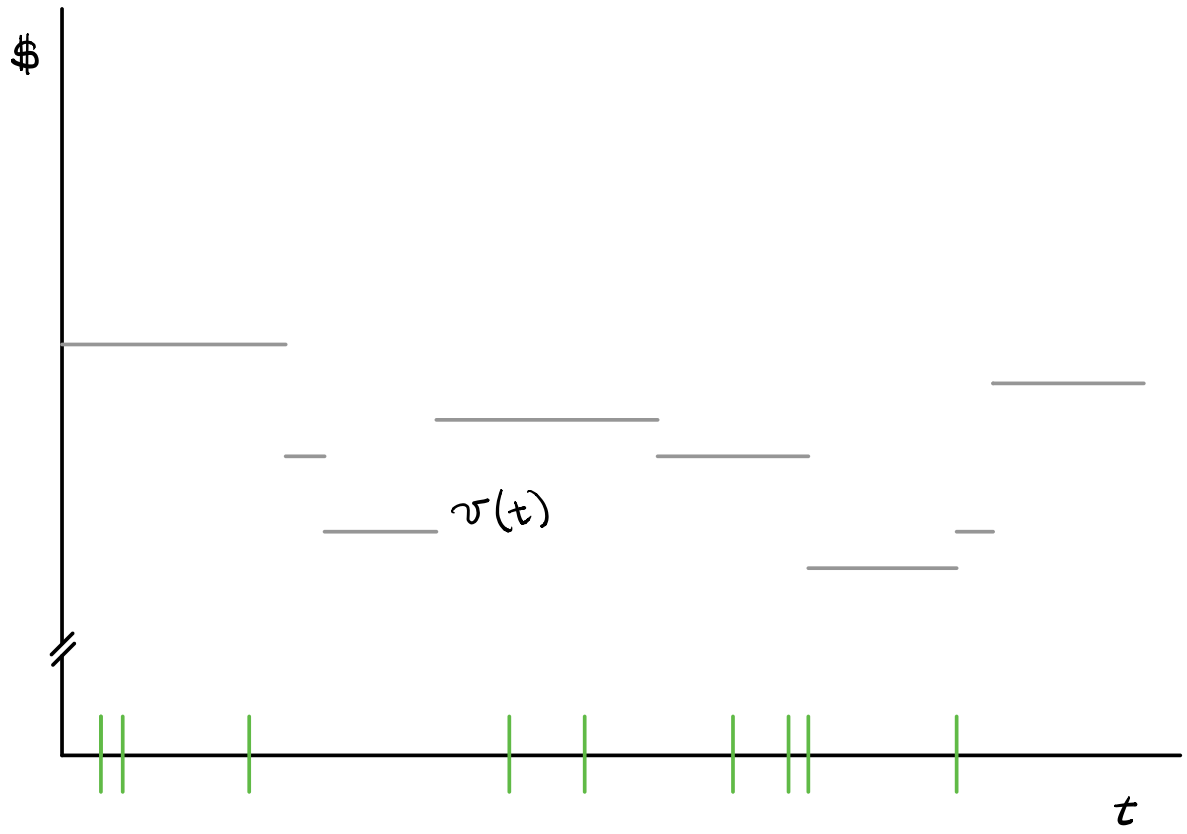
Budish, Cramton and Shim (QJE, 2015, hereafter BCS)
There is one **single asset**, trades in a single exchange.
Two exogenous processes generate incentives to trade:

1. the fundamental value of the asset, $V(t)$
   - publicly observed
   - evolves over continuous time following a compound Poisson jump process
   - arrival rate of λ_V per second and jump distribution F_V
2. a population of investors (noise traders) that
   - arrive at random times with Poisson rate of λ_I per second,
   - each places a unit market order to buy or sell with equal probability.

Profits are generated from reversing positions with respect to the fundamental value.

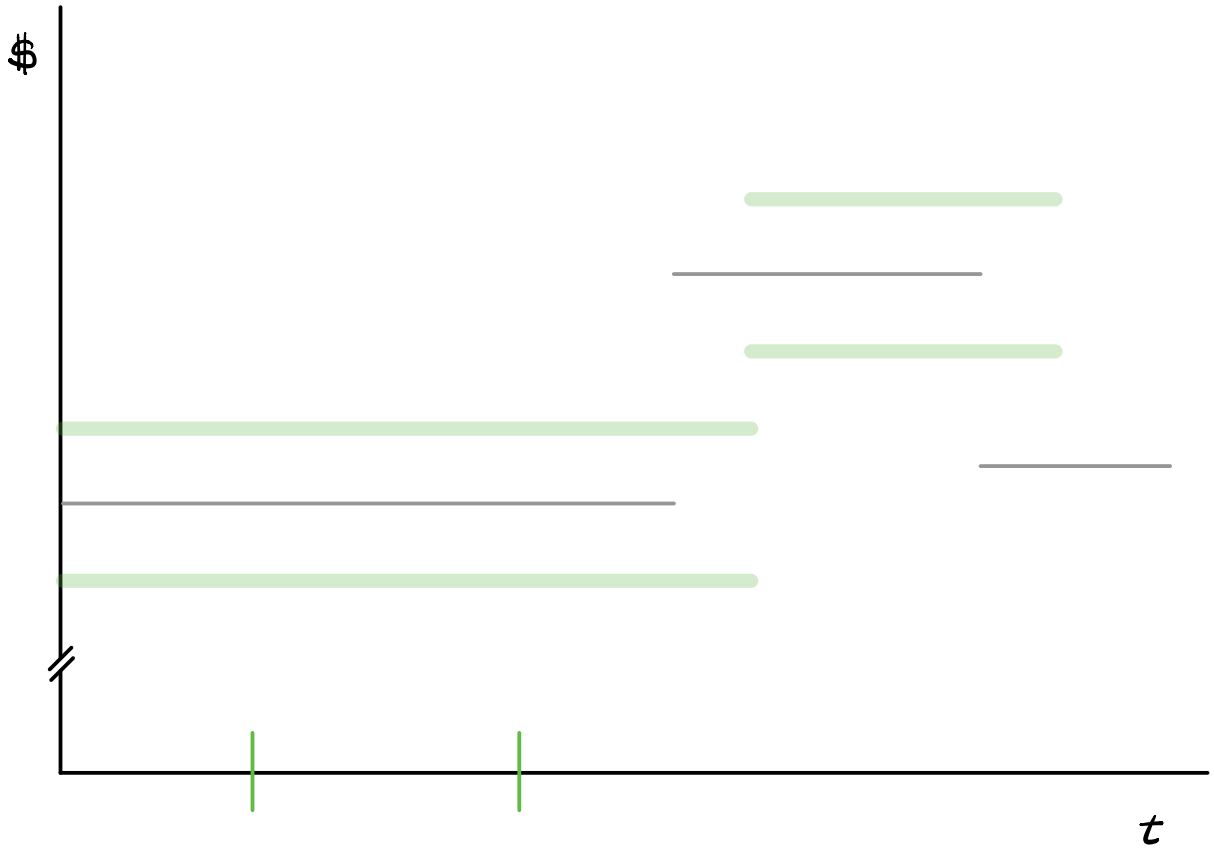
Experiment Environment BCS: Exogenous Processes

- V(t) (jump rate λ_V, Jump $N(0, \sigma^2)$)
- Investor arrivals (arrival rate λ_I)



Experiment Environment BCS: orders

Limit orders, market orders and latencies (slow and fast).



Market Format 1: The CDA

Continuous Double Auction (CDA):

- Trade can happen at any moment of time.
- Strict price, time priority.

Trading strategies:

- exit the market (out)
- market maker
- sniper

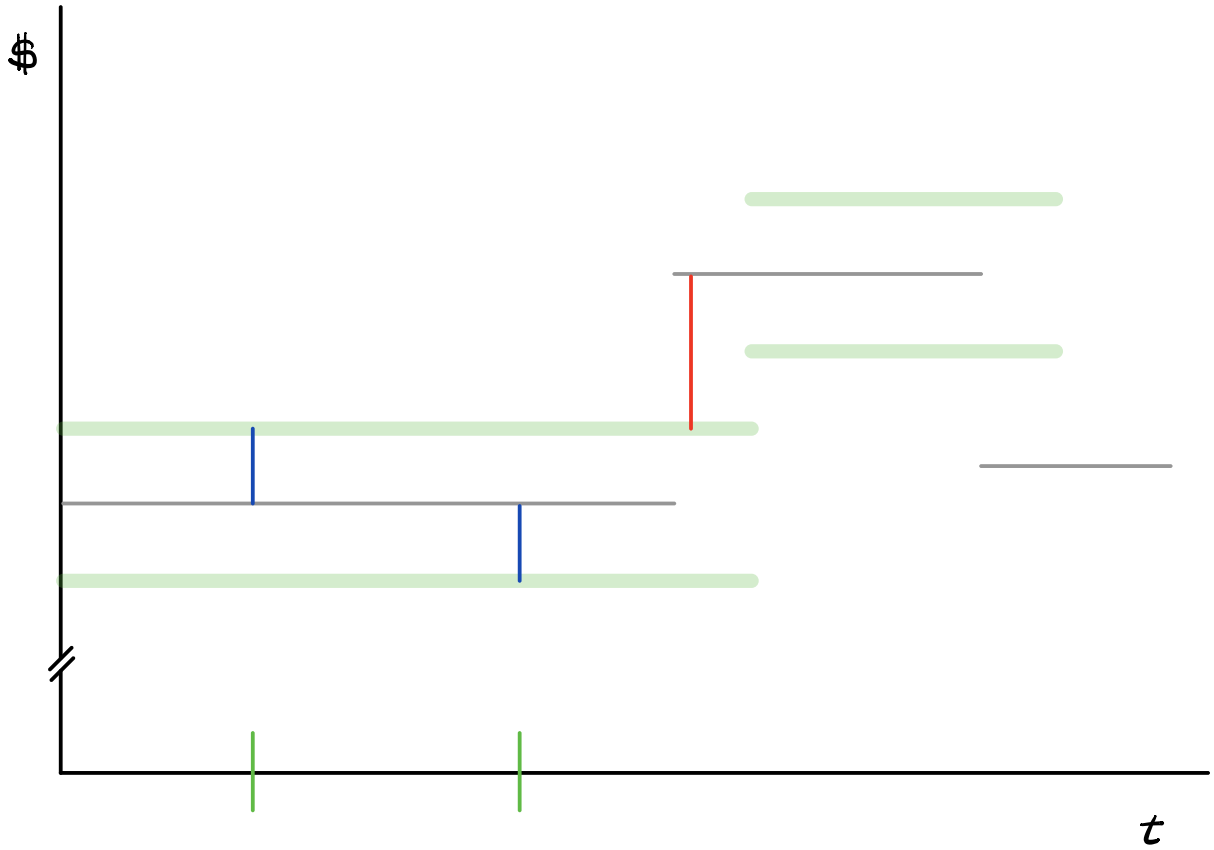
Technology strategy:

- Traders can subscribe to faster (lower-latency) communication technology at a cost of c_{speed} per second.

There is value to reacting faster to public signal

Market Format 1: The CDA

Investor arrivals and value jumps in the CDA. ▸ Equilibrium



Market Format 1: The CDA

Equilibrium in BCS environment under CDA:

- Finite numbers of participants N^*
- Only one trader plays market maker
- $N-1$ are snipers.
- All N traders purchase fast communication technology
- $s^* > 0$, $\lambda_I \frac{s^*}{2} = N^* c_s$
- Every trader earns zero profits: the cost of speed, purchased by all traders, is borne entirely by investors via market spread.

▸ FBA

Market Format 2: The FBA

Frequent Batch Auction (FBA):

- Trade does NOT happen at any moment of time, but **periodically** (say, each tenth of a second).
- Trading day is divided in **many uniform price double auctions**:
- There is a batching period for each auction.
- At the end of the batching period, supply and demand cross and **market clears**.

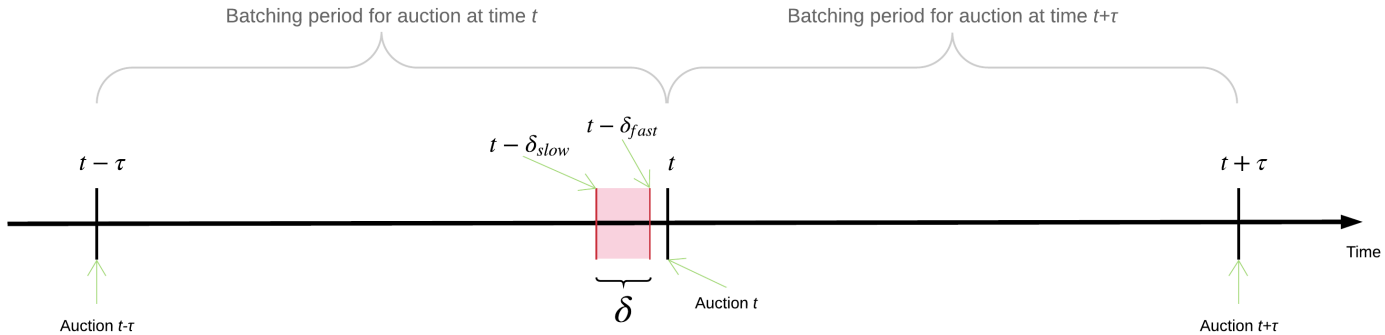
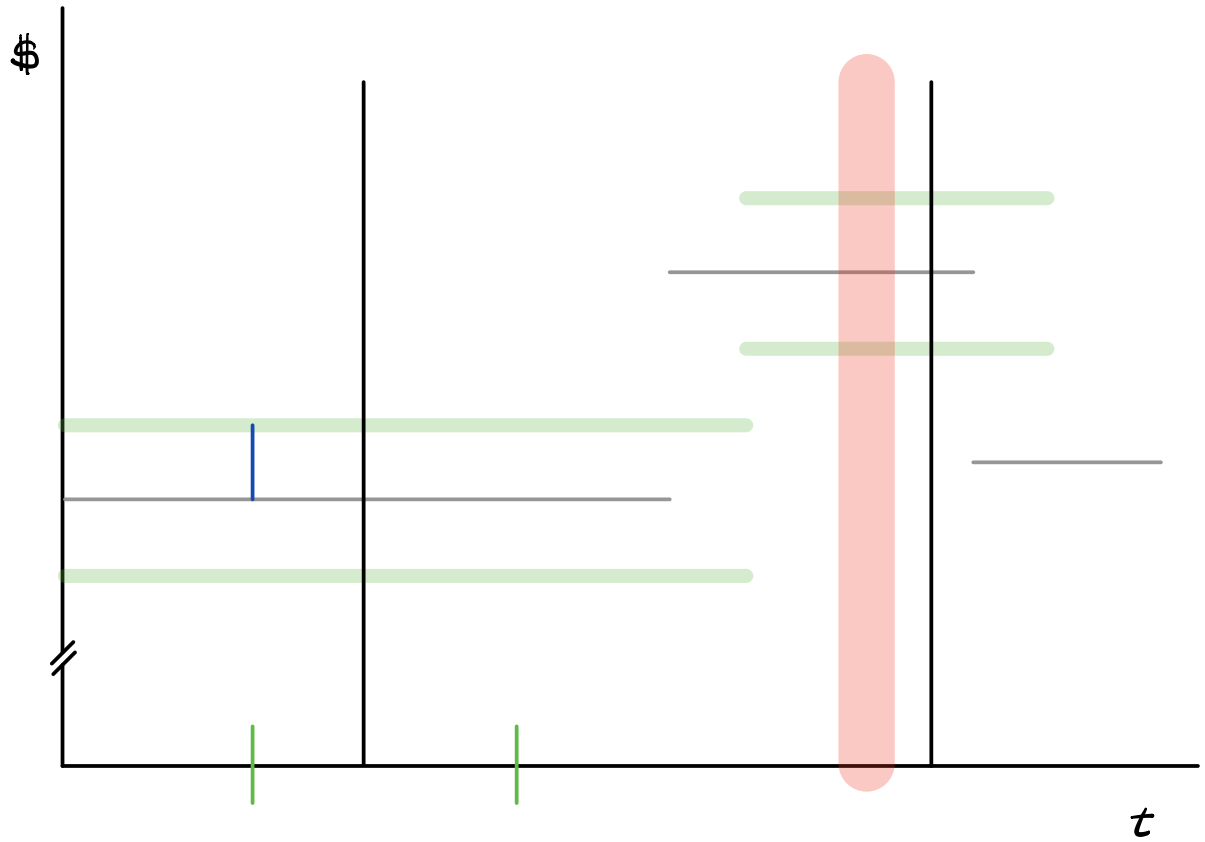


Figure: Timing in the FBA format (adapted from Budish et al. (2015)).

Market Format 2: The FBA

Investor arrivals and value jumps in the FBA



Market Format 2: The FBA

Strategy space is the same as in the CDA

Equilibrium of the FBA in the BCS environment:

- Everyone is a *slow maker* with zero spread ($s^* = 0$).
- There are no sniper
- No one purchases fast technology.
- True if the batching period is substantially larger than default communication latency.

Experiment

Choice Space:
Human subjects choose between 3 roles:

1. Out: stay out of the market
2. Maker: Post buy/sell orders at $V \pm s/2$, can freely update s. With lag δ, bot updates when V jumps.
3. Sniper: Try to pick off stale quotes when V jumps.

Speed subscription:

- at flow cost $c > 0$, reduce latency δ_{slow} to δ_{fast}.

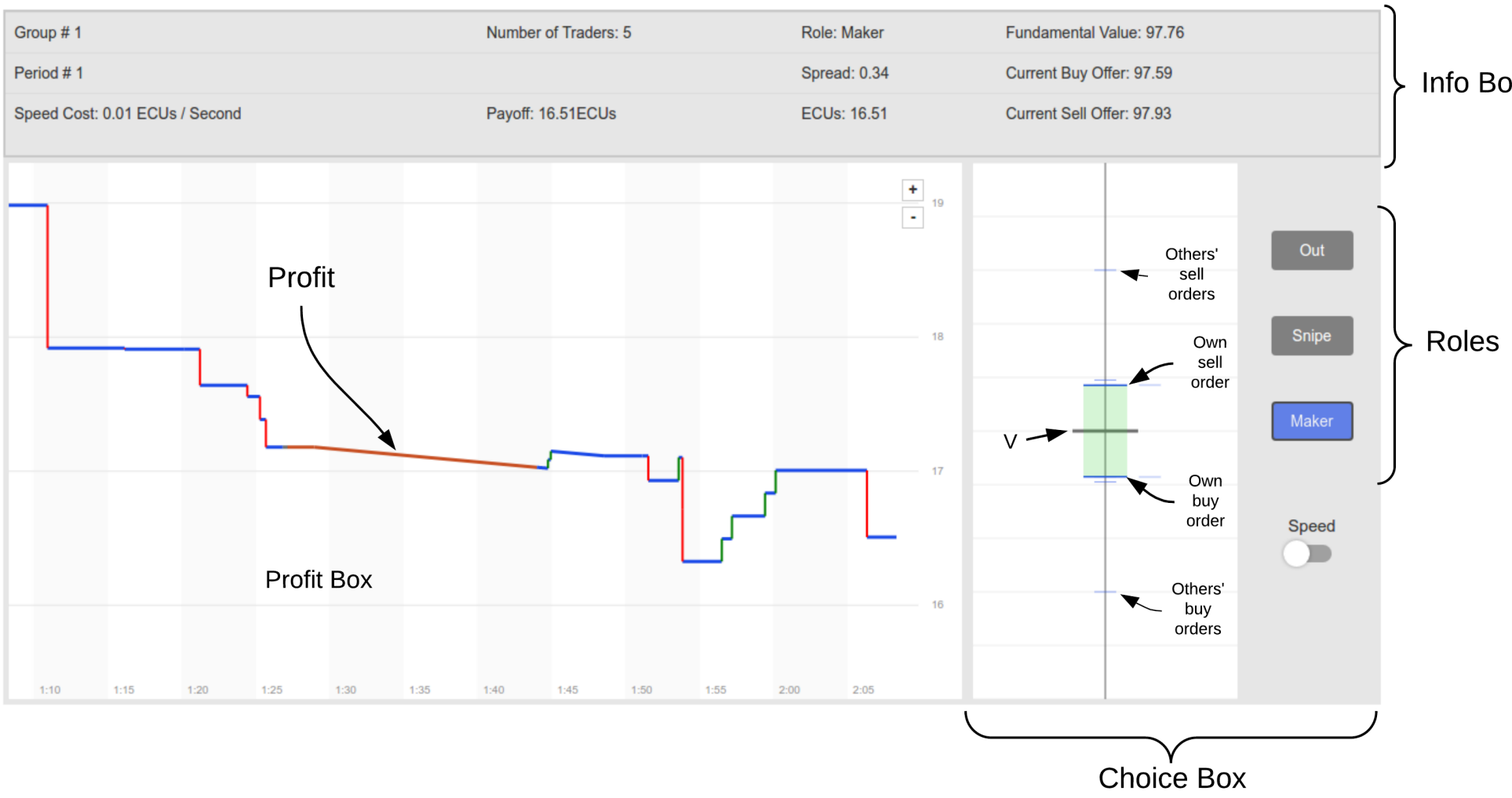
Treatments, Sessions

- Six treatments $\{CDA, FBA\} \times \{C1, C2, C3\}$.
- Between-subjects design
- Group size $= 6$; fixed-group matching.
- A session $=$ eight consecutive trading periods of four minutes each
- Data for 24 markets or groups (4 groups per treatment, 12 sessions total).
- Initial endowment: 20 ECUs; Exchange rate: 2 ECUs $=$ 1 USD;
- Subjects paid for one randomly chosen period plus 7 USD.
- Summary information between periods.
- Sessions conducted at the LEEPS Laboratory at UCSC.

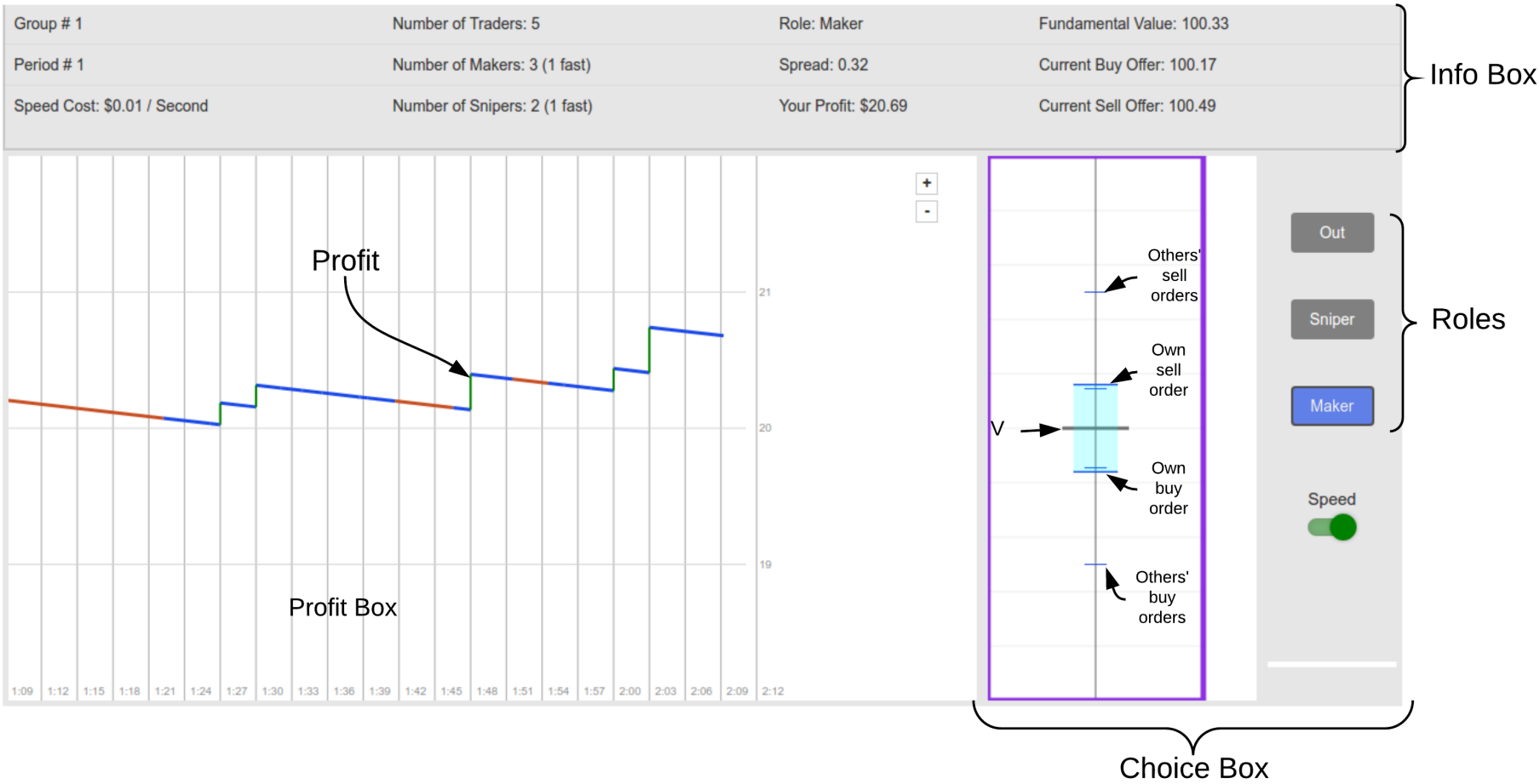
Treatments, Sessions

	Config 1	Config 2	Config 3
Parameters:			
λ_I	1/3	1/5	1/2
λ_V	1/4	1	1
c_{speed}	0.01	0.01	0.022
Number of trading periods	8	8	8
Trading period length (secs)	240	240	240
Groups (sessions) per treatment	4 (2)	4 (2)	4 (2)

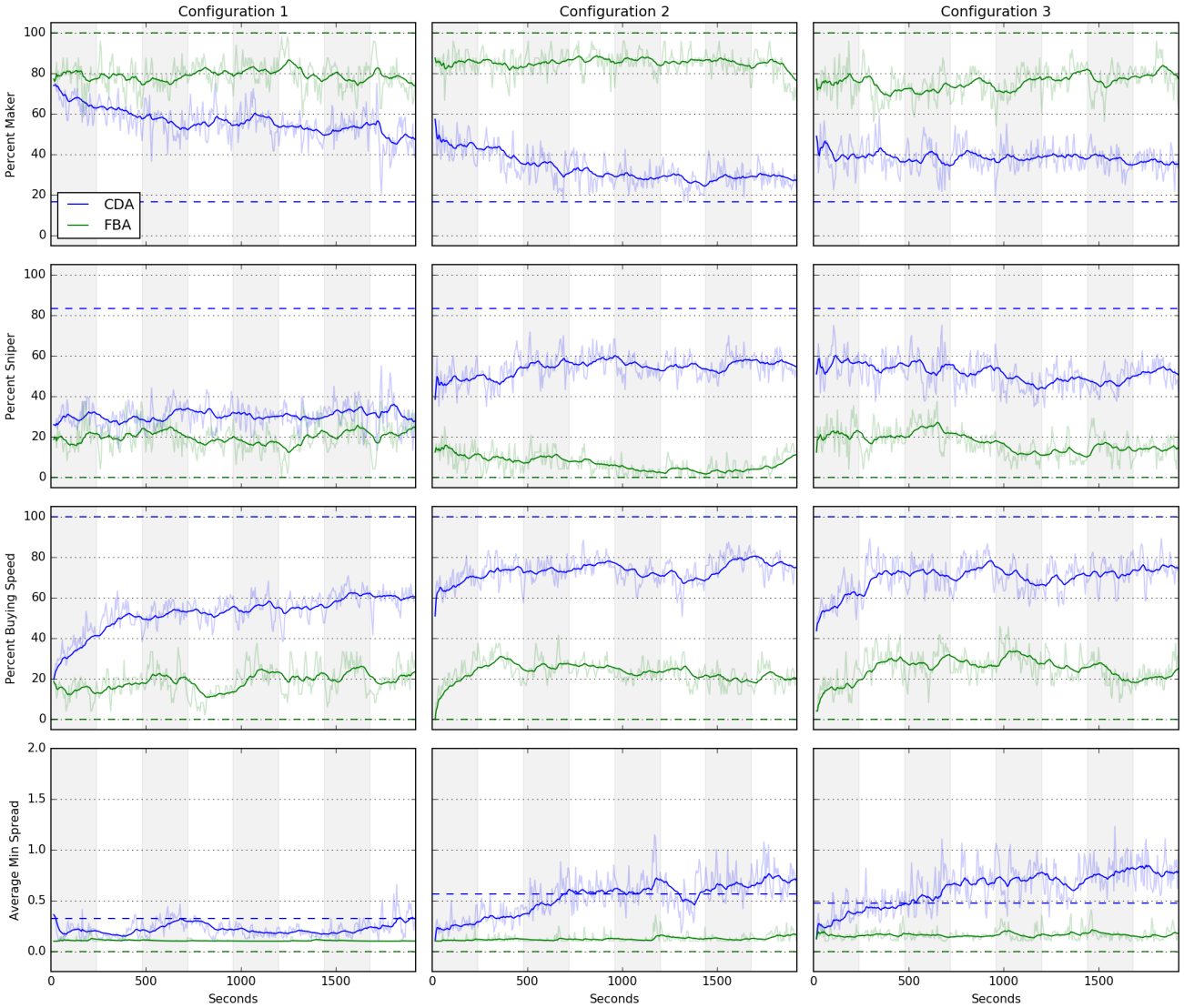
CDA User Interface



FBA User Interface



Results: All Plots



Results: Summary

In choice data, the FBA exhibits:

- more traders choose to act as makers
- fewer choose to act as snipers
- fewer choose to purchase speed services
- smaller market spreads

In market level data, the FBA:

- reduces the volatility of transaction prices and spread
- enhances price efficiency
- results in more stable trader choices

Results: Summary statistics for choices

Choices

		Config 1		Config 2		Config 3	
		CDA	FBA	CDA	FBA	CDA	FBA
Making (%)							
	Experiment	54	78.1	30.2	78.8	40.1	72.9
	Equilibrium	16.7	100	16.7	100	16.7	100
Sniping (%)							
	Experiment	31	20.8	58.1	14.5	49.5	14
	Equilibrium	83.3	0	83.3	0	83.3	0
Speed (%)							
	Experiment	56.1	19.7	69	31.7	69.2	20.7
	Equilibrium	100	0	100	0	100	0
Min. Spread							
	Experiment	0.226	0.103	0.677	0.179	0.709	0.147
	Equilibrium	0.324	0	0.566	0	0.475	0

Results: Summary statistics for market

(c) Market Stats

		Config 1		Config 2		Config 3	
		CDA	FBA	CDA	FBA	CDA	FBA
$Std(P_t - P_{t-1})$							
	Experiment	2.51	0.561	4.62	1.00	6.68	1.11
	Equilibrium	0.241	0.289	0.276	0.327	0.235	0.430
$Std(MinSpread)$							
	Experiment	0.204	0.0235	0.536	0.144	0.394	0.127
	Equilibrium	0	0	0	0	0	0
Status Changes							
	Experiment	20.5	6.26	31.6	6.26	17.0	7.34
	Equilibrium	N/A	0	N/A	0	N/A	0
$RMSD(P_t - V_t)$							
	Experiment	0.347	0.212	0.512	0.410	0.460	0.381
	Equilibrium	0.223	0.136	0.329	0.211	0.372	0.276
Transactions							
	Experiment	156	85.2	172	99.3	248	134
	Equilibrium	106	80	100	48	147	120
Period Profits							
	Experiment	.0869	.435	.603	.372	4.31	1.52
	Equilibrium	0	0	0	0	0	0

Results: Treatment Effects

To quantify treatment effects, we estimate the following model:

$$y_{g,t} = \sum_{j=1}^{3} [\alpha_j Cj_{g,t} + \gamma_j Cj \times FBA_{g,t}] + \epsilon_{g,t}, \quad (1)$$

where $y_{g,t} \epsilon \{Maker_{g,t}, Sniper_{g,t}, Speed_{g,t}, MinSpread_{g,t}\}$ is indexed by group and time, Cj is a dummy variable for market configuration $j \epsilon \{1,2,3\}$ and $Cj \times FBA_{g,t}$ is the dummy variable indicating the interaction between configuration j and the FBA format.

Results: Regressions Results

	(1) Maker (%)	(2) Sniper (%)	(3) Speed (%)	(4) Min. Spread	(5) RMSD
Configuration 1	54.13***	30.89***	56.12***	0.226***	0.347***
	(1.640)	(2.959)	(2.972)	(0.0438)	(0.00474)
Configuration 2	30.27***	58.11***	69.20***	0.678***	0.512***
	(4.507)	(3.294)	(1.594)	(0.114)	(0.00918)
Configuration 3	40.03***	49.51***	69.02***	0.706***	0.460***
	(2.368)	(2.888)	(4.498)	(0.0374)	(0.0170)
FBA × Config. 1	24.88***	-10.95*	-36.15***	-0.123**	-0.135***
	(5.022)	(5.507)	(5.399)	(0.0439)	(0.0119)
FBA × Config. 2	49.08***	-44.23***	-37.82***	-0.502***	-0.102***
	(6.494)	(6.214)	(3.968)	(0.118)	(0.0307)
FBA × Config. 3	33.10***	-35.55***	-48.37***	-0.560***	-0.0791***
	(5.255)	(4.309)	(5.024)	(0.0422)	(0.0246)
Observations	10934	10934	10934	10934	142

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Regressions

Equilibrium behavior is rejected
However, the comparative statics of the differences between the two formats predicted by the model are confirmed in the data.
Statistically, relative to the CDA:

- the FBA has more makers
- the FBA has fewer snipers
- the FBA has fewer traders purchasing speed technology
- the FBA has lower minimum spreads
- the FBA has lower RMSDs

Conclusions

- Differences between FBA and CDA in the lab are consistent with comparative statics of the BCS model.
- FBA outperforms CDA in transaction costs (BCS environment). Effect sizes tend to be smaller than predicted.
- Predatory behavior (sniping) is more prevalent in CDA than in FBA.
- More turbulent markets in terms of stock value volatility (Config 2 and 3) exhibit difference between CDA and FBA formats more clearly perhaps because more V-jump events.
- Next Steps in the larger project (Cramton, Friedman, Ockenfels)

Thank You

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Transitory Market Dynamics

To understand the dynamics of the market and the possible effects of transitory changes in the environment on subjects' decisions, we fit a vector autoregression of the form:

$$\mathbf{y}_t = \mathbf{a} + \mathbf{\Phi}\mathbf{y}_{t-1} + \varepsilon_t \tag{2}$$

$$\mathbf{y'}_t = [\%Sniper_t, \%Speed_t, MinSpread_t, Turbulence_t] \tag{3}$$

Estimates of the constrained VAR(1)

	Constant	$\%Sniper_{t-1}$	$\%Speed_{t-1}$	$MinSpread_{t-1}$	$Turbulence_{t-1}$
(a) CDA					
$\%Sniper_t$	10.1***	0.720***	0.0651**	-3.14**	0.141**
	(2.15)	(0.0354)	(0.0320)	(1.24)	(0.0670)
$\%Speed_t$	10.3***	0.0480	0.813***	-0.494	-0.00220
	(1.90)	(0.0313)	(0.0283)	(1.09)	(0.0593)
$MinSpread_t$	-0.00389	0.00250**	0.000877	0.656***	0.00665***
	(0.0611)	(0.00101)	(0.000911)	(0.0352)	(0.00191)
(b) FBA					
	Constant	$\%Sniper_{t-1}$	$\%Speed_{t-1}$	$MinSpread_{t-1}$	$Turbulence_{t-1}$
$\%Sniper_t$	4.66***	0.752***	0.0347	-10.1**	-0.0442
	(1.03)	(0.0317)	(0.0331)	(4.13)	(0.0529)
$\%Speed_t$	5.73***	-0.0129	0.752***	2.98	0.0182
	(0.995)	(0.0305)	(0.0319)	(3.97)	(0.0509)
$MinSpread_t$	0.0683***	-0.000182	0.0000620	0.529***	-0.000132
	(0.0102)	(0.000313)	(0.000327)	(0.0408)	(0.000523)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure: Standard errors are reported in parentheses. Panel (a) reports CDA estimates and panel (b) reports FBA estimates.

The results show that very-short term, innovations in market conditions impact behavior in the CDA, while such effects of transient market changes do not exist in the FBA.

Transitory Market Dynamics

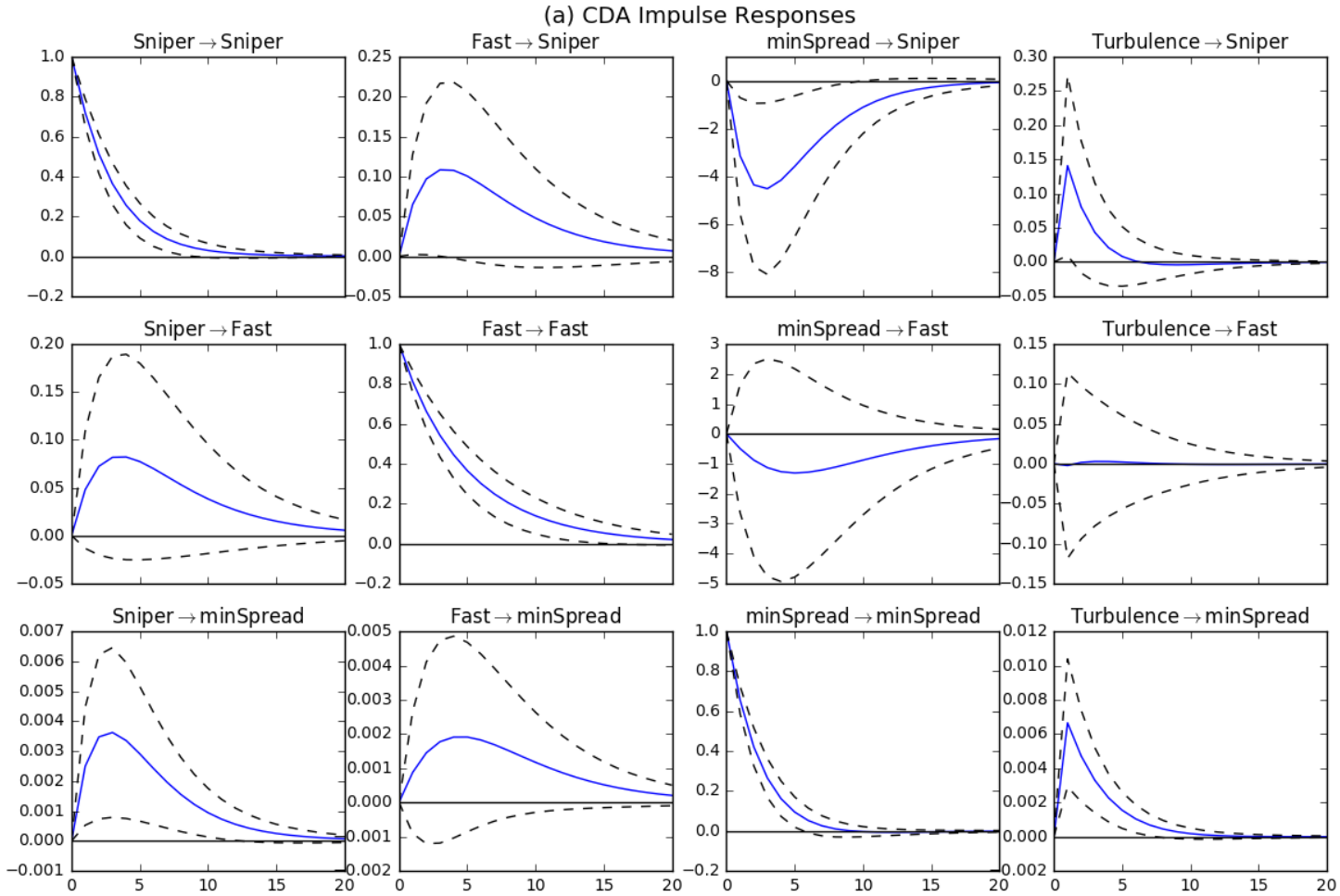

Figure: Unit impulse responses for the estimated VAR under CDA.

Transitory Market Dynamics

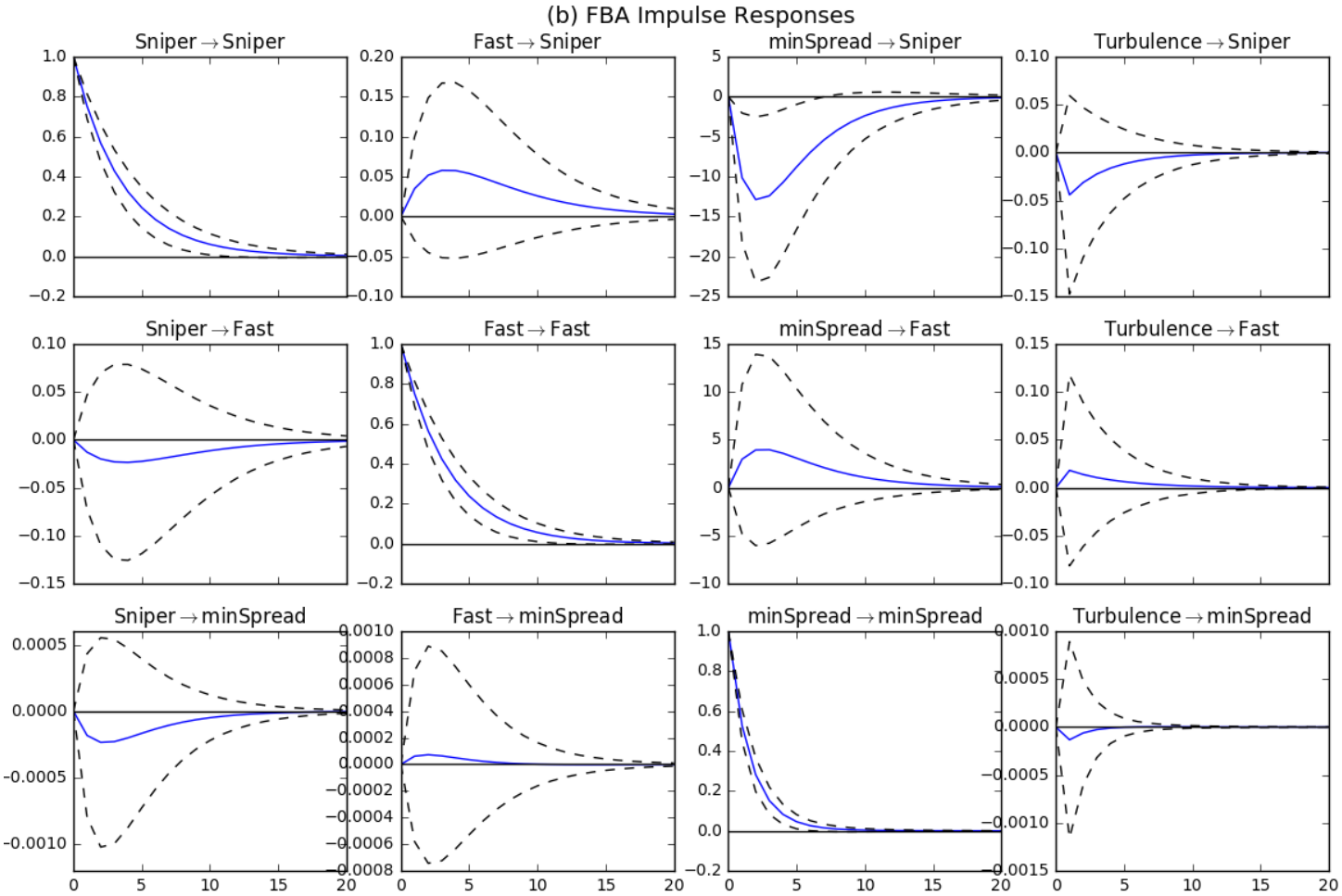

Figure: Unit impulse responses for the estimated VAR under FBA.