

Algorithmic Trading, Price Efficiency and Welfare: An Experimental Approach

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- Trading algos account for more than 50% of trades in stock markets
- We want to answer some questions in debate:
 - Do trading algos increase or decrease welfare in market?
 - How are profits distributed between algos and humans?
 - Do trading algos improve liquidity? Pricing? Volatility?
- **New experimental paradigm**
- Analysis largely pre-registered

Experimental Design: Assets

- Traders start round with cash and shares of asset
- Asset value is sum of private value ($\theta_i \in \{0, 10\}$) and common value ($\pi \in \{20, 80\}$)
- Common val realization publicly announced during trading
 - “News” is good or bad
 - Prior to news release, expected asset value is 50 or 60
- Private value realization is constant throughout experiment
 - Why private values? **Welfare analysis!** Asset allocation changes welfare, trade can increase surplus
 - Pareto-optimality: all low type traders sell all assets to high type traders

Round starts

- Traders get endowments in cash and shares of asset
- Double auction trading for 100 seconds
 - Can offer to sell or buy shares of asset for cash (limit order)
 - Can accept offers to sell or buy (market order)
 - Budget constraints and shortselling constraints
- After 40-60 seconds of trading, news about asset value
- After trading, payoff is cash+value from held assets

20 rounds overall, +1 practice round

8 traders per market

- 5 traders have high type ($\theta_i = 10$). Low asset/cash endowment
- 2 traders have low type ($\theta_i = 0$). Low asset/cash endowment
- 1 **large trader** has low type ($\theta_i = 0$). 3x asset/cash endowment
 - Depending on treatment, this is the algo trader

- **Market-order algo:** accept any offer that implies an expected profit
 - When offer arrives or when news changes values
- **Limit-order algo:** Offer trades (buy and sell) at prices that imply an expected profit
 - Undercut (sell) / overcut (buy) competition as long as profitable
- Algos act instantaneously; react faster than humans to news
- Max 1 algo active in market!

Experimental Design: Treatments

- 1 Baseline: The large trader is a human
 - 2 MarketAlgo: The large trader is the market-order algo
 - 3 LimitAlgo: The large trader is the limit-order algo
- Also vary within-subject whether news release time is precisely known in advance, or not

Results

Results: Welfare

	(1)	(2)
Dependent var.	Welfare	Small Trader Welfare
MarketAlgo	16.950 (19.322)	-85.690*** (32.687)
LimitAlgo	51.850*** (16.266)	1.895 (29.785)
KnownNewsTime	0.200 (9.513)	8.773 (13.856)
Constant	6308.900*** (17.601)	4466.725*** (35.990)
Control order	Yes	Yes
Observations	600	600
Clusters	30	30

- Welfare under LimitAlgo $>$ Welfare under MarketAlgo
- LimitAlgo realizes about 60% of possible welfare gains, compared to 43% and 35% for MarketAlgo and baseline

Results: Other market quality measures

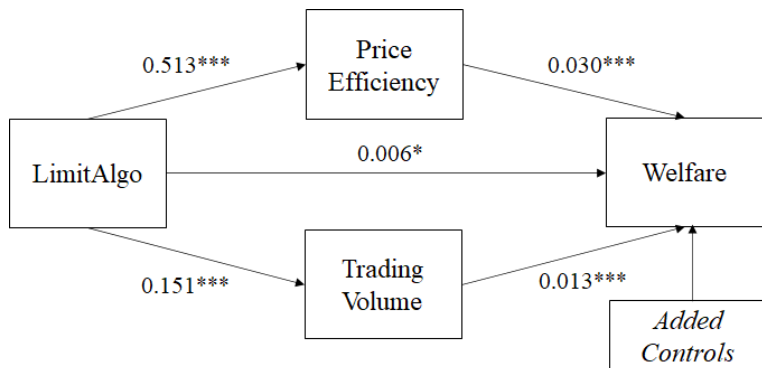
Dependent var.	Bid-Ask Spread	Trading Volume	Number of News Trades	Price Efficiency	Price Volatility
MarketAlgo	1.991 (2.640)	-2.200 (2.377)	2.545*** (0.384)	0.140** (0.070)	-74.390*** (28.610)
LimitAlgo	-23.878*** (2.271)	2.485 (2.199)	-0.145 (0.165)	0.246*** (0.055)	-100.007*** (27.124)
KnownNewsTime	0.638 (1.029)	1.207 (1.127)	-0.177 (0.132)	-0.031 (0.033)	12.137 (12.762)
Constant	21.404*** (2.568)	25.062*** (2.265)	0.772*** (0.189)	0.506*** (0.057)	156.557*** (25.038)

- LimitAlgo weakly improves all market quality measures
- Surprisingly, MarketAlgo also weakly improves them, even though it hurts humans. **Classical market quality measures not good proxy for welfare/human welfare**
- Trade volume under LimitAlgo > volume under MarketAlgo
- Higher number of news trades under MarketAlgo: human exploitation (stale limit orders)

Results: How do limit-order algos improve welfare?

Dependent var.	Welfare	Welfare
Trading Volume	2.939*** (0.456)	2.944*** (0.456)
Price Efficiency	151.751*** (22.322)	154.013*** (21.932)
Bid-Ask Spread	0.306 (0.231)	0.210 (0.239)
Price Volatility	<0.001 (0.023)	-0.002 (0.023)
LimitAlgo	14.541 (15.379)	
KnownNewsTime	3.636 (4.352)	3.723 (4.318)
Constant	4710.257*** (25.819)	4716.893*** (26.197)
Control order and π -realization	Yes	Yes
Observations	400	400
Clusters	20	20

Results: How do limit-order algos improve welfare?



- 74% of the impact of limit-order algos is mediated by the two mediators
- Price efficiency accounts for 88% of the mediation and trading volume accounts for 12%
- “Better” prices allow the right parties (low and high type) to transact; trade volume smaller role

Results: Effect of cognitive reflection (individual)

Dependent var.	Payoffs	Trading Volume	Mistakes Index	Trade ratio with Algo
MarketAlgo	54.096 (36.884)	-5.740** (2.598)	-0.119 (0.132)	0.266 (0.258)
MarketAlgo × CRT	-18.392*** (6.346)	2.545*** (0.396)	0.052** (0.026)	-0.006 (0.043)
CRT	26.065*** (5.563)	-0.642** (0.297)	-0.094*** (0.018)	0.045** (0.021)
LimitAlgo	81.794** (31.765)	-6.051** (2.292)	-0.419** (0.172)	
LimitAlgo × CRT	-14.205** (6.438)	1.039*** (0.382)	0.020 (0.037)	
MarketAlgo × NARS	-15.573 (10.301)	1.176* (0.659)	0.042** (0.036)	-0.093 (0.068)
NARS	15.061 (6.659)	-1.583*** (0.569)	-0.067** (0.031)	0.009 (0.037)
LimitAlgo × NARS	-20.516** (9.634)	1.519* (0.829)	0.128** (0.061)	

- High CRT traders earn more in baseline, but not in algo treatments

Results: Effect of cognitive reflection (market)

Dependent var.	Welfare	Price Efficiency
MarketAlgo	82.632 (60.596)	0.242 (0.174)
MarketAlgo \times Market CRT	-80.509* (47.211)	-0.168 (0.157)
Market CRT	110.893*** (34.713)	0.355*** (0.122)
LimitAlgo	170.603*** (45.153)	0.597*** (0.131)
LimitAlgo \times Market CRT	-129.766*** (42.820)	-0.381*** (0.133)
KnownNewsTime	0.200 (9.537)	-0.031 (0.033)
Constant	6,207.921*** (40.384)	0.176 (0.111)

- High CRT markets do better in baseline, but not in algo markets
- Algos neutralize effect of trader CRT

Concluding remarks

- First lab experiment to measure causal effect of different kinds of trading algos on welfare
- Welfare effect depends on type of algo and whose welfare (entire market vs human traders)
 - Limit-order algos: increase welfare, earn more than humans, average human as well off
 - Market-order algos: don't change welfare, earn more than humans, average human worse off
 - Both algos tend to improve market quality (price efficiency, liquidity, volatility)
- Proxies used in field research (liquidity, trading volume, price efficiency) not good proxies for human welfare

Appendix