# Algorithmic trading

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# Outline

1) Definition and typology of algos
2) Theoretical considerations on algos
    - Algos & limited cognition
    - Algos & adverse selection
    - Algos & moral hazard
    - Algos & systemic risk
3) Empirical evidence
4) Conclusion

# 1) Algos

Computers collect & process info faster than humans => trade on it

Even when humans not present or actively monitoring (no human intervention)

# What do they do?

| | |
|---|---|
| Determine which assets to trade | Trade fast on news<br><br>Identify & exploit arb or investment opportunities |
| Predefined choice of assets | Work orders<br><br>Consume or supply liquidity<br><br>Search for best execution |

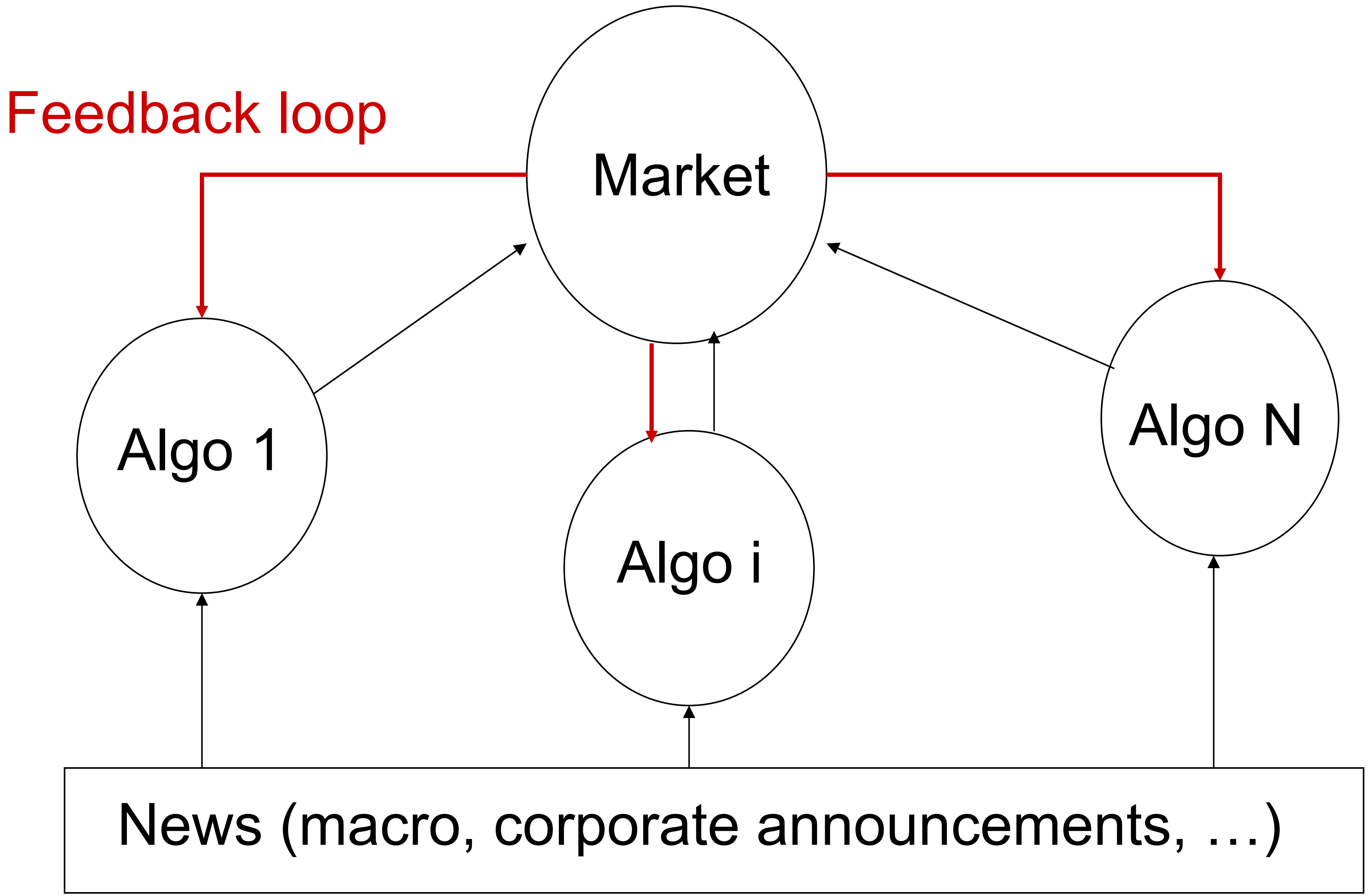
# Who uses them?

| | | |
|---|---|---|
| Determine which assets to trade | Trade fast on news<br><br>Identify & exploit opportunities | → Prop traders<br>Hedge funds |
| Predefined choice of assets | Work orders<br><br>Consume or supply liquidity<br><br>Search for best execution | → Prop traders<br>Hedge funds<br>Brokers |

# What info do they use?

| | | | |
|---|---|---|---|
| Determine which assets to trade | Trade fast on news<br><br>Identify & exploit opportunities | → | Info about market (depth & quotes) & common value of asset |
| Predefined choice of assets | Work orders<br><br>Consume or supply liquidity<br><br>Search for best execution. | → | Info about market (depth & quotes) & private value of trader |

# Algos, traders & markets



# 2)Theory

# What are the pros & cons of algos?

Perfect market => algos don’t matter

What market imperfections?

i) Limited cognition → pros

ii) Moral hazard

iii) Adverse selection → cons

iv) Systemic risk

# With limited cognition algos improve gains from trade

Without algos, information collection & processing delays slow down order placement & matching of buyers and sellers (with different private values)

Algos enhance order placement opportunities & improve speed and quality of matching

=> greater gains from trade, more liquidity

=> market more resilient to shocks

=> less transient volatility in prices

=> greater informational efficiency

# “Limited cognition, liquidity shocks & order book dynamics”

Biais, Hombert & Weill (2010)

Market hit by aggregate liquidity shock transiently reducing willingness to hold asset of all traders.

Traders emerge from distress at random times: when they do, they recover high valuation for asset.

Efficient allocation of asset to high valuation traders hindered by limited cognition: It takes time for traders to evaluate their own position (have they emerged from stress?) & design optimal strategies.

Algos reduce delay on investors’ trades => improve efficiency of allocation/gains from trades => liquidity.

# With limited cognition algos improve speed at which info is incorporated into prices

Without algos, information collection & processing delays slow down incorporation of new information in quotes & prices

Algos enhance ability of traders to digest and express info

=> greater informational efficiency

# Algos & agency problems

Moral hazard: actions of agents not observable

Example: Is broker really providing best execution?

Algorithm: search for price & execution strategy of broker observable

=> mitigates agency problem

=> reduces rents for brokers, costs for investors

=> facilitates delegation & reliance on more sophisticated strategies (dynamics, splitting, multi-market, etc…)

=> market effectively more liquid & transactions less costly for final investors

# Algos can reduce adverse selection for liquidity suppliers

Foucault, Roell, Sandas, Review of Financial Studies (2003)

Algos => fast electronic monitoring of market

If liquidity suppliers use fast algos

=> they face less adverse selection

=> spreads tighten & liquidity improves

=> price discovery enhanced too, as quotes more informative

# Algos can also increase adverse selection for liquiditty suppliers

If fast algo traders use market orders to hit slow limit orders, this worsens adverse selection for the limit order traders

=> spread widens & liquidity supply lower

# Algos & information asymmetry

There is information about (common) value of assets waiting out there to be used

Algos get it faster than the others

=> Information asymmetry between algos & others

=> Trading profits for algos / costs for others

Prices informationally efficient a little bit faster, but slow investors more reluctant to participate in market => lower gains from trade & liquidity

# Level playing field?

High fixed cost of algos

=> develop computer program, hire specialists

=> buy fast connection to exchange servers (co-location)

Large traders fast, small traders slow

=> small traders face adverse selection

=> compete less aggressively to supply liquidity

=> liquidity supply less competitive

=> spreads widen / depth decline

# Algos & systemic risk

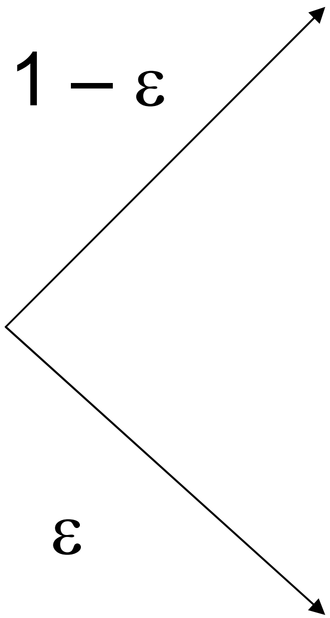
Normal times: algo trades not too correlated/not too big in aggregate => don't move prices too much.

Algos designed to trade optimally in this context.

Rare shocks: exceptional/sudden increase in correlation between algos => aggregate algo trade big => push price.

Algos react fast & automatically to this price movement (without taking time to think about its exceptional nature) => push price further => spiral.

# A simple synthetic model of pros & cons




Normal times:

- Algos enable trades without human intervention
- Algo traders get surplus

Rare shocks:

- Dangerous to act before thinking
- Algos can make losses

# 2 trading environments

$1-\varepsilon$

Normal times:

| 1 \ 2 | Fast | Slow |
|---|---|---|
| Fast | x,x | y,-y |
| Slow | -y,y | 0,0 |

x=gains from trade, y= private info rent

$\varepsilon$

Rare shocks:

| 1 \ 2 | Fast | Slow |
|---|---|---|
| Fast | -L,-L | -L,0 |
| Slow | 0,-L | 0,0 |

L = loss from action without human intervention under exceptional circumstances

# Utilitarian social welfare

If both fast = $2\,[(1-\varepsilon)\,x - \varepsilon\,L]$
If one fast, the other slow = $-\,\varepsilon\,L$
If both slow = 0

Fast is socially optimal if $\varepsilon$ and L low and x high:

$$(1-\varepsilon)\,x > \varepsilon\,L$$

Otherwise slow is socially optimal

# Equilibrium when $\varepsilon=0$

| 1 \ 2 | Fast | Slow |
|---|---|---|
| Fast | x,x | x+y,x-y |
| Slow | -y,y | 0,0 |

E(profit|I am fast, the other is fast) = x
E(profit|I am fast, the other is slow)= y
E(profit|I am slow, the other is fast)= -y
E(profit|I am slow, the other is slow)= 0

Fast = dominant strategy: enables to reach gains from trade, and avoids informational disadvantage.

# Equilibrium when $\varepsilon>0$

E(profit|I am fast, the other is fast) = $(1-\varepsilon)\,x - \varepsilon\,L$
E(profit|I am fast, the other is slow)= $(1-\varepsilon)\,y - \varepsilon\,L$
E(profit|I am slow, the other is fast)= $(1-\varepsilon)\,(-y)$
E(profit|I am slow, the other is slow)= 0

Fast = Nash equilibrium if

$$(1-\varepsilon)\,(x+y) > \varepsilon\,L$$

Slow = Nash equilibrium if

$$(1-\varepsilon)\,y < \varepsilon\,L$$

# Inefficient equilibrium

If

$$(1-\varepsilon)\ y > \varepsilon\ L > (1-\varepsilon)\ x$$

Fast = unique symmetric pure Nash equilibrium

This equilibrium is socially suboptimal

Prisoners' dilemma: algos socially suboptimal, but if others use algos I must do the same.

# 3) Empirical evidence

# “Does Algorithmic Trading Improve Liquidity?”

## Hendershott, Menkveld & Jones
## Forthcoming Journal of Finance

Proxy for algo trading: ratio of messages (orders, cancels, modifications, etc…) to volume

Instrument: start of autoquoting on NYSE

Finding: For large-cap stocks, quoted and effective spreads & informativeness of quotes increase.

But realized spreads increase: rents for the (smaller number of) liquidity suppliers who became fast.

# “Algorithmic Trading and Information”

## Hendershott & Riordan, 2010

Algorithmic trades, 30 DAX stocks, Deutsche Börse.

AT liquidity demand (market orders) = 52% of volume

Algos supply liquidity on 50% of volume.

Algos monitor the market for liquidity & deviations of price from fundamental value.

Algos consume liquidity when it is cheap and supply liquidity when it is expensive.

AT contributes to efficiency by placing efficient quotes & trading to move towards efficient price.

# “Rise of the Machines: Algorithmic Trading in the Foreign Exchange Market”

Chaboud, Chiquoine, Hjalmarsson, Vega 2010

Interdealer trading in currency market 2006 2007

Algo trades correlated

No causal relationship between algo trading & volat

Algos less active in the minute following macro releases, but algos supply liquidity over the hour following release

# “What happened to the quants in August 2007?” Khandani & Lo, 2010

August 6, 2007: Hedge funds/prop traders hit by shock from credit market

$\Rightarrow$margin calls & reduction in position limits

$\Rightarrow$fast unwinding in equity market

$\Rightarrow$push price down: spiral

August 10, 2007: market recovers.

These quantitative funds processed lots of data => used algos: Was the spiral due to algos? Would it happen without algos? Was it worsened by algos?

# What happened on May 7 2010?


Was the 9% drop in the Dow due to spiral of algos?

# 4) Conclusion

# Conclusion: What do we learn from theory?

Pros: Algos can help mitigating limited cognition & moral hazard problems, and thus improve liquidity & gains from trade.

Cons: But they can also reduce competition or increase systemic risk.

The cons are less clearly understood by theory than the pros

# Conclusion: What do we learn from empirical observations?

There are only a few studies, so far.

Econometric studies of normal times suggest that algos don't reduce liquidity & increase price efficiency.

Case studies of rare crisis suggests algos might worsen systemic risk.

Very little data available: need more data to conduct more systematic studies.

# Conclusion: preliminary & tentative policy implications

Co-location: creates potential information asymmetry, without obvious huge efficiency improvement

=> Regulation could improve liquidity by enforcing level playing field

Algos might be destabilizing in exceptional circumstances

=> High frequency monitoring by market organizers & trading halts (enforced across market venues) could provide useful safeguards