The Survival of Short Memory Traders in an Agent-based Financial Market

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Financial Markets as an Evolutionary Process
Evolution and Market Efficiency

*Older Theories*

- Natural selection in finance and economics
  - Unprofitable *investors* eliminated
  - Unprofitable *firms* eliminated

- Observed rational behavior

- Market as efficient parallel information processor

- Does the world really work like this?
Financial Theory and Coevolution

- Trading strategies compete and evolve
- Poor performing strategies die away
- New niches created for others
- Equilibrium versus Continuing Change
Why an Evolutionary Approach to Finance?

• Empirical puzzles
  - Large price swings (bubbles)
  - Volatility
  - Large moves (crashes)
  - Trading volume

• New tools
  - Agent-based computational markets
S&P 500 and “Rational” Price (Shiller)
Other Agent-based Equity Market Platforms

- Santa Fe Artificial Stock Market
- Lux
- Farmer
- Levy, Levy, and Solomon
- Many others
Overview

• Market setup
• Computer experiments and financial data
  – Calibration
• Extensions and future
  – “Beyond Calibration”
Market Pieces

- Assets
- Agents
- Trading strategies
Assets

• Equity
  – Risky dividend
    • Annual growth = 2%, std. 6%
  – Fixed supply (1 share)

• Risk free (cash)
  – Infinite supply
  – Constant interest rate: 0%
Agents

- 500 Agents
- Consume constant fraction of wealth
- Choose investment portfolio rules to maximize risk adjusted returns
- Estimate strategy returns over past
Short Memory Traders

- Use small amounts of past information
- World is **nonstationary**
  “New Economy”
- Less rational??
- *Reasonable* irrationality
Agent Memory
(Long versus Short)

Past

Return History

2 years

5 years

6 months

Present

Future
Agent Evolution

- Agents with more wealth have greater impact on prices
- Bankrupt agents replaced
Trading Strategies

$x_t(I_t)$

1

0.5

T
Strategies

• 250 Rules

• Information converted to portfolio recommendation

• Information
  – Lagged returns
  – Dividend/Price ratios
  – Price momentum

• Neural network
Strategy Evolution

- Strategies not in use removed
- New strategies evolved to take their place
Rule Selection

- Agents examine pool of rules
- Choose rules that maximize returns over their particular memory length
Rules in Use

All Rules

Active Rules
Trading

- Rules chosen
- Demand for shares $= f(p)$
- Find $p$, so that $f(p) = 1$ (total shares)
Computer Experiments

- Time period = 1 week
- Simulation = 25,000 weeks = 480 years
Financial Data

• S&P 500
  – Period = 1928 - 1998
  – Weekly: Daily price levels (Wednesday)
  – Annual: Compounded quarterly with dividends
  – All returns excess of U.S. Tbill rates
    • Stock return – Tbill return

• Trading Volume
  – IBM shares traded 1990-2002 (weekly)
Two Experiments

• **All memory**
  – Agent memory $[0.5, 20]$ years

• **Long memory**
  – Agent memory $[17, 20]$ years
All Memory Price/Volume

![Diagram showing log price and trading volume over time.](image)

- Log Price
- Trading Volume
- Period
Price Versus Equilibrium Price
S&P 500 and “Rational” Price (Shiller)
Weekly Returns

![Weekly Returns Graph](image-url)
Weekly Return Histograms

![Histograms showing S&P and Sim. Return frequencies against their respective returns.](image)
Return Distribution Tails

Proportion of returns that are less than -x

-10^3 to -10^{-1}
### Weekly Return Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>All Memory</th>
<th>S&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.17%</td>
<td>0.15%</td>
</tr>
<tr>
<td>Std.</td>
<td>3.73%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>10.5</td>
<td>11.6</td>
</tr>
<tr>
<td>5% VaR</td>
<td>-5.49%</td>
<td>-3.74%</td>
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# Annual Return Summary Statistics

(Excess Returns)

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<tr>
<td>Mean</td>
<td>11.80%</td>
<td>8.70%</td>
</tr>
<tr>
<td>Std.</td>
<td>35.80%</td>
<td>20.40%</td>
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<tr>
<td>Kurtosis</td>
<td>2.88</td>
<td>3.00</td>
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<tr>
<td>ACF(1)</td>
<td>-0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>ACF(2)</td>
<td>-0.18</td>
<td>-0.17</td>
</tr>
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Dividend/Price Ratios
(Upper = S&P, Lower = Sim)
Trading Volume
Autocorrelations

![Autocorrelation Plot]

- ACF Lag (weeks)
- Autocorrelation

Legend:
- IBM
- Sim
Empirical Summary

• Large price swings (bubbles)

• Volatility
  – Magnification
  – Persistence

• Large moves (crashes/kurtosis)

• Trading Volume
Further Experiments

- Population heterogeneity and crashes
- Short memory traders and instability
Heterogeneity and Crashes

![Graph showing price and heterogeneity over time. The graph illustrates the dynamic changes in price and heterogeneity throughout the period, highlighting periods of significant price fluctuations and corresponding changes in heterogeneity.](image)
Removing Short Memory Traders

- Long memory only
  - Memory = 17-20 years
- Will these traders converge?
Long Memory Only
All Versus Long Memory

Log Price vs Period

Trading Volume vs Period
Long versus All Memory
Dividend/Price Ratios

![Graph showing Long Memory and All Memory Dividend/Price Ratios over quarters.](image)
### Weekly Return Summary Statistics

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Removing Instability

- Remove short memory traders
- Slow learning
- Ignore crashes
Beyond Calibration

• Thought experiments
  – Evolution of short memory traders
  – Importance of crashes
  – Changing predictability

• Applications
  – Trading mechanisms
  – Crash indicators
  – Forecasting??
  – Policy probes