Policy Optimization in Stock Market

An Agent-Based Model Approach Integrating Evolutionary Computation

Interim Progress

Du Yusen

2025/12/03

Background

- In macroeconomics, regulation policies are considered an effective means of artificial intervention in the market. For example, a RRR cut implies releasing liquidity, thereby stimulating the market.
- However, because policymakers and investors do not always make rational decisions, macroeconomic regulation often fails. This is referred to as **individual irrationality**.[1]

Figure 1. To mitigate panic following the 2015 Chinese stock market turbulence, the SSE approved a trading curb rule on the first trading day of 2016. However, the policy backfired accelerating the market crash.

Methodology [2]

Feature	CGE Computable General Equilibrium	DSGE Dynamic Stochastic General Equilibrium	ABM
Concept	**Top-Down**	**Bottom-Up**	**Bottom-Up**
Modeling Agents	**Macroeconomic sectors**	**Rational agent**	**Every investor**
Real Data Requirements	High: require social accounting matrix	Middle, require	Low, only for validation
Solution Method	Solves algebraic equations	Solves dynamic systems	Simulation-based
Stochasticity	Deterministic	Via stochastic shocks	Native support
Computational Cost	Low	Middle	High
Key Advantage	Numerical analysis and experience base	Based on logic and policy transmission	Heterogeneity, interaction, and emergence

Table 1. Three Algorithms for Economic Policy Analysis

Goal

- Find optimized macroeconomic regulation policy.
  - **Simulation (This Presentation Focusing)**
    - Build an **ABM Simulation** for the stock market.
  - Optimization
    - Evolve the optimal policy through **Genetic Algorithm**.
  - Validation
    - Construct an **Evaluation Framework** and functions to quantify policy scores.

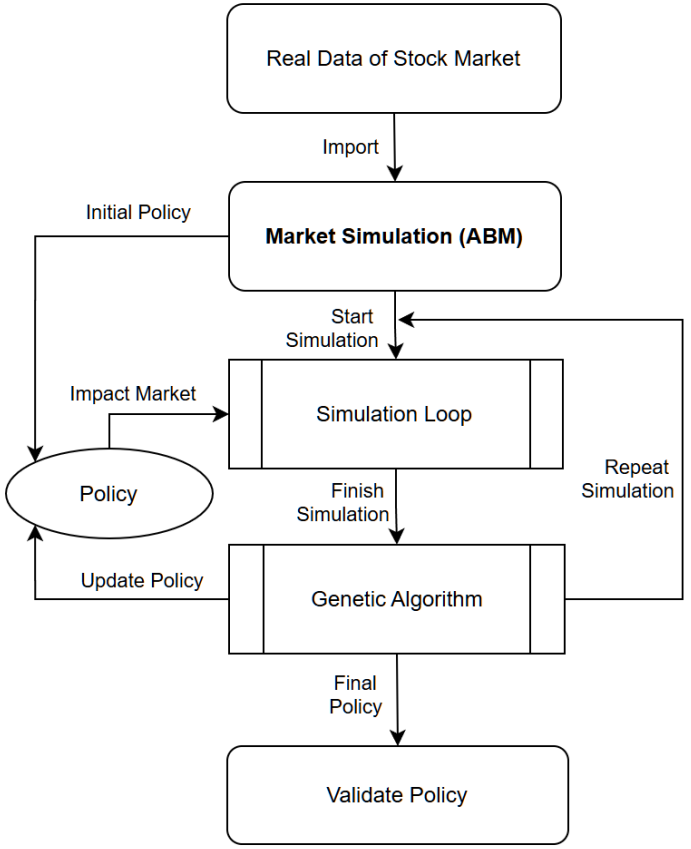


Figure 2. A complete process of policy optimization.

Environment

- Market:
  - Market Indicators: Composite Index, Turnover, etc.
- Stocks: A set of tradable risky assets.
  - Fundamental Indicators: Capitalization, Revenue, P/B, P/E, etc.
  - Trading Indicators: Trading Volume, Turnover Rate, etc.
- Matchmaking System: CLOB

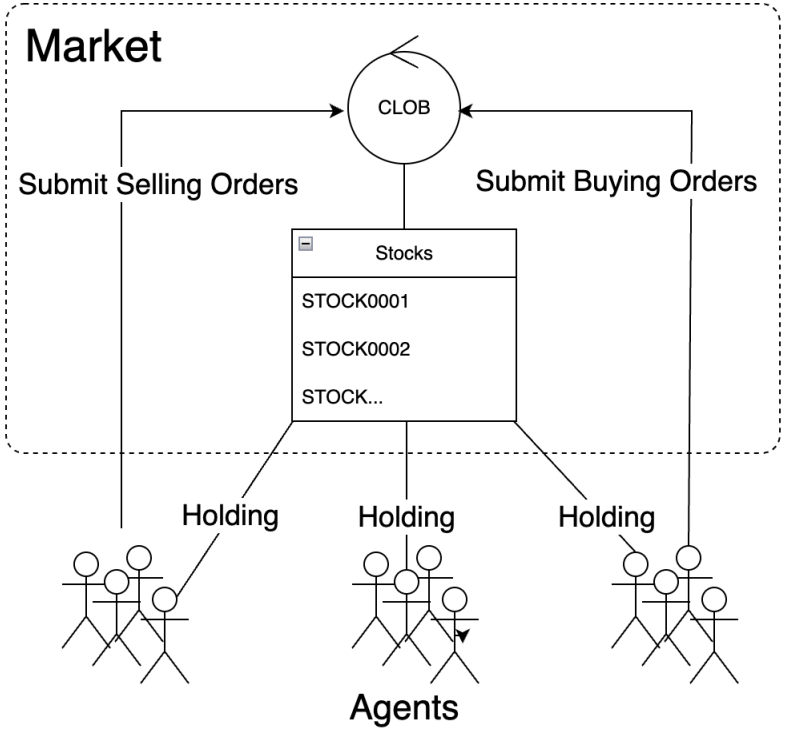


Figure 2. Structure of simulated market.

Environment: CLOB

- Central Limit Order Book (CLOB) is the standard double-auction mechanism used in global assets markets to match buyers and sellers.
- Core Logic: Price-Time Priority
  - **Price Priority:** Higher Bids and lower Asks represent better prices and are prioritized.
  - **Time Priority:** For orders at the same price, earlier orders are executed first.

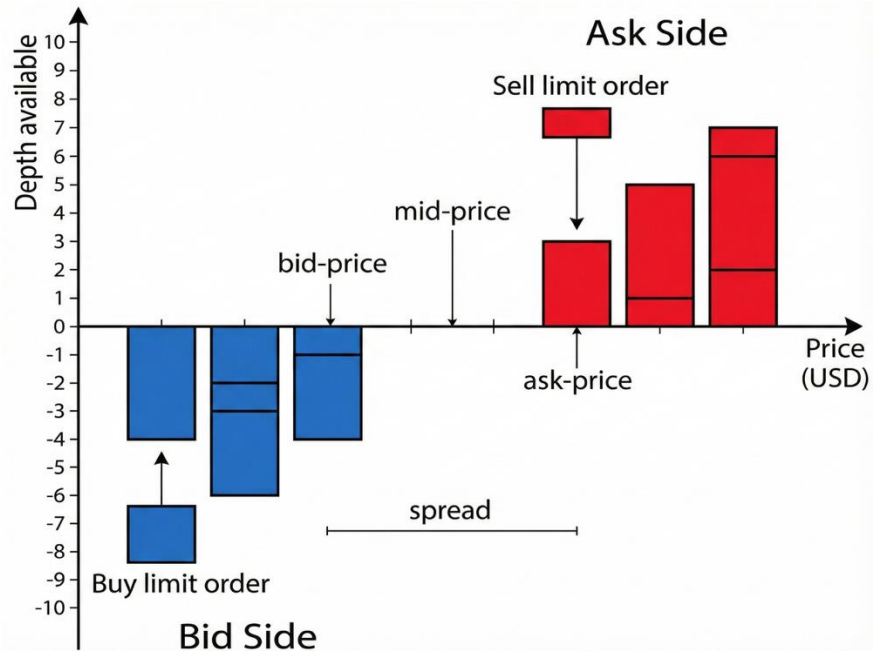


Figure 3. Graphical representation of the Limit Order Book. Ref. DOI:10.13140/RG.2.1.1490.5684

Agents

- Institutional Trader Agents
  - Prefer Low-risk Assets.
  - Lower Trading Frequency.
  - Decision Logic: Valuation Model.
- Retail Trader Agents
  - Higher Risk Tolerance and Trading Frequency.
  - Decision Logic
    - Normal Retail Trader: Based on fundamental analysis but also taking short-term trends into account.
    - Noise Retail Trader: Only focus on short-term trends, buy high and sell low.

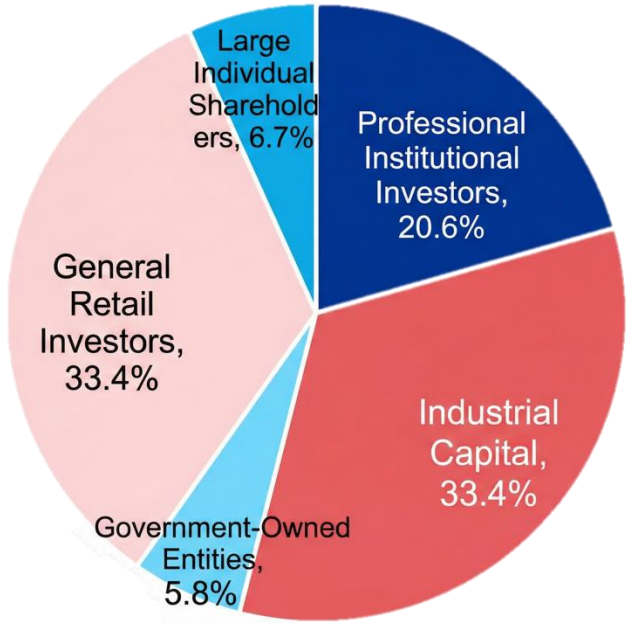


Figure 4. Composition of Investors in the Chinese Stock Market (2023).

Agents:
Attributes

- Portfolio
  - Shares Holding
  - Cash
  - Padding Cash (For Pending Order)
  - Creditor's Rights *(Future Work)*
- **Risk Tolerance** $\left(\tau_i(t)\right)$
  - The main reasons for market irrationality in this simulation.
  - The lower means the more conservative to valuation.

$$Action_i(t)\begin{cases}\text{Buy} & Score_i(t) > 1+\tau_i(t)\\ \text{Sell} & Score_i(t) < 1-\tau_i(t)\\ \text{Hold} & \text{otherwise}\end{cases}$$

Agents:

Fundamental Analysis And Valuation Model

- Fundamental Analysis
  - A framework to assess the quality and price of assets. The simulation here uses it to generate Fundamental Indicators.
- Valuation Model
  - A model using Fundamental Indicators to calculate asset valuation. The simulation here uses it to generate decision scores for stock selection.

$$Score = \frac{\left[(V_{base} \times (1+g) \times \beta_{sec} \times \beta_{sent}) \times w_{fund} + P_{trend} \times w_{trend}\right] \times (1+\epsilon)}{P_{current}}$$

**Decision scoring equation [3], detail in Appendix 2.*

Interactions

- Agent-Environment
  - Submit Buying Orders
  - Submit Selling Orders
- Agent-Agent *(Future Work)*
  - Information Sharing
  - Panic Spread
  - Leverage
  - Bet-on Agreement
  - Others …

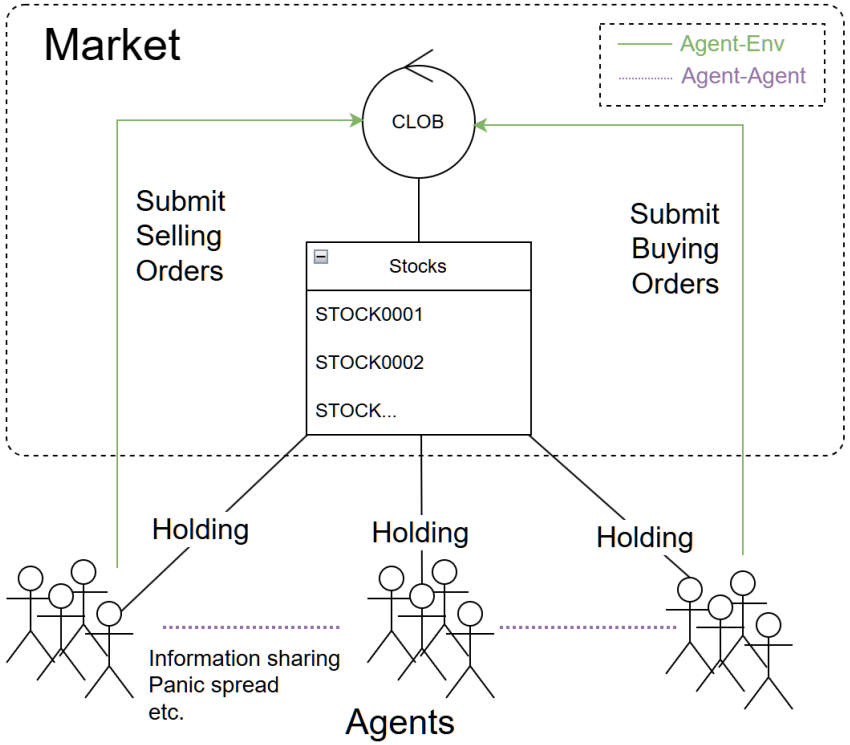


Figure 5. Interactions in simulation

Startup Simulation

- Approach 1: Generate Virtual Data
  - Step 1: Generate a total capital pool.
  - Step 2: Divide the total capital into Retail and Institutional sub-pools based on the real-world ratio.
  - Step 3: Allocate capital to individual agents within each sub-pool following a normal distribution.
  - **Step 4: Initial stock allocation**
    - Approach 1: Initial Public Offerings (IPO)
    - Approach 2: Forced Allocation
- Approach 2: Import Real Market Data *(Future Work)*

IPO or Forced Allocation?

- IPO
  - Subscribing for new shares with lot winning rate.
  - More realistic, like a real-world market.
  - Assets Undervalued and Artificial Bubble.
- Forced Allocation
  - Forced allocation of shares to agents and deducting their cash.
  - High stability and convergence.

Startup:
Limitations of IPO

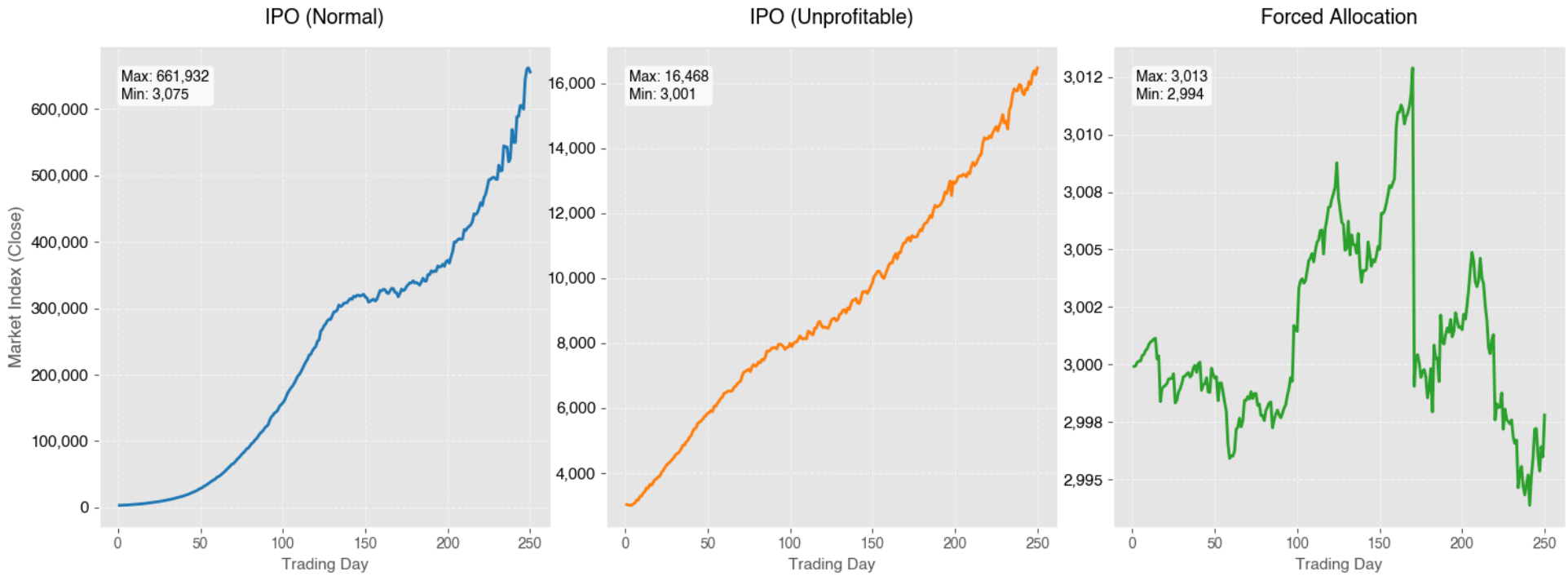


Figure 6. Contrast of market index with different startup conditions. Even it's an unprofitable market, the market index still growth abnormally.

Event Slot

- The Event Slot is a system designed to dynamically modify various parameters of both the Environment and Agents. It allows us to inject quantified policy impacts into the simulation at any specific time.

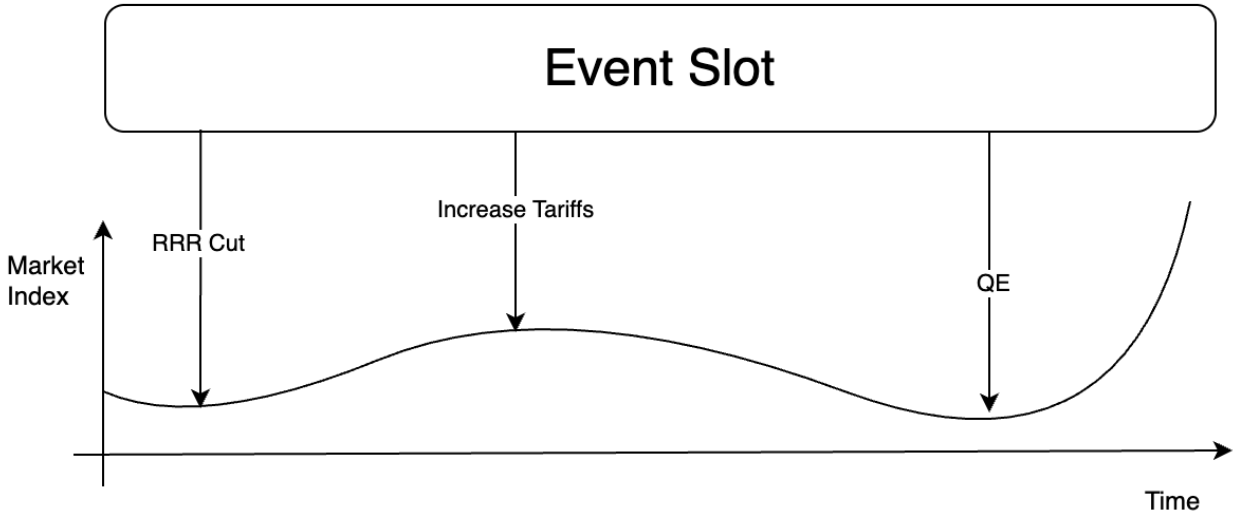


Figure 7. Schematic of how events impacts the market.

Mean Reversion

- In finance, it is a general market law that asset prices tend to revert to their mean over time in a closed system.
- The emergence of this phenomenon in the simulation serves as a strong basis for its validation.

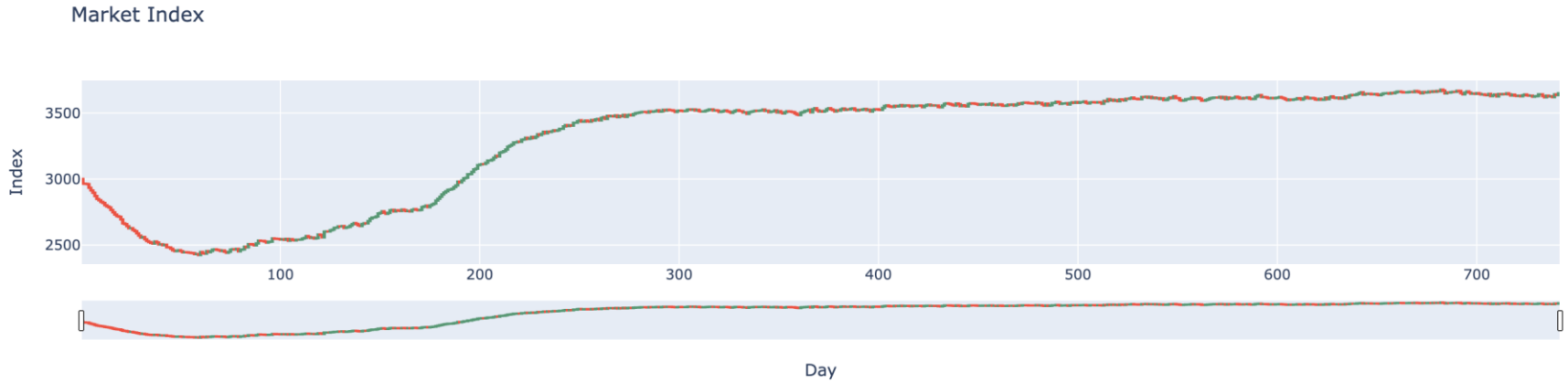
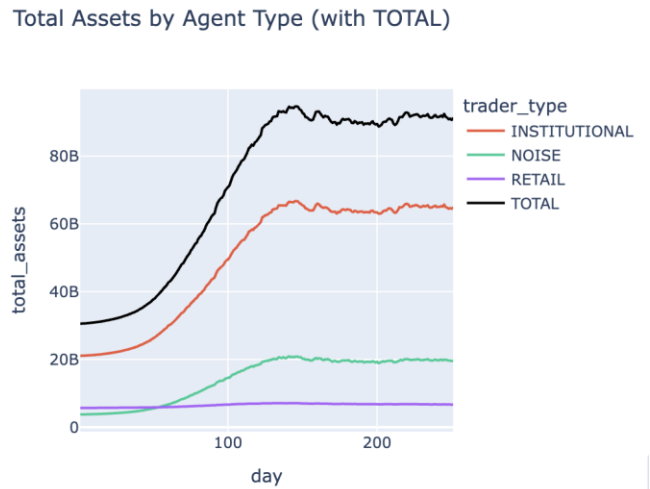


Figure 8. A complete simulation in closed-system. showing the market regressing to the mean at approximately Day 300.

Irrational Exuberance: Market Bubble

- Total Assets Fluctuation in Closed System
  - Even in a closed system with fixed initial capital and constant productivity, the total market assets does not remain static.
- The Bubble and The Undervaluation
  - Bubble: Phantom capital generated by trend-chasing behavior.
  - Undervaluation: Real capital evaporated due to panic selling.
- Decoupling of Price and Value
  - Without fundamental growth, driven by profit-seeking and irrationality valuation cause market prices to detach from intrinsic value.



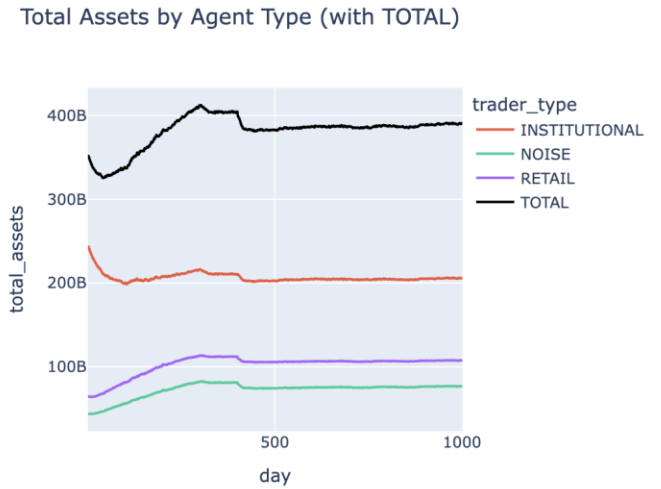


Figure 8 & 9. Total capital trend in different startup condition.

Market Impact

- Day 400
  - Positive News in Tech Sector Release: β_{sent} rise.
- Day 500
  - Interest Rate Hike: Liquidity tightening and leading to a decrease in risk tolerance.
- Day 600
  - Healthcare Sector Bubble Burst: Sharp decline in EPS.
- Day 700
  - QE: Liquidity injection, total capital rise.

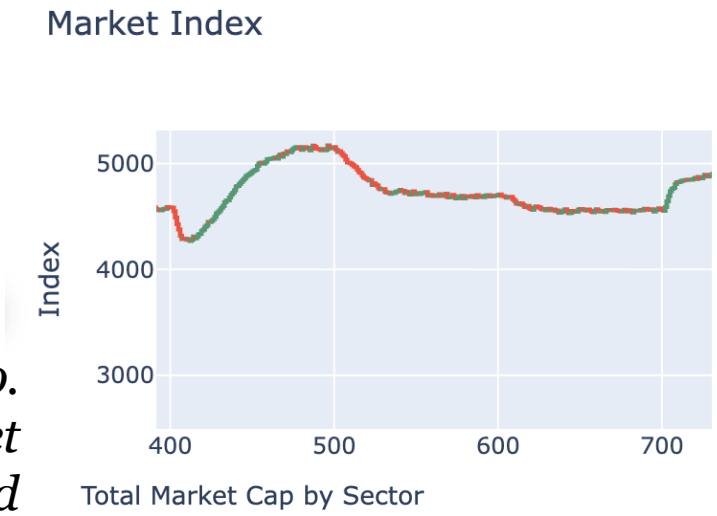


Figure 10. Market index trend

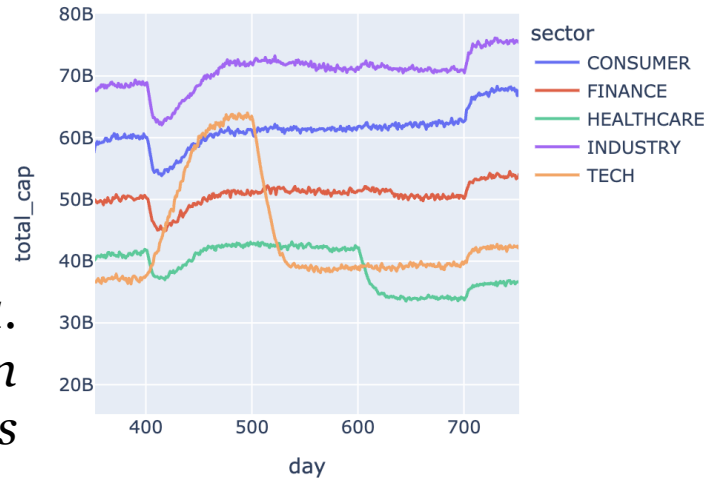


Figure 11. Capital trend in different sectors

Future Works

- Improve The Simulation
- **Genetic Algorithm**
- Validation Framework
- Import Real Market Data
- Interactions Between Agents

Appendix 1. Reference

- [1] Oskari Juurikkala, The Behavioral Paradox: Why Investor Irrationality Calls for Lighter and Simpler Financial Regulation, 18 Fordham J. Corp. & Fin. L. 33 (2012).
- [2] Fagiolo, G. and Roventini, A. (2012). Macroeconomic Policy in Dsge and Agent-Based Models. Revue de l'OFCE, 124(5), 67-116. https://doi.org/10.3917/reof.124.0067
- [3] Courteau L, Kao J L, O'Keefe T, et al. Relative accuracy and predictive ability of direct valuation methods, price to aggregate earnings method and a hybrid approach[J]. Accounting & Finance, 2006, 46(4): 553-575.

Appendix 2. Valuation Model

- Basic Valuation (V_{base})
  - N: Net Assets Per share
  - E: Earnings Per Share (EPS, Negative indicate deficit)
  - M_{PB}: P/B Ratio
  - M_{PE}: P/E Ratio

$$V_{base} = \begin{cases} \frac{(N \times M_{PB}) + (E \times M_{PE})}{2} & E > 0 \\ N \times M_{PB} & E \leq 0 \end{cases}$$

- Revised Valuation ($V_{revised}$)
  - g: Earnings Growth Ratio
  - β_{sec}: Sector Bonus Ratio (Static, Inherent Property)
  - β_{sent}: Sector Sentiment Factor (Dynamic, Information Disclosure Based)

$$V_{revised} = V_{base} \times (1 + g) \times \beta_{sec} \times \beta_{sent}$$

- Weighted Valuation ($V_{weighted}$)
  - W_{fund}: Fundamental Weight
  - W_{trend}: Trend Weight
  - P_{trend}: Trend Price

$$V_{weighted} = V_{revised} \times W_{fund} + W_{trend} \times P_{trend}$$

- $Score$
  - ϵ: Noise
  - $P_{current}$: Current Price

$$Score = \frac{V_{weighted} \times (1 + \epsilon)}{P_{current}}$$