MODELLING AND SIMULATION

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PROBLEM & MOTIVATION

- Real stock markets have numerous traders acting simultaneously.
- Their interaction can create mispricing, high volatility, bubbles, and crashes.
- Because these effects are emergent, they are hard to study with purely analytical models.
- Regulators introduce rules to reduce extreme behaviour (e.g., taxes, leverage limits, short-selling bans).
- But rules can also reduce liquidity and distort price discovery.
- We employ an agent-based simulation to examine these trade-offs in a controlled environment.

Goal: understand how trader heterogeneity and regulation jointly shape market outcomes.

OBJECTIVES

Build an agent-based stock market simulation with heterogeneous traders:

- Fundamentalists
- Chartists
- Noise traders

Implement a price formation mechanism using **Walrasian tâtonnement**:
Iteratively adjust the price to reduce excess demand and reach a market-clearing level

Compare regulatory regimes

- **No regulation** (baseline)
- **Moderate regulation** (small transaction tax + leverage limit)
- **Excessive regulation** (strong constraints: higher tax, tight leverage, short ban, position cap, cash floor)

Measure outcomes with simple KPIs

- **Efficiency**: mispricing vs fundamental value
- **Risk**: volatility and drawdowns; bubble/crash episodes
- **Liquidity**: trading volume/turnover
- **Distribution**: wealth inequality (Gini)

METHODOLOGY AND APPROACH

KEY COMPONENTS

The model stores **price** Pt, **dividend** Dt, **policy rules**, and **history**.

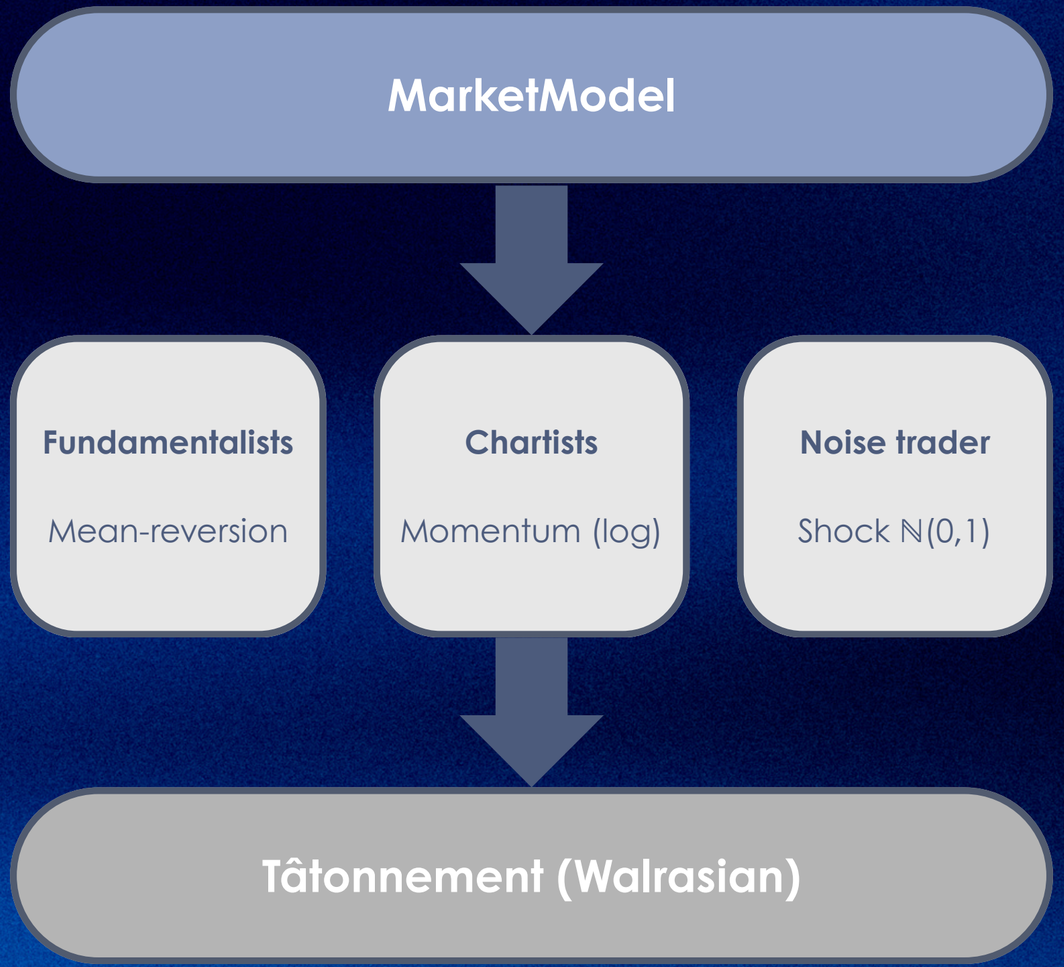
Three heterogeneous trader types:

- **Fundamentalists**: mean-reversion toward fundamental value
- **Chartists**: trend-following (momentum)
- **Noise traders**: random expectation shocks

Common decision rule: agents compute a desired order (buy/sell) under risk aversion.

Price formation: **Walrasian tâtonnement** adjusts P until **aggregate excess demand** ≈ 0.

ARCHITECTURE



METHODOLOGY AND APPROACH

STEP CYCLE

Settlement: update cash with interest and pay dividends; compute each agent's starting wealth.

Expectations: each agent forecasts next price and dividend (based on its strategy).

Price clearing: A Walrasian tâtonnement process adjusts the price until total excess demand is close to zero.

Trading: apply regulation rules, execute trades, and update cash and share holdings; measure trading volume.

Dividend update: generate the next dividend using an AR(1) process.

Data collection: store KPIs (price, returns, mispricing, drawdown, volume, and Gini).

EXPERIMENTAL SETUP

Experiment configuration

- **Horizon:** 50 steps, with burn-in = 5 (metrics computed after burn-in)
- **Replications:** 30 random seeds per policy
- **Policies tested:** none / moderate / excessive
- **Population:** 300 agents total (100 fundamentalists + 100 chartists + 100 noise)
- **Fixed baseline params:** Q=300, r=0.05, P0=20, D0=1; dividends AR(1) (ρ=0.95, σ_d=0.15)

Policy presets

None:
- τ = 0 (transaction tax)
- L_max = ∞ (leverage cap)
- no short-ban
- q_max = ∞ (position cap)
- C_min = -∞ (minimum cash)

Moderate:
- τ = 0.003 (transaction tax)
- L_max = 1.3 (leverage cap)

Excessive:
- τ = 0.01 (transaction tax)
- L_max = 1.0 (leverage cap)
- short-ban
- q_max = 2 (position cap)
- C_min = 0 (minimum cash)

KPIS & EVENT DEFINITIONS

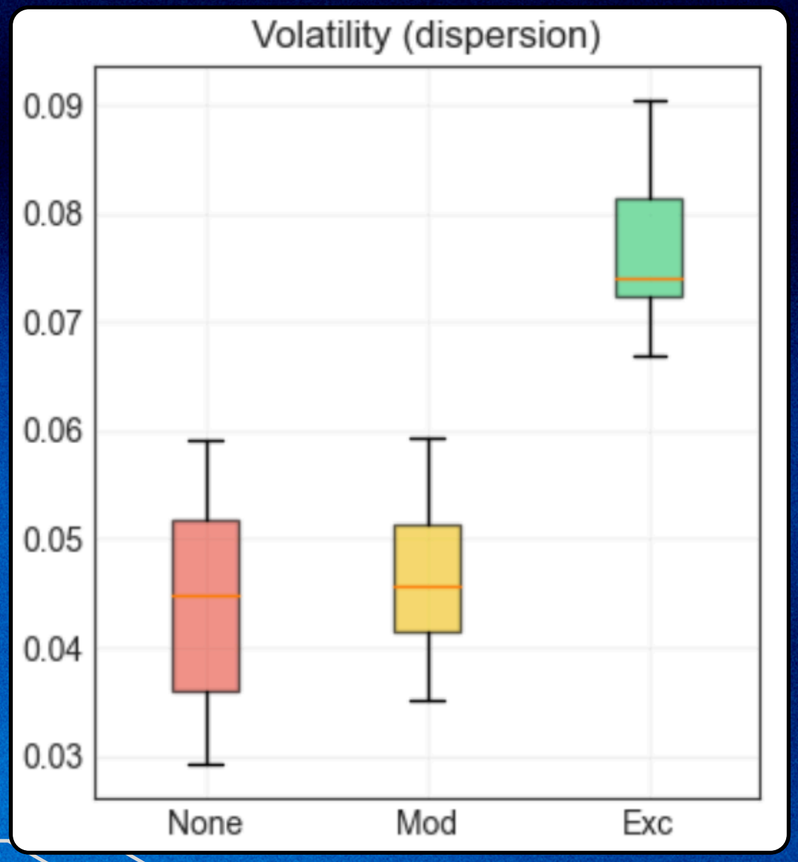
KPIs

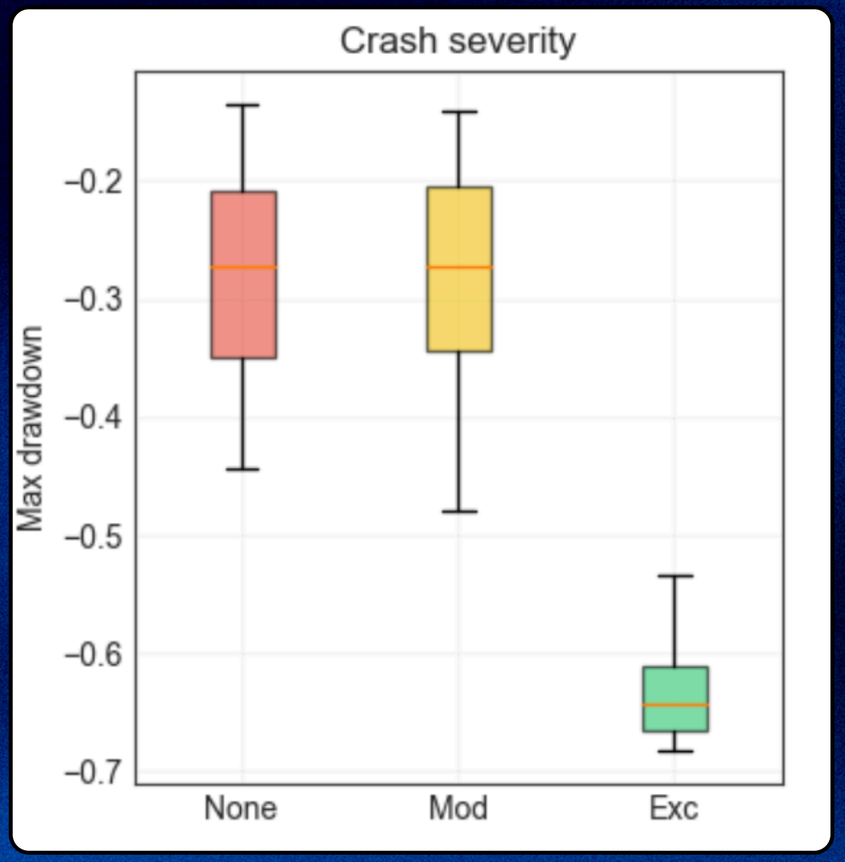
- **Mispricing (efficiency):** distance to fair value (absolute + relative)
- **Volatility (stability):** variability of log-returns
- **Max drawdown (tail risk):** worst peak-to-trough drop
- **Volume & turnover (liquidity):** trading activity
- **Crashes & bubbles (extremes):** frequency + bubble peak intensity
- **Final Gini (distribution):** end-of-run wealth inequality

Event detection rules (thresholds)

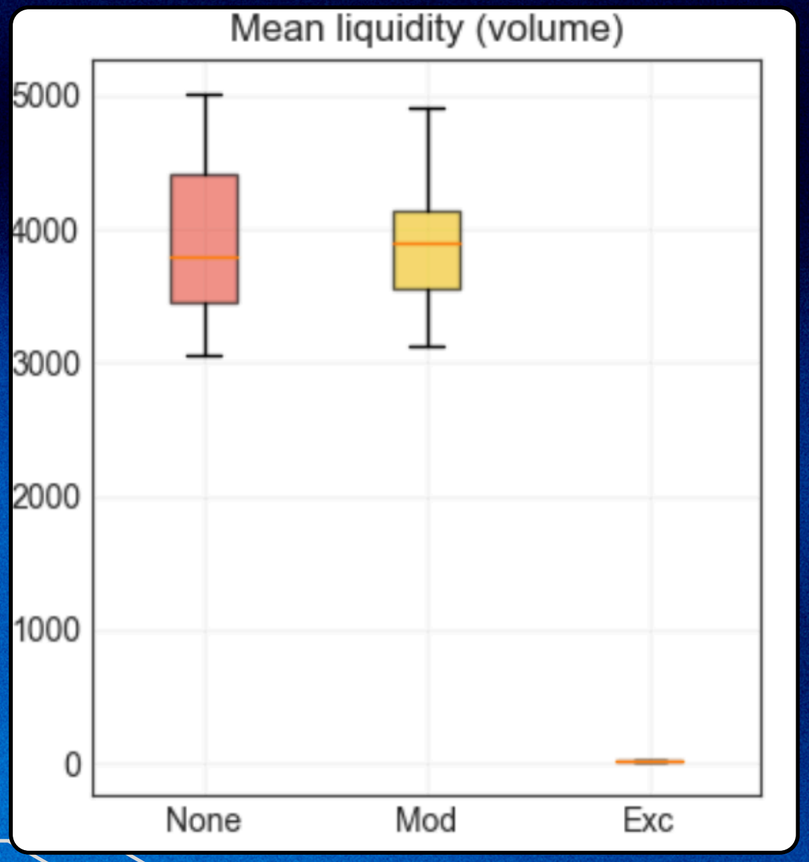
- **Rolling volatility window:** 20 steps
- **Crash (returns):** return < −2 × rolling volatility
- **Crash (drawdown):** drawdown < −25%
- **Bubble:** price stays above 1.5× fair value for ≥ 10 steps
- **Peak intensity:** max price / fair value during the bubble

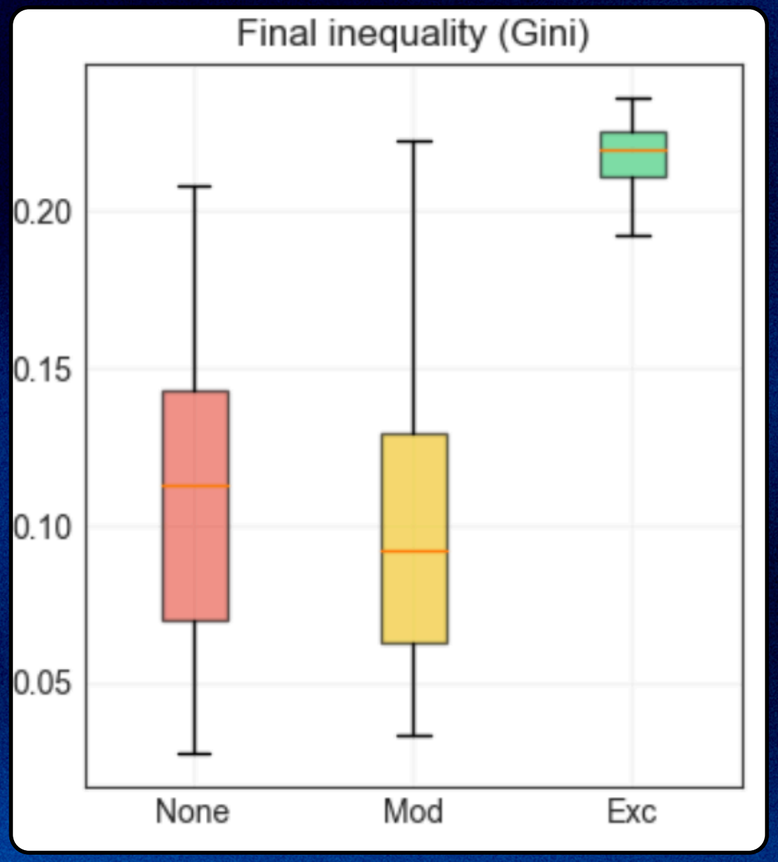
RESULT AND ANALYSIS



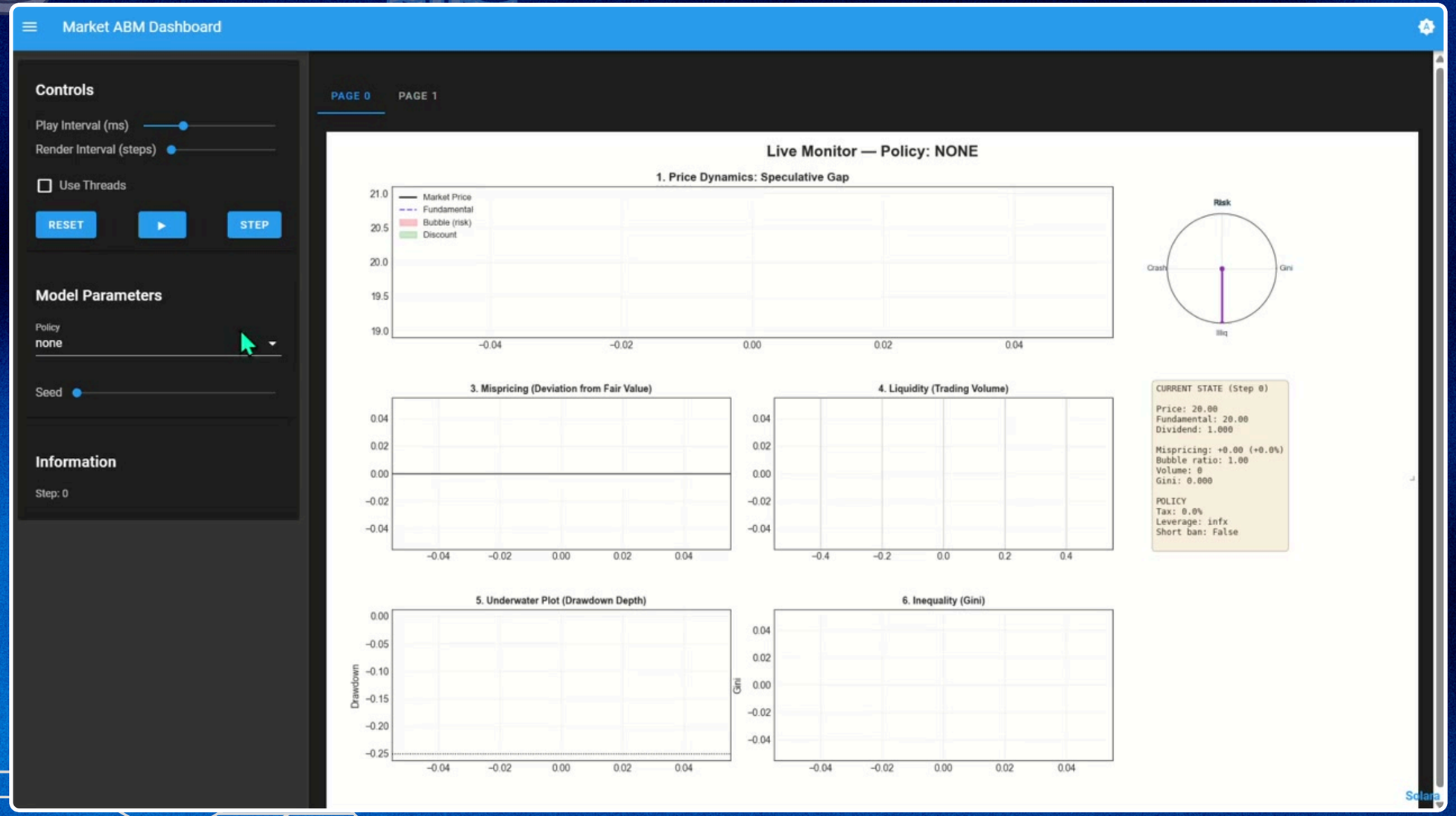


RESULT AND ANALYSIS





DEMO


Market ABM Dashboard
Controls
Play Interval (ms)
Render Interval (steps)
Use Threads
RESET
STEP
Model Parameters
Policy
none
Seed
Information
Step: 0
PAGE 0
PAGE 1
Live Monitor — Policy: NONE
1. Price Dynamics: Speculative Gap
Market Price
Fundamental
Bubble (risk)
Discount
Risk
Crash
Gini
Illiq
3. Mispricing (Deviation from Fair Value)
4. Liquidity (Trading Volume)
CURRENT STATE (Step 0)
Price: 20.00
Fundamental: 20.00
Dividend: 1.000
Mispricing: +0.00 (+0.0%)
Bubble ratio: 1.00
Volume: 0
Gini: 0.000
POLICY
Tax: 0.0%
Leverage: infx
Short ban: False
5. Underwater Plot (Drawdown Depth)
Drawdown
6. Inequality (Gini)
Gini
Solara

CONCLUSION

In summary, the **baseline scenario without regulation** maintains an active market, characterized by high trading volumes and occasional bubbles or crashes. **Moderate regulation** produces similar outcomes, though with reduced mispricing and fewer bubble episodes, while liquidity remains largely unchanged.

In contrast, **excessive regulation** leads to a near cessation of market activity: trading volume collapses, prices deviate significantly from fair value, and drawdowns or crash events become more pronounced.

Future research will involve conducting **longer simulations**, exploring a broader range of **parameter values** (including tax and leverage limits), and implementing additional robustness checks such as varying agent compositions, increasing the **number of simulation seeds**, and performing diagnostics on **constraint clipping** and **tâtonnement convergence** to ensure the observed patterns are robust and not artifacts of the current experimental setup.

BACKUP SLIDES

MERCADO WALRASIANO

$$Z(P) = \sum_i \Delta q_i^{eff}(P)$$

$$Z(P^*) \approx 0$$

- Se Z(P) > 0: no total querem comprar → o preço deve subir.
- Se Z(P) < 0: no total querem vender → o preço deve descer.
- O leiloeiro ajusta P até “equilibrar” compras e vendas (Z(P) ≈ 0).

AGENTES: REGRAS DE EXPECTATIVAS

Fundamentalistas

Preço esperado:

$$E_t[P_{t+1}] = P_t + \kappa_f(P_t^* - P_t)$$

Dividendo esperado:

$$E_t[D_{t+1}] = \bar{d} + \rho(D_t - \bar{d})$$

Chartistas

Momentum (log):

$$m_t = \ln\left(\frac{P_t}{P_{t-L}}\right)$$

Preço esperado:

$$E_t[P_{t+1}] = P_t \cdot \exp(\kappa_c m_t)$$

Dividendo esperado:

$$E_t[D_{t+1}] = \bar{d}$$

Noise traders

Preço esperado:

$$E_t[P_{t+1}] = P_t \cdot \exp(\sigma_n \xi_t)$$

Dividendo esperado:

$$E_t[D_{t+1}] = \bar{d}$$

FORMAÇÃO DO PREÇO (TÂTONNEMENT)

Excesso de procura:

$$Z(P) = \sum_i \Delta q_i^{eff}(P)$$

Atualização do preço (por iteração k):

$$P^{(k+1)} = P^{(k)} \cdot \exp\left(\eta \cdot \tanh\left(\frac{Z(P^{(k)})}{Q}\right)\right)$$

- Z(P) diz se o mercado quer comprar (positivo) ou vender (negativo).
- O preço sobe/desce em pequenos passos até Z(P) ≈ 0.
- Tanh limita o passo (evita instabilidade).
- Exp garante P > 0.
- Q normaliza o efeito (escala do mercado).

REGRA DE TRADING

Payoff esperado de 1 ação

$$\mu_i = E_t[P_{t+1}] + E_t[D_{t+1}]$$

O agente soma “quanto acha que a ação vai valer” + “quanto acha que vai receber de dividendos”.

Comparação com a alternativa sem risco

$$\Delta\mu_i(P) = \mu_i - (1+r)P$$

- Se Delta > 0 → parece “barato” → comprar.
- Se Delta < 0 → parece “caro” → vender.

Ajuste por risco (aversão e incerteza)

$$s_i = \frac{\beta\Delta\mu_i}{\gamma_i\sigma_i^2}$$

- Maior gamma_i (mais avesso) → mexe menos.
- Maior sigma_i^2 (mais incerteza) → mexe menos.

Valor-alvo na ação

$$x_i^* = W_{i,t} \cdot \tanh(s_i)$$

tanh limita extremos: mesmo com sinal muito grande, a posição não explode.

REGRA DE TRADING

Quantidade-alvo de ações

Posição-alvo:

$$q_i^* = \frac{x_i^*}{P}$$

Ordem desejada:

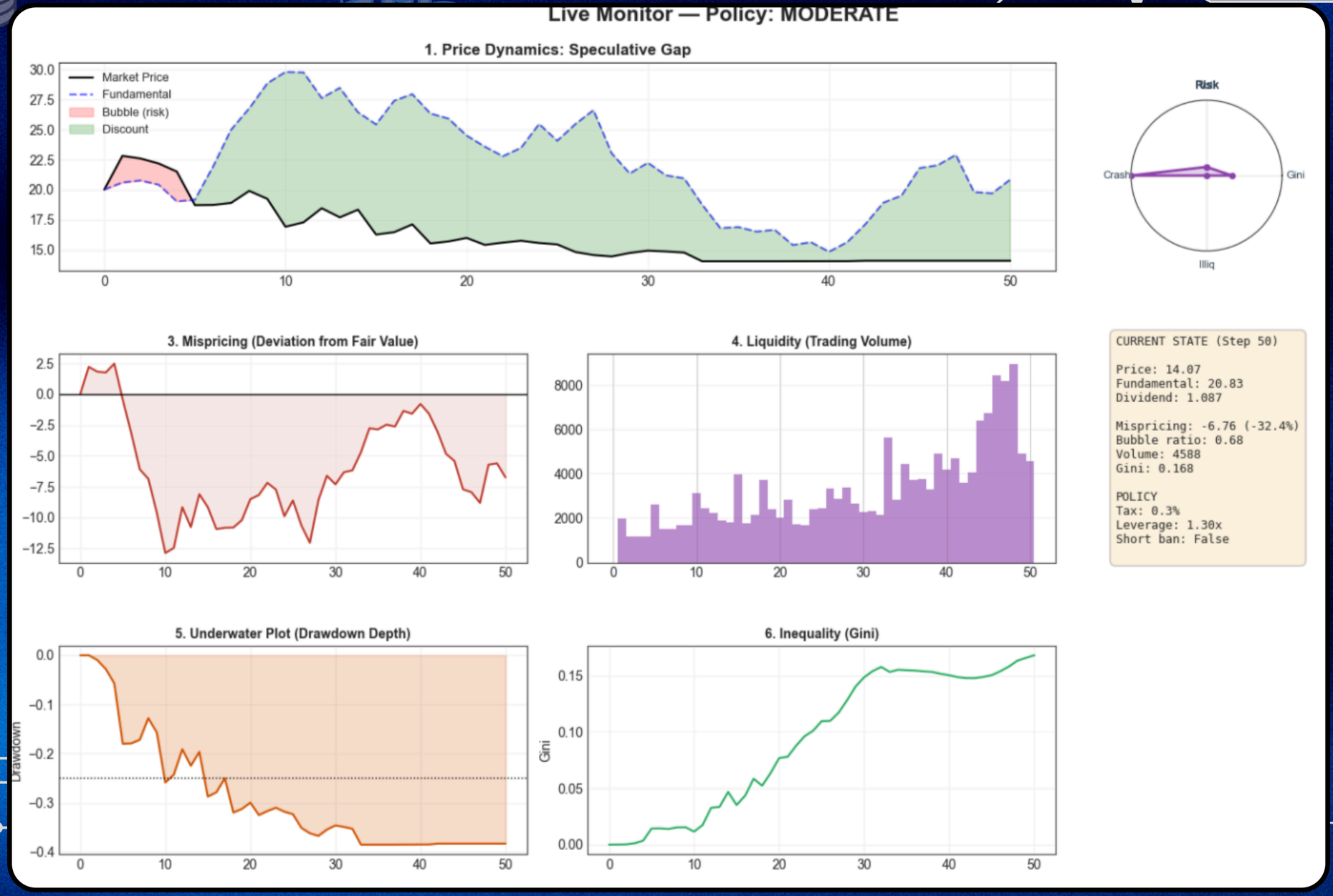
$$\Delta q_i = \phi(q_i^* - q_i)$$

- O agente ajusta gradualmente (phi): não vai logo “all-in”.
- Depois aplica-se a política para obter a ordem efetiva.

POLICY - NONE


Live Monitor — Policy: NONE
1. Price Dynamics: Speculative Gap
Market Price
Fundamental
Bubble (risk)
Discount
Risk
Crash
Gini
Illiq
3. Mispricing (Deviation from Fair Value)
4. Liquidity (Trading Volume)
CURRENT STATE (Step 50)
Price: 18.53
Fundamental: 20.83
Dividend: 1.087
Mispricing: -2.30 (-11.1%)
Bubble ratio: 0.89
Volume: 19915
Gini: 0.138
POLICY
Tax: 0.0%
Leverage: infx
Short ban: False
5. Underwater Plot (Drawdown Depth)
6. Inequality (Gini)
Gini

POLICY - MODERATE



POLICY - EXCESSIVE