Informed Local Managers and Global Financial Crises

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- The base ABM for Financial Markets
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- Introduction of Informed Local Managers
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On Global Financial Crises

- **What is a GFC**
  Episodes in which two markets or more fall into crises simultaneously

- **Examples of GFC**
  - 1997 Asian financial market crisis
  - 2008 Lehman shock

Synchronized crashes of stock markets¹)

¹) [http://www.msci.com/](http://www.msci.com/)
On Global Financial Crises

- Study on GFC
  - Factor & Behavioral Models: Why does it occur?
    - Direct trade flows, bank lending, direct investment, ...
    - Investors’ behavior
      herding, margin calls, leverage trading, asymmetric information, diversification strategies, ...
  - Agent-based modeling approach
    - Multi-asset/market ABM development
    - Behavioral finance incorporated
      loss aversion, under and overreaction to information, etc.

1) Forbes and Chinn, 2004
2) Calvo, 2004
3) Westerhoff, 2004
4) Brock et al., 2009
5) Bianconi et al., 2009
6) Kahneman and Tversky, 1979
On Global Financial Crises

- Characterizing GFC
  - Frequency of GFC
    Relating to the definition of GFC (30% or 20% drawdown, in half a year or a month)

1) Feldman, 2010
On the Global Financial Crises

- Characterizing GFC
  - Time evolution of correlation of stock indices

Duration of the high correlation coefficients

Sharp rise of the correlation coefficients
On Global Financial Crises

Characterizing GFC

Scattergraph of Log Returns of Stock Indices (Argentina vs Columbia)
Characterizing GFC

Statistics for synchronized crashes (20% dd in 1m)

<table>
<thead>
<tr>
<th></th>
<th>Asia</th>
<th>Europe</th>
<th>South Ame.</th>
<th>North Ame.</th>
<th>Total number</th>
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<td>13</td>
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<td>Charac. Corr.</td>
<td>16</td>
<td>17</td>
<td>13</td>
<td>10</td>
<td>56</td>
</tr>
</tbody>
</table>

Possible meaning
- Sharp rise: critical behavior?
- Duration of high correlation: memory effects?
General features of the base model

- **ABM study of finance**
  Financial markets are modeled as interacting groups of *learning, boundedly rational* agents, and behavior is described mainly by *running computer simulations* rather than by solving equations or proving theorems.

- **Characteristics**\(^1\)
  - Fund managers as agents (<100)
  - Portfolio and leverage trading
  - No payoff maximization
  - Gradient dynamics (a continuous tuning of strategy)
  - Constant learning
  - Loss aversion behavior

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\(^1\) Friedman and Abraham, 2009
Formulation of the base model

- **Assets**
  - A riskless asset: \( R_0 \)
  - A risky asset (market portfolio): \( R_1 \)

- **Fund managers**
  - Portfolio weights and size: \( x_i \in [0, \infty), \ z_i \geq 0 \)
  - Gross return: \( R_i^G = (1 - x_i)R_0 + x_iR_1 + \epsilon_i \)

Ornstein–Uhlenbeck stochastic process

\[
\epsilon_i = e^{-\tau h} \epsilon_i(t-h) + \sqrt{\frac{1-e^{2\tau h}}{2\tau}} \sigma v
\]

- Cost of the fund: \( R_0 + \frac{1}{2} c_2 x_i^2 \)
- Net return:
  \[
  R_i(x_i) = x_i(R_1 - R_0 + \epsilon_i) - \frac{1}{2} c_2 x_i^2
  \]
Formulation of the base model

- Loss aversion
  - Loss evaluation with constant learning:
    \[ L_i = \max \{0, -R_i^G\} \quad \hat{L}_i(t) = e^{-\eta h} \hat{L}_i(t-h) + (1-e^{-\eta h})L_i(t) \]
  - Memory decay rate: \( \eta \)
  - Risk evaluation:
    \[ c_2 = \beta \hat{L}_T(t) \quad \hat{L}_T(t) = \sum_i z_i \hat{L}_i(t) / \sum_i z_i \]
    Sensitivity to the perceived loss: \( \beta \)

- Gradient Dynamics
  - Manager’s payoff function: \( \phi_i(x_i, F) = R_i(x_i) \)
  - Manager’s adjustment of leverage: \( dx_i / dt = \partial \phi_i(x_i, F) / \partial x_i \)
    Cumulative distribution of leverages: \( F(x) \)
  - Average demand:
    \[ \bar{x} = \int_{0}^{\infty} xF(dx) \approx \sum_i z_i x_i / \sum_i z_i \]
Formulation of the base model

- Price formation
  - Fundamental value of the risky asset:
    \[ V(t) = V(0)e^{gst} = e^{gst} / (R_s - g_s) \]
    Growth rate: \( g_s \)  Discount rate: \( R_s = R_0 + d_R \)
  - Fundamental-oriented supply of the risky asset:
    \[ S = (P / V)^a \]
    Asset price: \( P \)  Elasticity: \( a = 1 / \alpha \)
  - Demand of the risky asset: \( D = \bar{x} \)
  - Price of the risky asset: \( S = D \Rightarrow P = V\bar{x}^\alpha \)
  - Return of the risky asset:
    \[ R_1 = e^{gst} / P + \dot{P} / P = (R_s - g_s)\bar{x}^{-\alpha} + g_s + \alpha \dot{x} / \bar{x} \]

  - Dividend yield
  - Capital gain due to price change
  - Capital gain due to economic growth
Properties of the base model

- Recovery of fat tail and volatility clustering

Baseline Parameters

\[ N = 30, R_0 = \sigma_R = 0.03, g_s = 0, \alpha = 2.0, \sigma = 0.2 \]
\[ \eta = 0.7, \beta = 1.8 \]
Base ABM for Financial Markets

- Phase diagram for the recovery of stylized facts

![Phase diagram](image)

- **Memory decay rate**
- **Sensitivity to perceived losses**
Two–market ABM\(^1\))

- **Assets**
  - Two riskless assets: \(R_0\) (arbitrage free)
  - Two risky assets:
    - Managers
      - Local managers
        - Payoff function
          \[\phi_{i,m}(x_{i,m}, F_m) = x_{i,m} (R_m - R_0 + \varepsilon_{i,m}) - \frac{1}{2} A_m \sigma_m^2 x_{i,m}^2\]
        - EWMA model:
          \[\sigma_m = \sigma_t \cdot e^{-\eta h} + (1 - e^{-\eta h}) \sigma_{m-1}\]
        - Loss aversion model for risk cost:
          \[A_m = \beta \hat{L}_{T,m}(t)\]

- **Managers**
  - Adjustment of leverage:
    \[dx_{i,m} / dt = \partial \phi_{i,m}(x_{i,m}, F_m) / \partial x_{i,m}\]

1) Feldman, 2010
Extended ABM for GFC

- Two-market ABM
  - Global managers
  - Payoff functions:
    \[ \phi_k^G(x_{k,1}, x_{k,2}, F_1, F_2) = x_{k,1}(R_1 + \varepsilon_{k,1}) + x_{k,2}(R_2 + \varepsilon_{k,2}) + (1-x_{k,1} - x_{k,2})R_0 \]
  - Loss aversion: \( A_m = \beta \hat{L}_{T,m}(t) \)
  - Adjustment of leverage:
    \[
    \begin{align*}
    \dot{x}_{k,1} &= R_1 + \varepsilon_{k,1} - R_0 - A_1 \sigma_{1}^2 x_{k,1} - \rho \sigma_1 \sigma_2 A_1 x_{k,2} \\
    \dot{x}_{k,2} &= R_1 + \varepsilon_{k,2} - R_0 - A_2 \sigma_{2}^2 x_{k,2} - \rho \sigma_1 \sigma_2 A_2 x_{k,1}
    \end{align*}
    \]
  - Correlation coefficient: \( \rho \)
  - Covariance Risk:
    \[ \frac{1}{2} A \mathbf{x}^T \mathbf{V} \mathbf{x} \]

Different luck in different markets

Covariance matrix: \( \mathbf{V} \)

Correlation coefficient: \( \rho \)

\[
\text{Cov}(t) = e^{-\eta h} \nu_1(t-1)\nu_2(t-1) + (1-e^{-\eta h})\text{Cov}(t-1)
\]
Extended ABM for GFC

- Typical simulation results
  - The role of GM
    \[ \hat{L}_{T,m}(t) = \frac{\sum z_i \hat{L}_i^m(t)}{\sum z_i} + \frac{\sum z_k \hat{L}_k(t)}{\sum z_k} \]

Small # of GM: Stabilizing (diversification of risk)
Large # of GM: Destabilizing (less risk averse)
Extended ABM for GFC

- Typical simulation results
  - Frequency of GFC
    - GFC in simulations: Synchronized crashes of price (30% drawdown in half a year)
Extended ABM for GFC

- Typical simulation results
  - Correlation of the two markets
Inclusion of informed local managers (iLM)

- The concept of iLM
Introduction of iLM

- Inclusion of informed local managers
  - Payoff functions:
    \[
    \phi_{j,m}^{IL}(x_{j,m}, F_m) = x_{j,m} (R_m - R_0 + \varepsilon_{j,m}) - \frac{1}{2} x_{j,m}^2 \sum_m A_m \sigma_m^2
    \]
  - Loss aversion: \( A_m = \omega_m \Delta P_m \)
    - Evaluation of loss:
      \[
      \Delta P_m = \max \{0, -[\log P(t+h) - \log P(t)]\}
      \]
    - Unreasonable to evaluate the market loss by using other managers’ loss
    - Perceived losses evaluated based on public information
  - A hysteresis model for the risk cognition
    - iLMs recognize the risk from the other market only when *big events* take place
    - Risk from the other market gets lost in iLMs’ oblivion through the *forgetting curve*
Introduction of iLM

A hysteresis model of the risk cognition for the observed market

\[ \sigma(t) / \bar{\sigma}_m > \text{threshold} \]

\[ \propto \log t \]

volatility increase

Forgetting Curve

\[ \propto e^{-\mu(t-t_0)} \]

volatility decrease

Weights

Volatility
Simulations of GFC

- Simulation of GFC
  - Synchronized crashes

Without iLM
GM = 40%

With iLM
LM = GM = 40%
\[ \mu = 0.01 \]
Simulations of GFC

- Frequency of GFC

  Without iLM, GFC frequency *gradually* increases with GM fraction.
  
  With iLM GFC frequency *drastically* increases over a *critical* GM fraction.
Simulations of GFC

- Duration of high correlation coefficient (with ILM)

\[ \mu = 1.0 \]
Simulations of GFC

- Duration of high correlation coefficient (without iLM)
The role played by iLM

- ILM alone can cause GFC
- The trigger of GFC with iLM (a typical scenario)
  - A solo crash occurs in Market 1
  - iLMs in Market 2 begin to count the risk of Market 1
  - Correlation coefficient increases
  - Synchronized crash in both the markets

The role played by GM

- GMs have a larger exposure to risk
- GMs increase the tendency of GFC
Concluding Remarks

- Why do GFCs occur?
  - Existence of GM
  - Existence of iLM
  - Streaks of luck for fund managers in trading

- How often do GFCs occur?
  - Increase with the number of GM
  - Increase with the number of iLM

- Can we predict GFCs?
  - Easier to occur after solo crashes
  - Maybe by monitoring the inter-correlation of markets
Concluding Remarks

- Possible new characteristic behaviors
Concluding Remarks

- Correlation of fundamental values
  Trading, Investment, ...

![Graph showing correlation of fundamental values and prices]