UNIVERSITY OF CALIFORNIA

Office of the Chief Investment Officer

Financial Crisis and the Failure of Economics

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Growing Portfolios Building Partnerships

UC Investments

Risk Management Versions 1.0 to 3.0

Problem: How do we deal with crisis risk? With market dislocations?

Risk Management Version 1.0: Historical Data

"How often have we seen this?" → Value at Risk (VaR) Models

Risk Management Version 2.0: Static Scenarios

"What if this happens?" → Stress Tests

Risk Management Version 3.0: Dynamic Interaction

"And then, what happens next?" → Agent-based Models

Agent-based Models: The Traffic Engineer's Problem

Agents
Cars and Drivers

Environment
Roadway and other (visible) agents

Heuristics
Speeders, lane-changers

Dynamic
The agents act, the environment changes

Running the ABM

- Draw agents from a distribution of heuristics
- Pepper the roadway with the agents
- Result after many runs: A distribution of traffic flows.

Components of an Agent-based Model

Agents

- Employ heuristics
- Act with some degree of independence or autonomy

Environment

- Each agent observes its environment
- Acts according to its heuristic

Interaction

- Agents' actions change the environment
- Each agent sees its new environment, and takes action again

It boils down to:

- Dynamics of interactions
- Driven by the heterogeneous agents in their environment
- With interactions that alter the environment (Reflexivity)

Why Agent-based Models?

We interact with one another: **Computational Irreducibility**

We interact with our environment: **Emergence**

We change from our experiences: **Non-ergodicity**

We create and change our world: **Radical Uncertainty**

The Four Horsemen of the Econopolypse

Computational Irreducibility

Emergence

Non-ergodicity

Radical Uncertainty

Agent-based Models versus Standard Economics

Computational Irreducibility

Open (Simulations)	Closed (Solvable; deductive)

Emergence

Heterogeneous Agents	Representative Agent; Regularity

Non-ergodicity

Interactive and changing world	Atomistic and Equilibrium World

Radical Uncertainty

Heuristics	Optimization

Agent-based Models: The Fire Marshall's Problem

If there is a fire, how many will make it out?

- Egress
- Flammability
- Crowding

People do not walk out in a single file

Agent-based Models: The Crisis Manager's Problem

If there is a fire, how many will make it out?

- Egress
- Flammability
- Crowding

Egress	⇔	**Liquidity**
Flammability	⇔	**Leverage**
Crowding	⇔	**Concentration**

Crisis Dynamics: Leverage, Liquidity, Concentration

The Crisis Dynamic

Asset Shock or Funding Shock

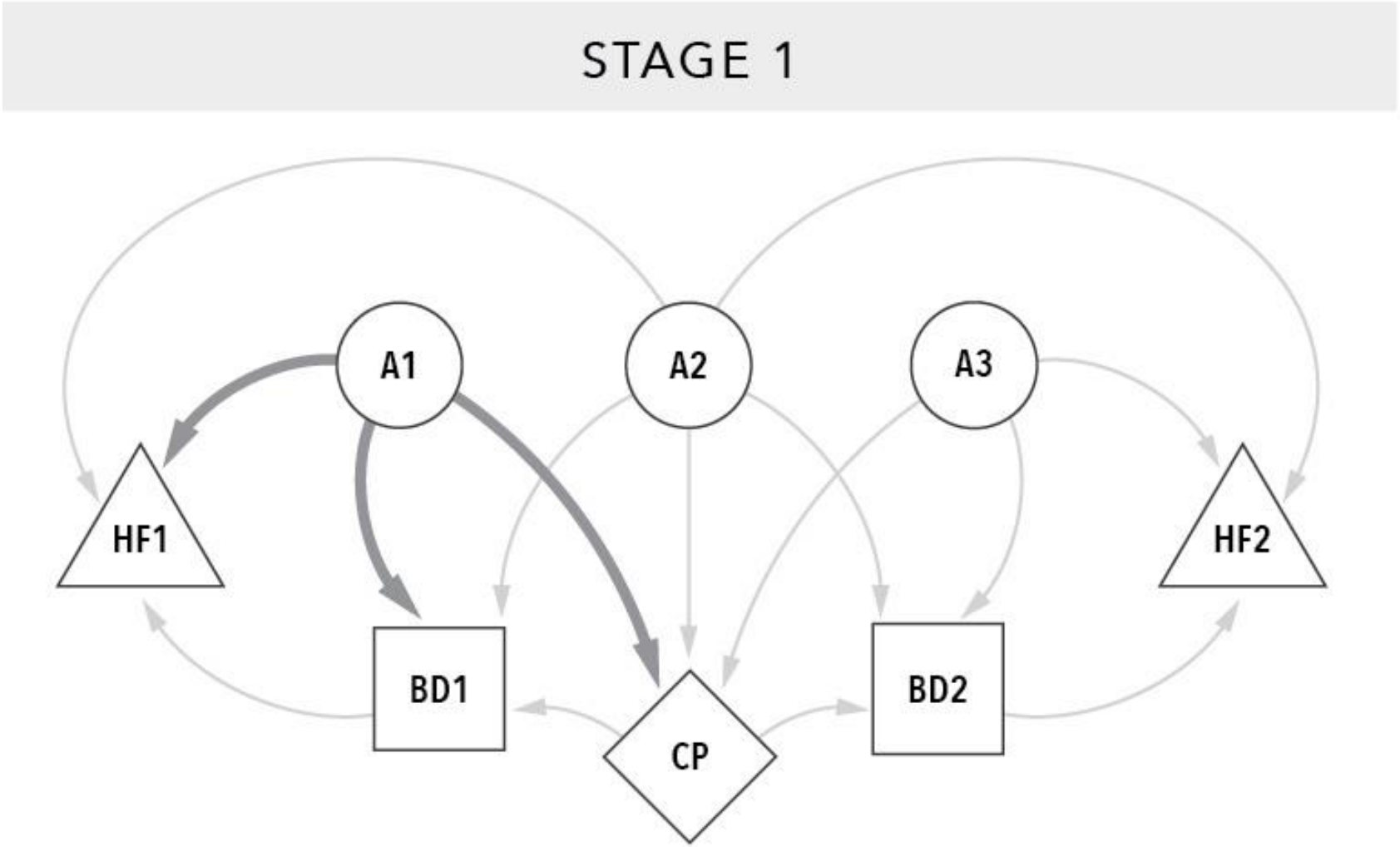
→ Forced sales *due to leverage*

→ Price effects *due to concentration*

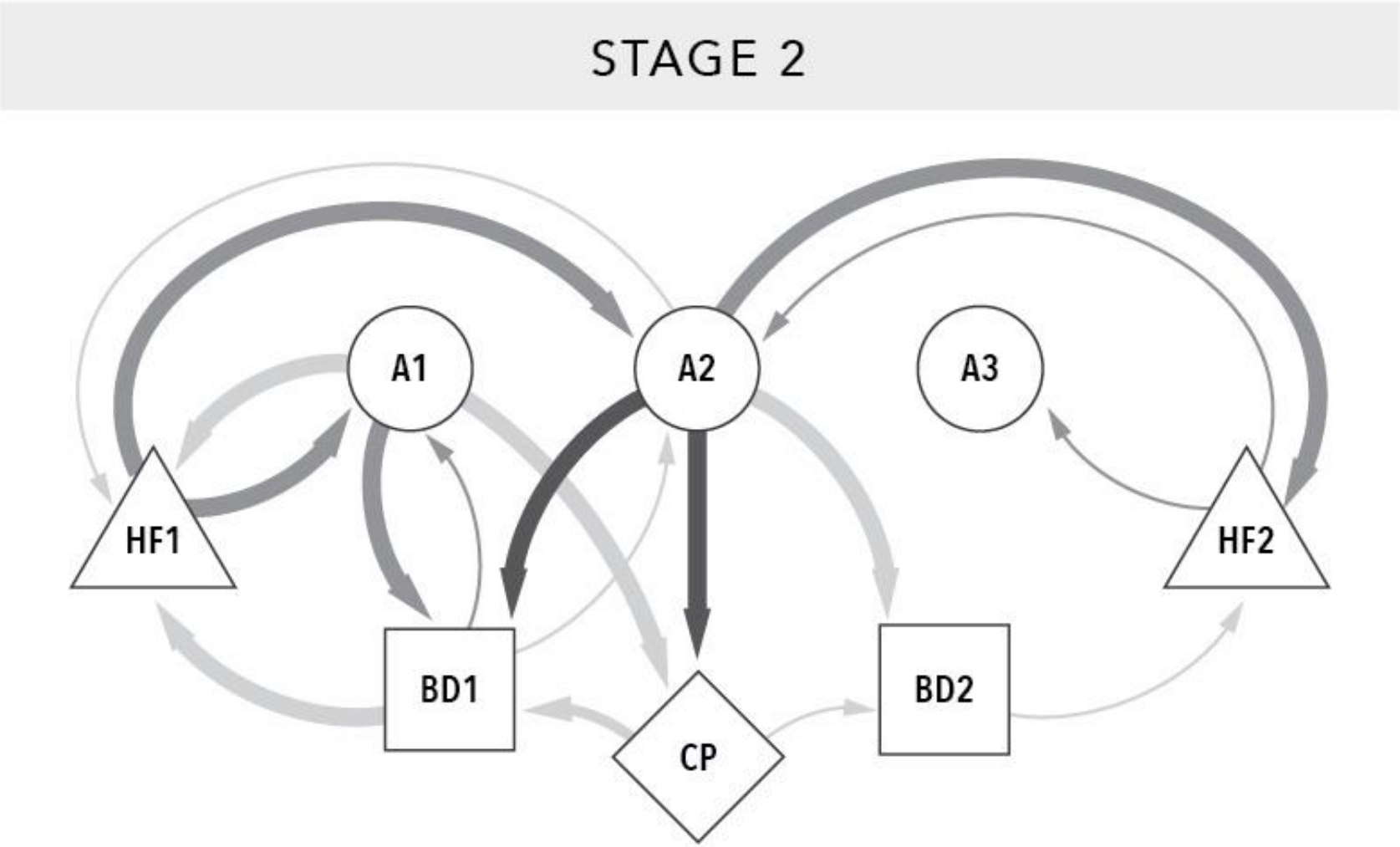
→Further declines *due to illiquidity*

⇒ Cascades and Contagion

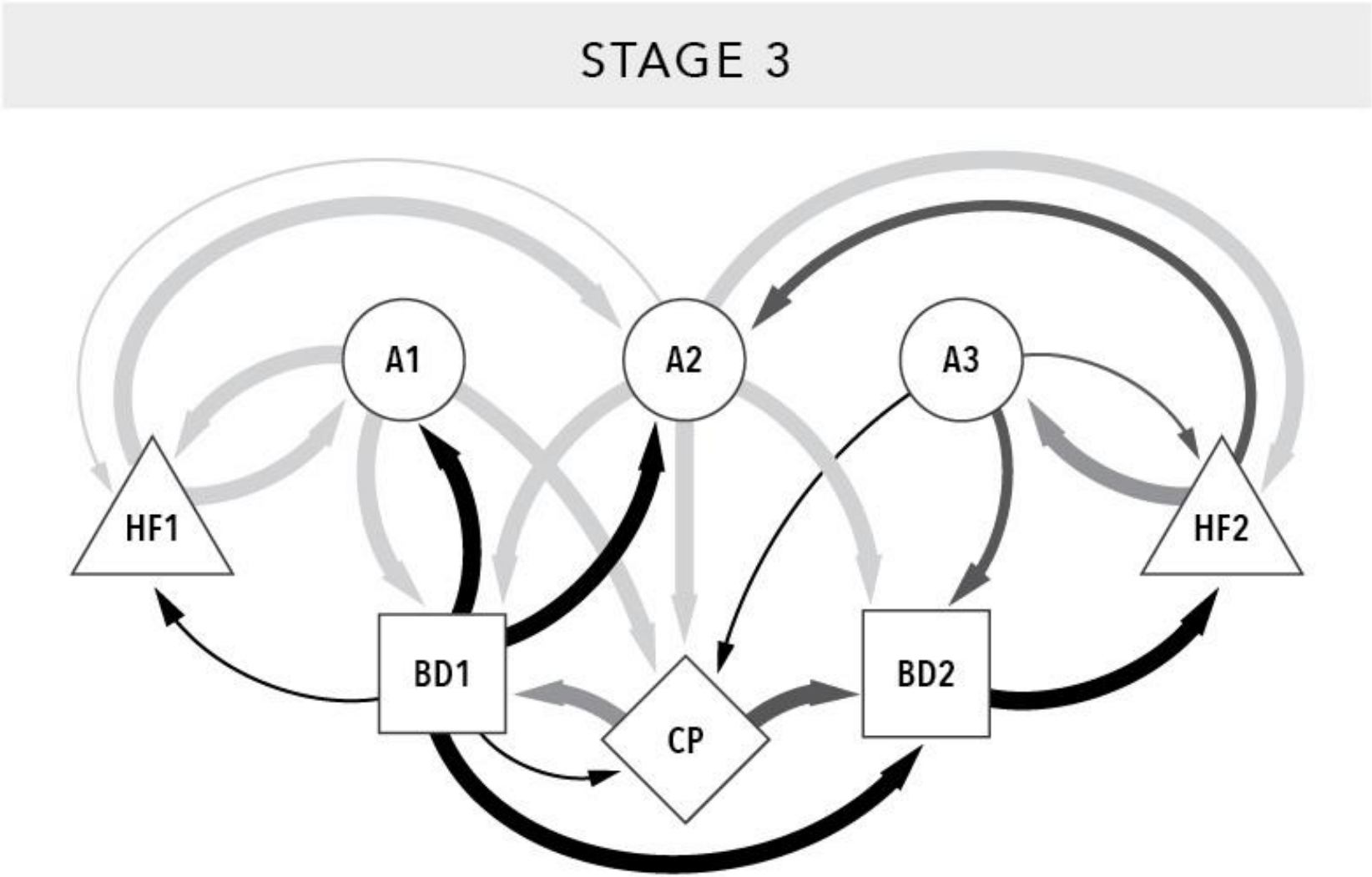
Propagation and Crisis Dynamics Stage 1



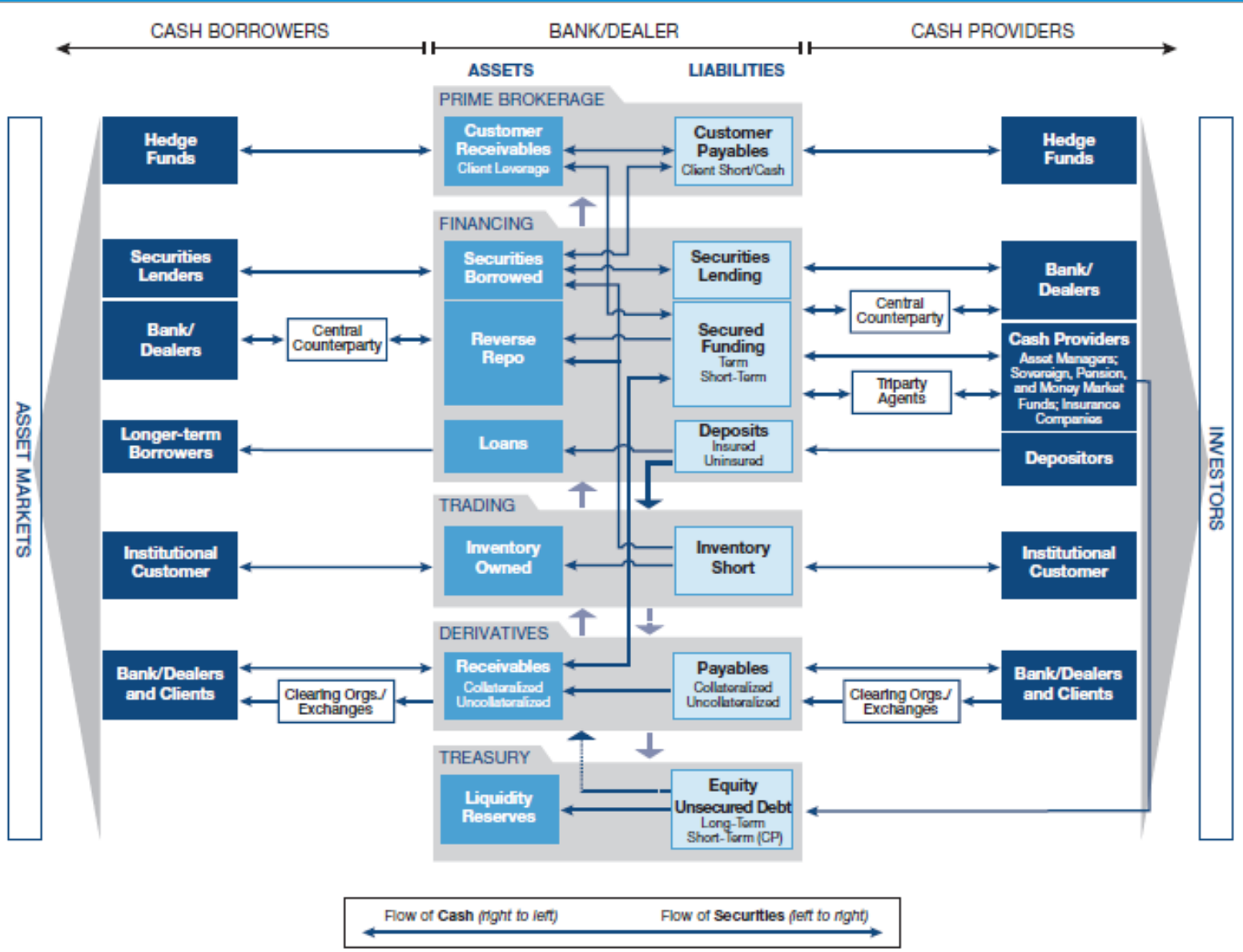
Propagation and Crisis Dynamics Stage 2



Propagation and Crisis Dynamics Stage 3



The Agents in Real Life



The Agent-based Model in Operation

Language

- Go – highly scalable and excellent at multithreading (thus parallel) processing.
- Javascript – for presentation, including D3.

Server

- Amazon Web Services (AWS) for our cloud infrastructure
- Master-worker architecture of Docker containers to parallelize simulations

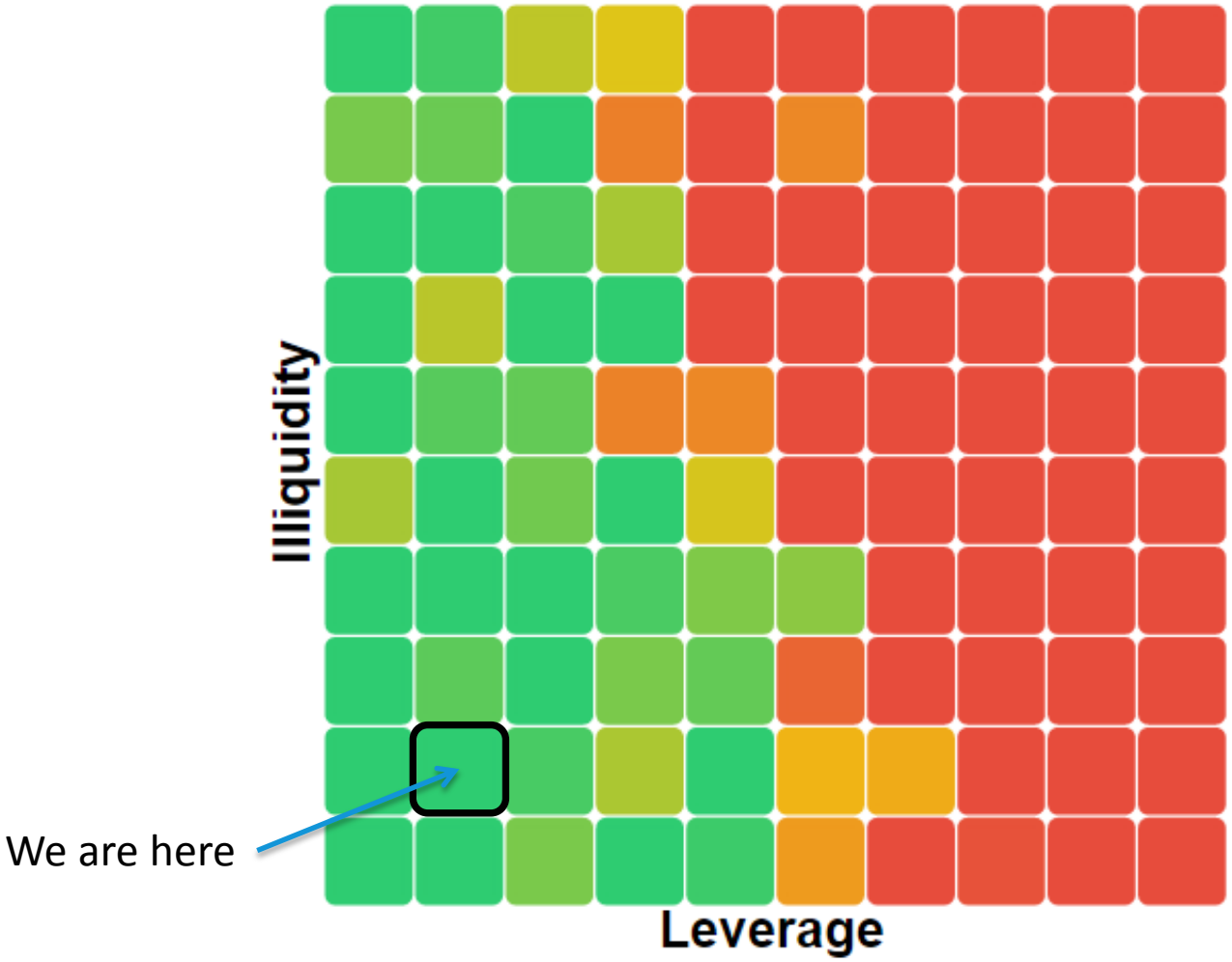
Storage

- Results stored as *static* web sites on AWS's S3 storage solution

Operation

- Begin with Var/Covar of Risk 1.0
- Calibrate the Risk 3.0 model using a genetic algorithm
- Specify leverage / liquidity characteristics to generate a heat map
- Take any Risk 2.0 set of shocks and regenerate our heat map.

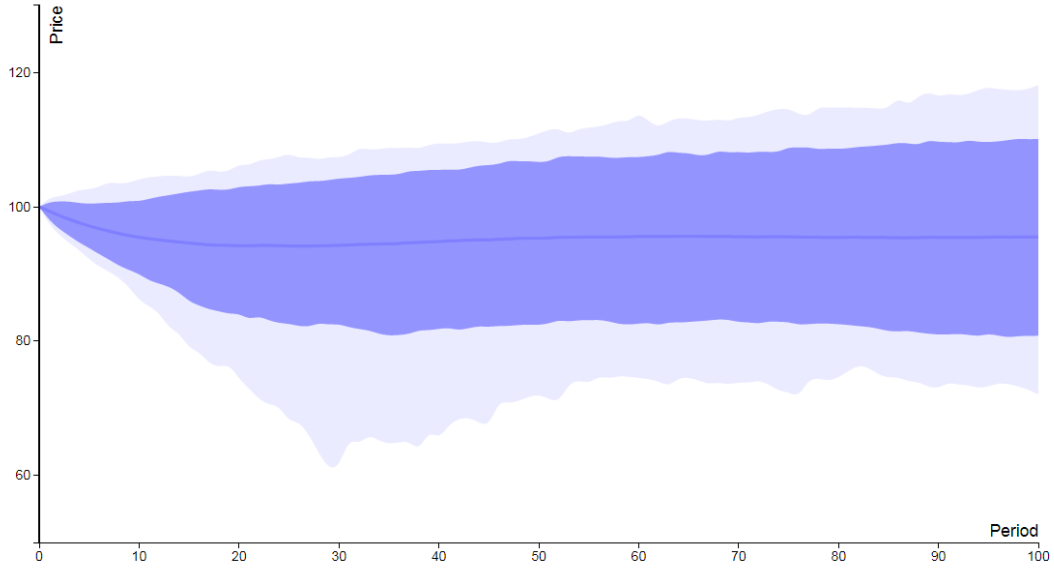
Heat Map for Usual Case



Risk within the Heat Map for Usual Case

Each square shows distribution of assets and thus of a portfolio over time.

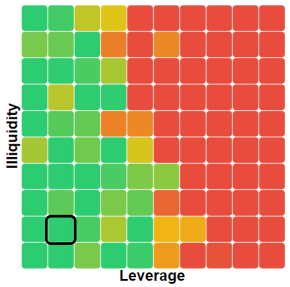
- Not symmetric.
- Movement into the tails is not smooth.
- Risk doesn't resolve at a constant rate.



Heat Map for Stress Scenario

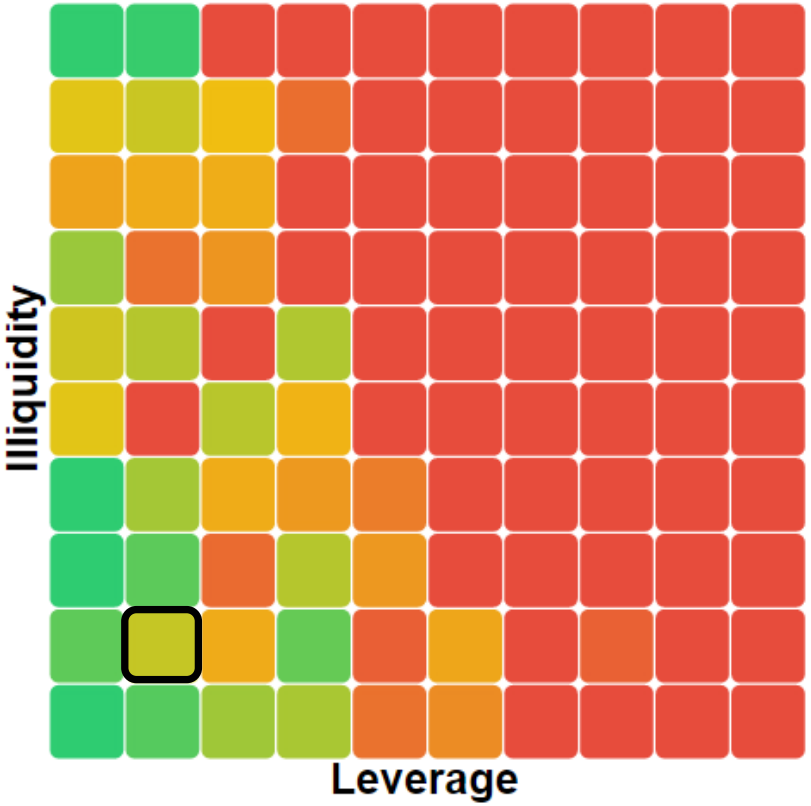
Not a totally different world.

Baseline



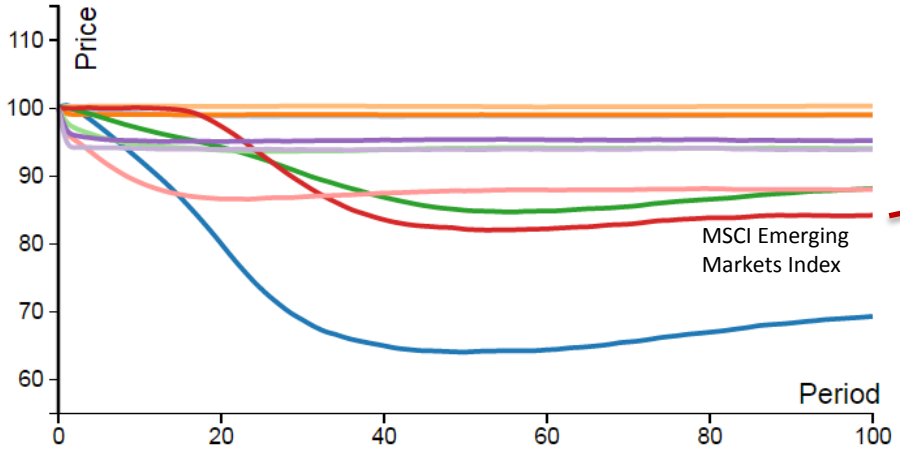
Asset Shocks

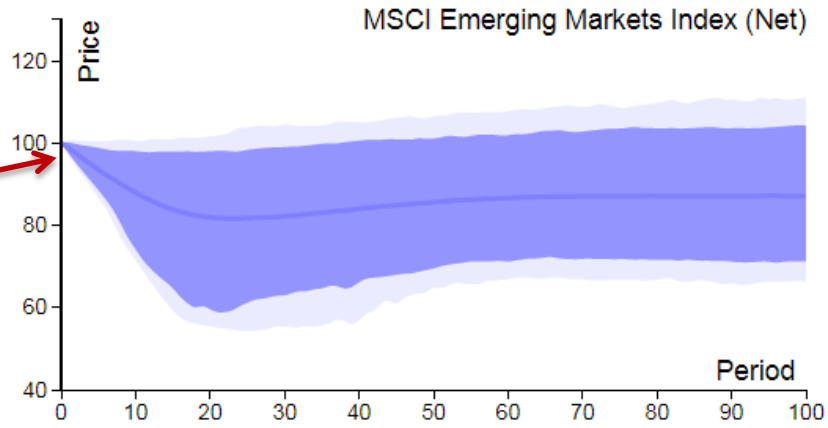
Value Reversal



Risk within the Heat Map for Stress Scenario

Cascades and contagion evident here.





Risk and the Investment Process

Develop a scenario

Crowd-source to get the data

- Leverage
- Positions
- Funding liquidity
- Market maker capacity and market impact

Integrate into the investment process

- Build a narrative
- Build an improvable, consistent structure
- Test critical assumptions and variable
- Amass data in same way as for the investment decision process