An Agent-based Model of Insurance Market
To analyze the dynamics of the insurance cycles

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The Actuarial Profession
making financial sense of the future

Purpose

Build a Multi-Agent system of general insurance market to:

- Analyze the dynamics of this market

- Explain the movements of the insurance cycles

- Examine the effects of potential changes in the market

- **Finally, to better understand the risk and uncertainty!**

(If you enjoyed the panel discussion of Gillian Tett, Michael Thompson and Alice Underwood this morning, then we hope you will enjoy this session as well.)

Literature Review

- Insurance cycles is a phenomenon that has been recognized since 1920s, it has a pattern but unpredictable nature.

- Existing explanations: entry and exit, irrational forecasting errors, time delays and reporting lags, cash flow underwriting cycles, and capital constraints, etc.

- BUT cycles emerge from a combination of different factors and endless interactions of players in a dynamic process.

- Agent-based models are designed to analyze these bottom-up interactions and better understand this complex system.

Overview of our ABM insurance market

System: Insurance market with its unique features

- **Insurance:** horizontal product differentiation
- **Contract:** price now but exchange goods in the future
- **Competition:** business strategy and information process

Agents: Underwriters and insurance companies

- **Behavior:** obey simple realistic rules
- **Objective:** earn profits and balance risk/return
- **Interaction:** competition with direct competitors

Targets: Customers with risk and uncertainty

A Simplified Example: System

- A closed Motor Insurance market

- Two rating factors (age of driver and cost of car)

- Customers are grouped by the rating factors

- Their risks are defined by the size of the bubbles

- Their uncertainties are defined by the number of exposures in each group
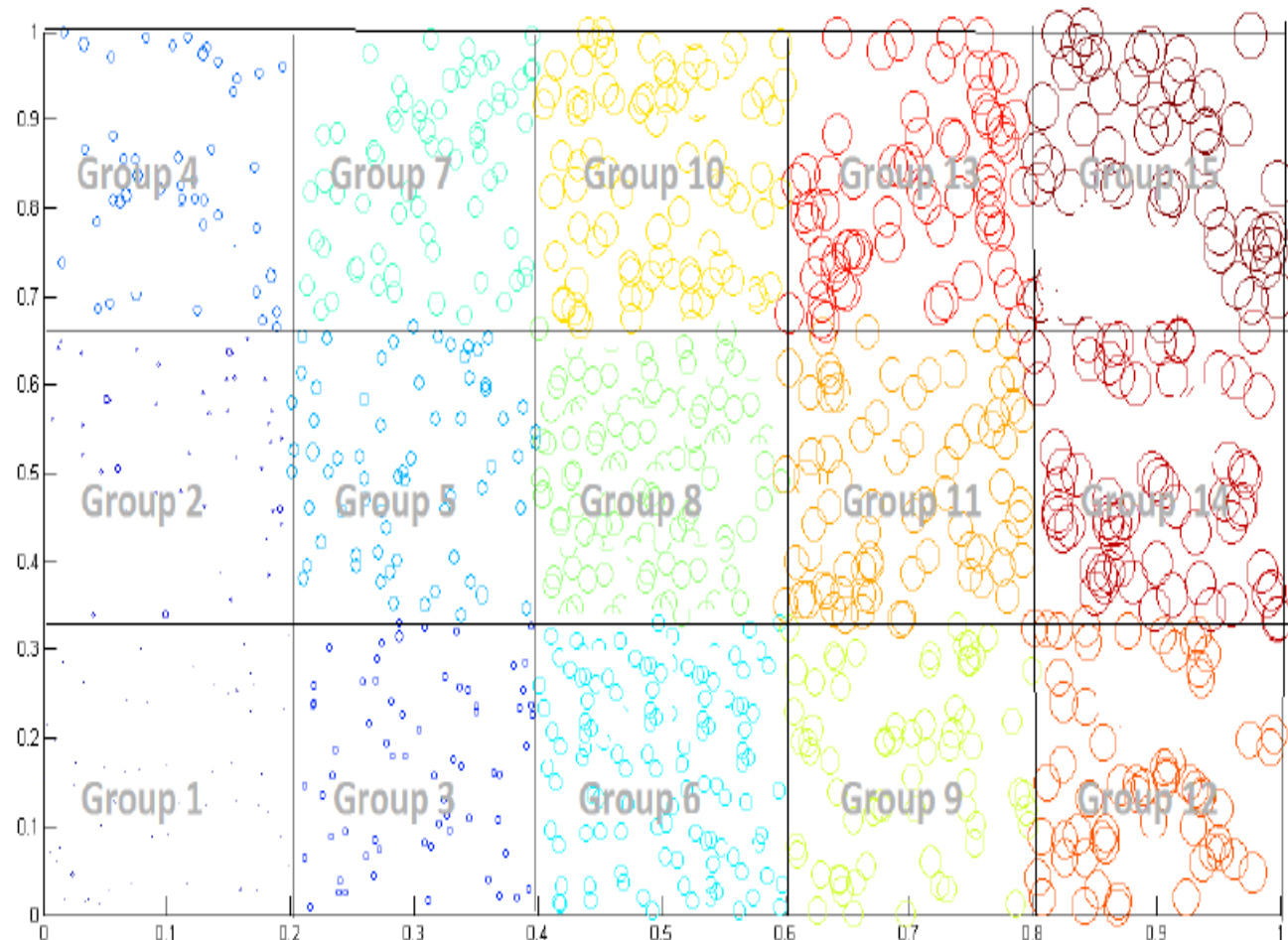
A Simplified Example: Agents and Customers

- A few individual insurers as agents (see: squares)

- Customers are defined by their rating factors (see: bubbles)

- Insurers change their business strategies by moving their positions

- Each insurer offer one price to each customer, which depends on several elements

- Customers take the lowest price with some stickiness
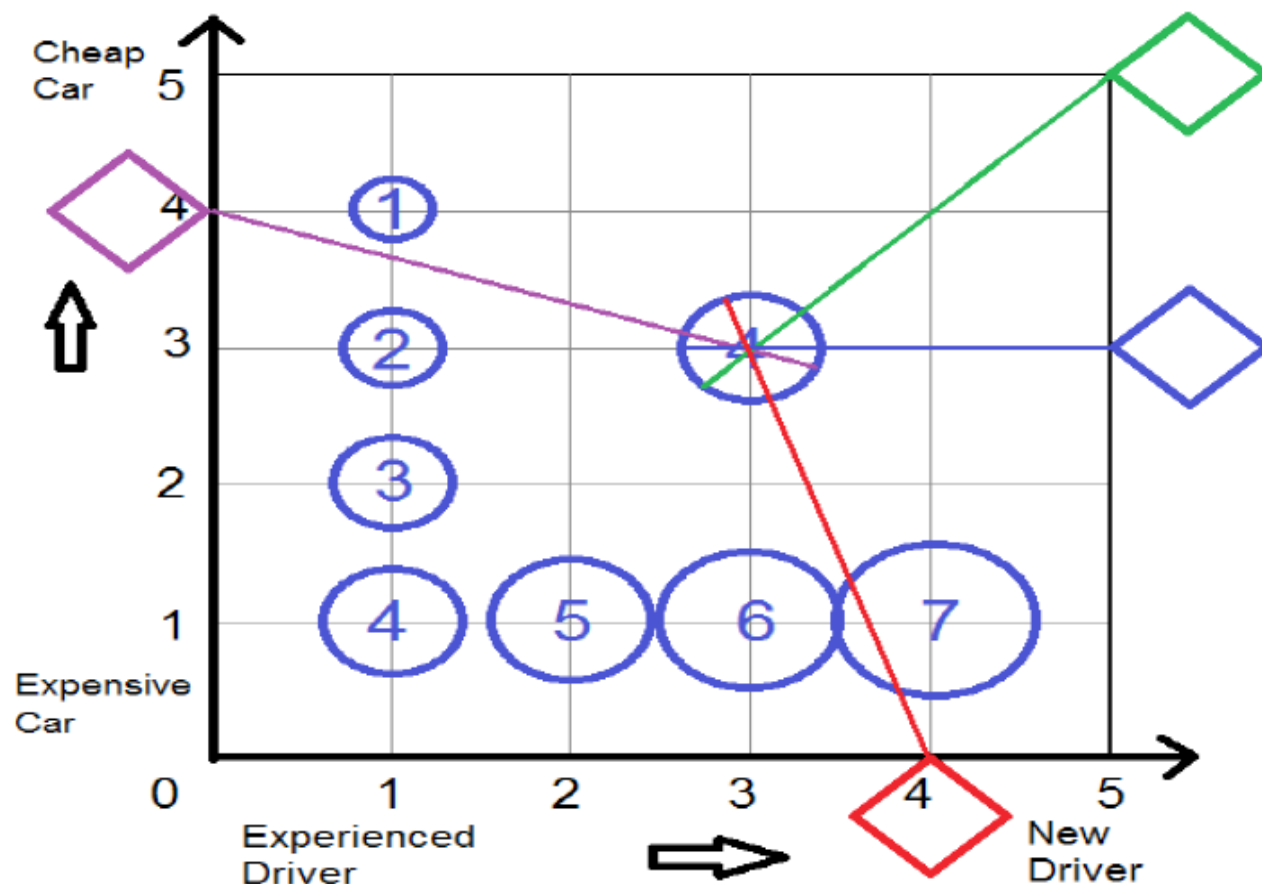
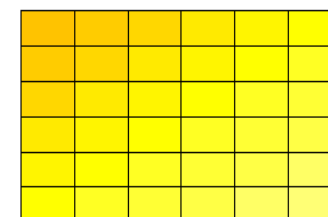# A Simplified Example: Price and Capital
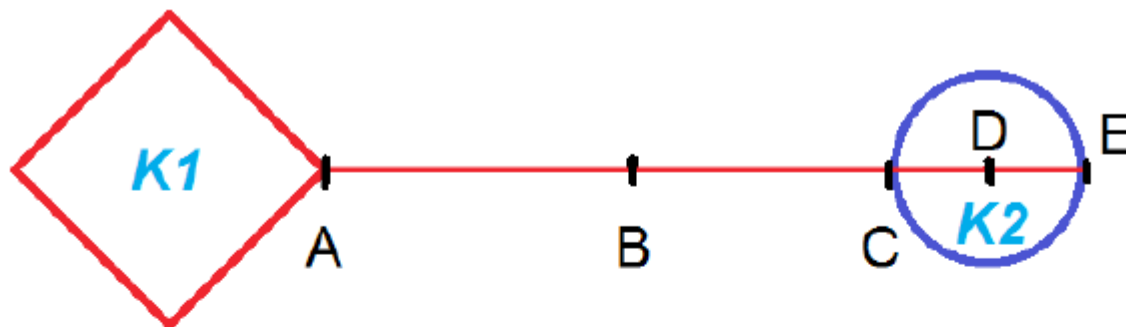
- Insurer **RED** has a total capital *K1* (area), offers a price **AE** to a customer **BLUE**

- The business with **BLUE** requires a minimum capital of *K2* (area, depend on radius **DE**)

- Radius **DE** is the insurer's expected average future claim of this customer (a number)

- **CD** is a profit loading (a ratio), that is **1-to-1** match to **DE** (higher claim, higher profit)

- **AB** measures the information set about this customer (uncertainty)

- **BC** defines the comparative advantage of this insurer's business strategy

- Therefore: Price **AE** = function (**AB, BC, CD, DE**)
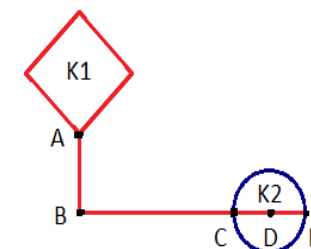
A Simplified Example: Complete View

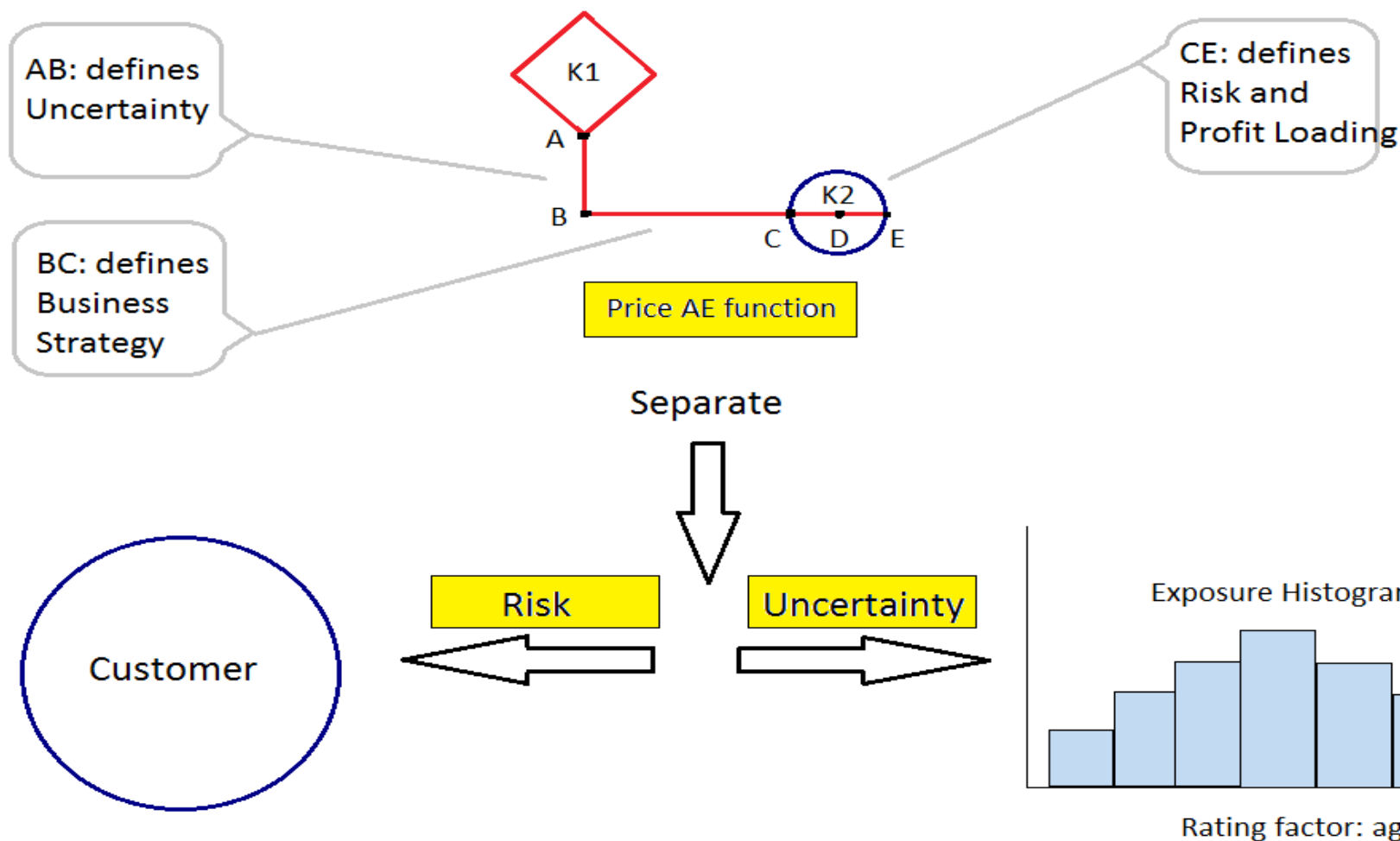3D View: Customer Exposure Histogram and Uncertainty Intensity Map

Exposure Histogram
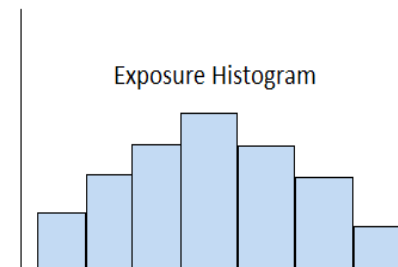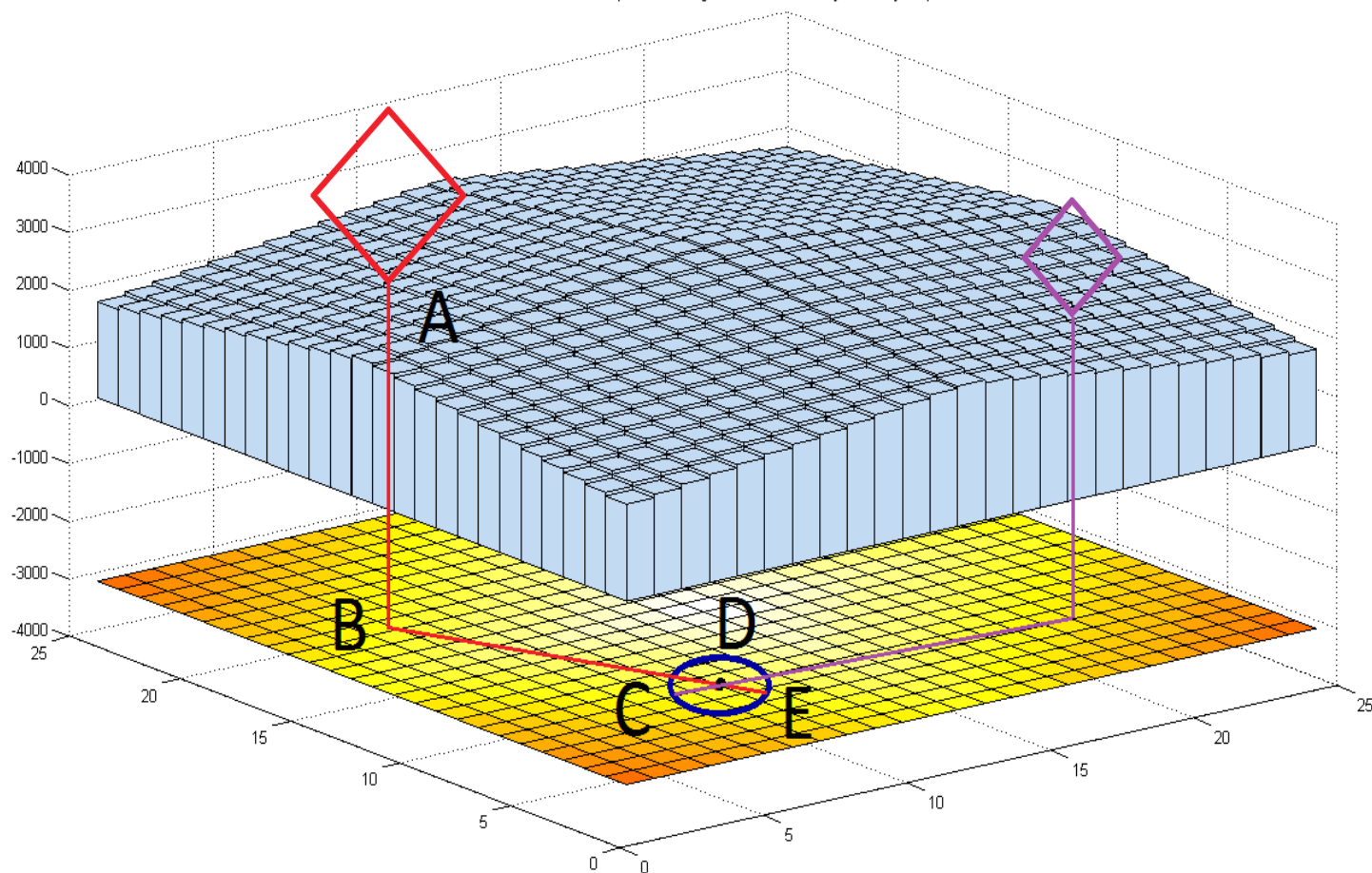
Rating factor: age

2D Customer space

Price AE function

A Simplified Example: Risk and Uncertainty

AB: defines Uncertainty

BC: defines Business Strategy

CE: defines Risk and Profit Loading

K1

A

B

K2

C D E

Price AE function

Separate

Risk

Uncertainty

Customer

Exposure Histogram

Rating factor: age

A Simplified Example: Agents Behavioral Rules (I)

Rule #1: Strategic Movements => (1) Compare profits with neighbours (similar strategy)
(2) Move to the next target group with more profits
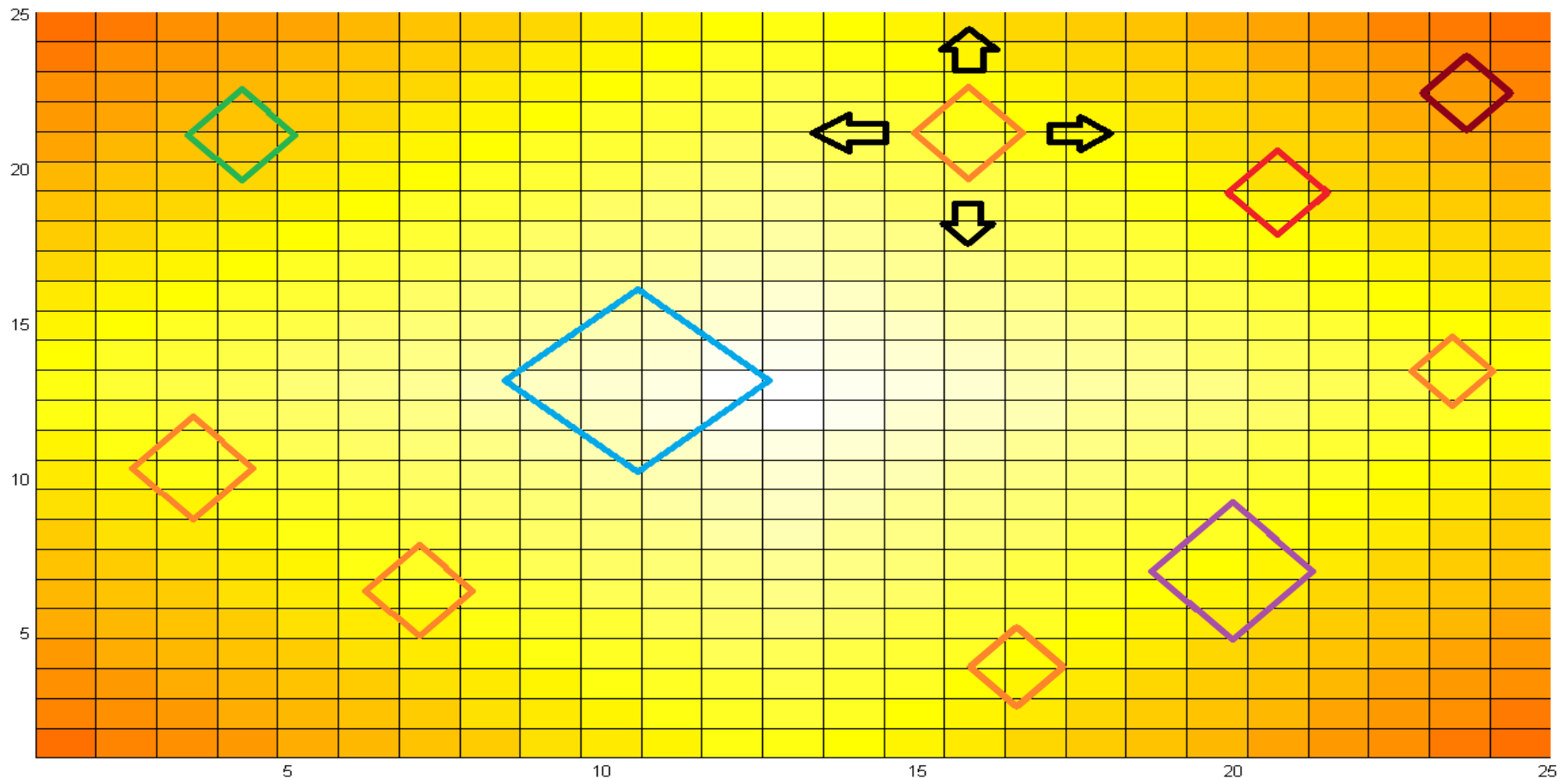
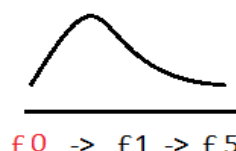# A Simplified Example: Agents Behavioral Rules (II)

Rule #2: Competitive Pressures => (1) Closer with other insurers, more competitions
(2) Pressure to adjust price under uncertainty

Extreme Case 1: Certain

= £ 1 with 100%

Extreme Case 2: Random

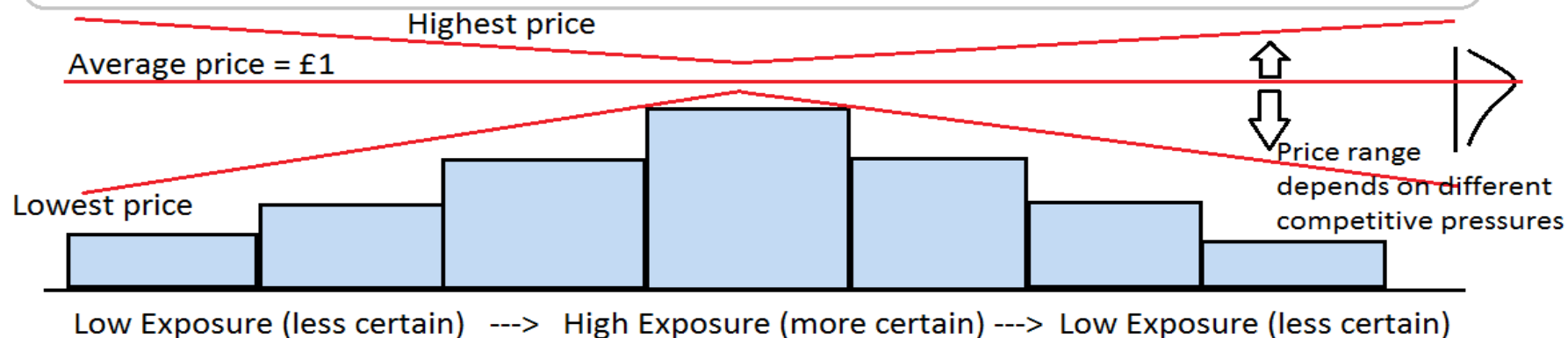£ 0 -> £ 1 -> £ 5

Extreme Case 3: Very Uncertain

= £2 with 50%

= £0 with 50%

For the above 3 cases with different uncertainty levels, how much will you price a contract under competitive pressures?
=> Case 1: whatever competitive pressures, I always price £1. If I increase price, other competitors will get the customer
=> Case 2: I will price the contract anywhere between two thresholds, depends on the current competitive pressures
=> Case 3: I have two choices: whether to price at a higher level, or give up this customer under a higher competitive pressure

Highest price

Average price = £1

Lowest price

Price range depends on different competitive pressures

Low Exposure (less certain) ---> High Exposure (more certain) ---> Low Exposure (less certain)

A Simplified Example: Simulation Results

Despite its simplicity:

- The agents are replicating the realistically basic rules;

- It produces a market with a similar structure of real world;

- It shows that the larger insurers are able to take more risky customers and compete general business, but smaller insurers also can focus on their specialized areas;

- Niche business emerge, because of insurers' comparative advantages;

- **Those unique features of general insurance market create systemic movements, cycles emerge!**

A Simplified Example: Market Dynamics

Initial Market Structure
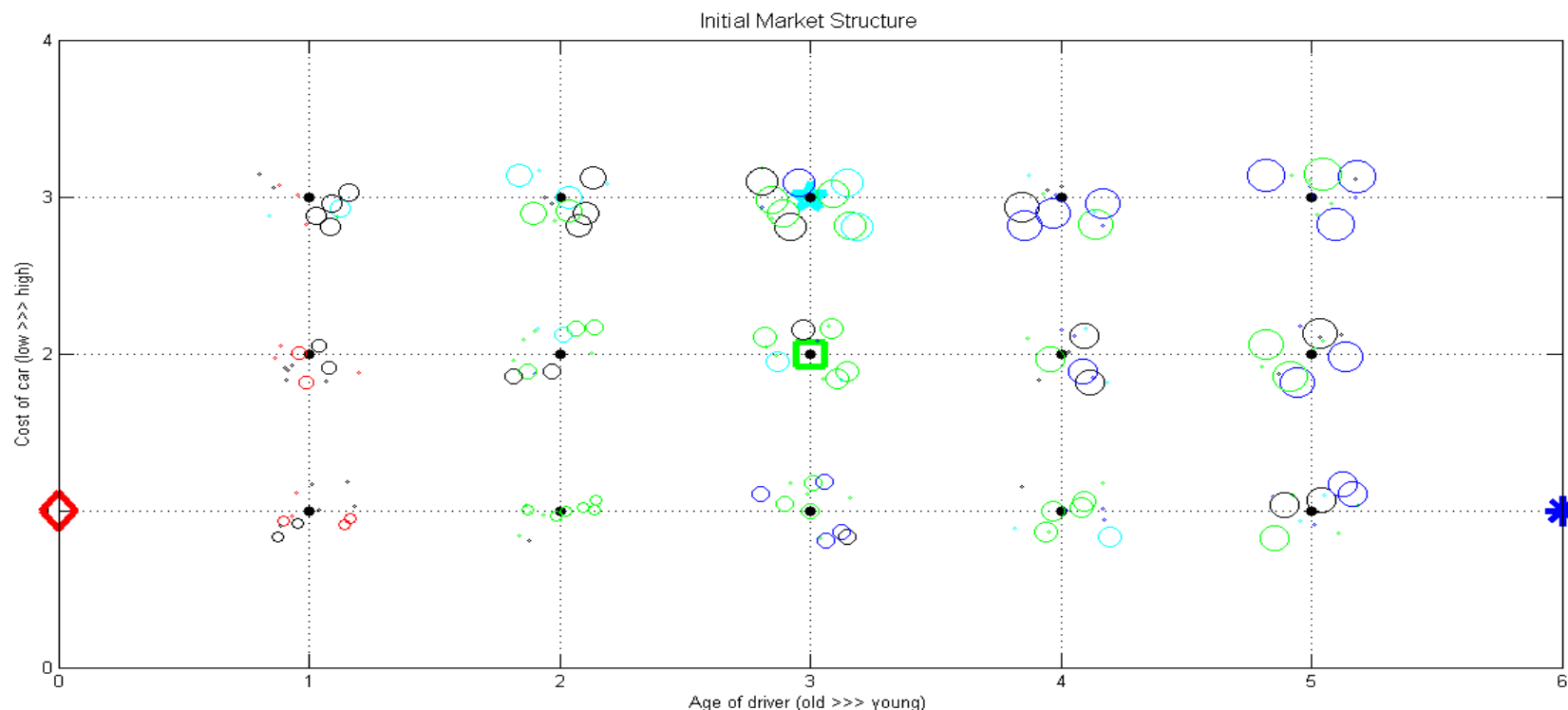
Market dynamic process:

Step1: Insurers offer different prices to different risk groups (pricing function)

Step2: Customers select the lowest prices (or allocate shares equally if same prices)

Step3: Those selected customers are colored as same as the insurer

Step4: Insurers update risk estimation based on selection and move their strategies
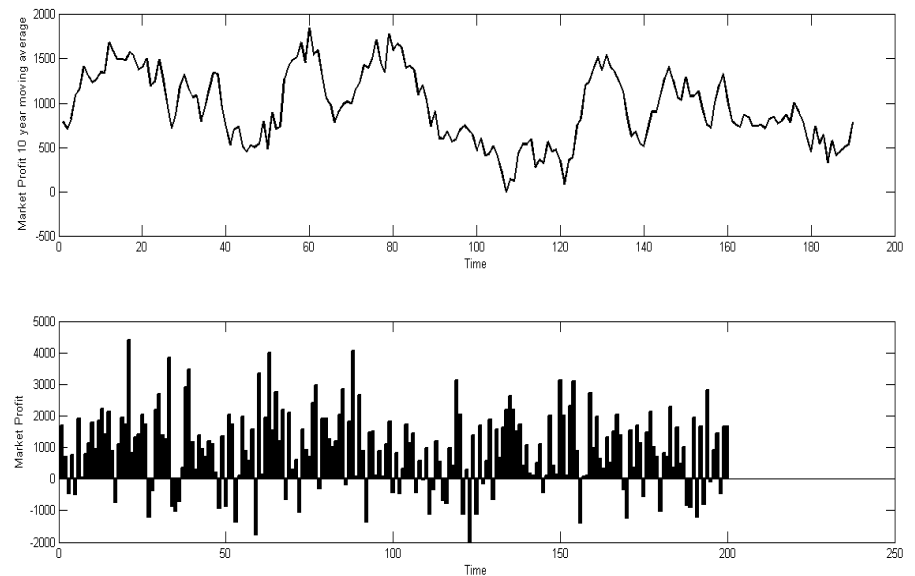
A Simplified Example: Basic Elements
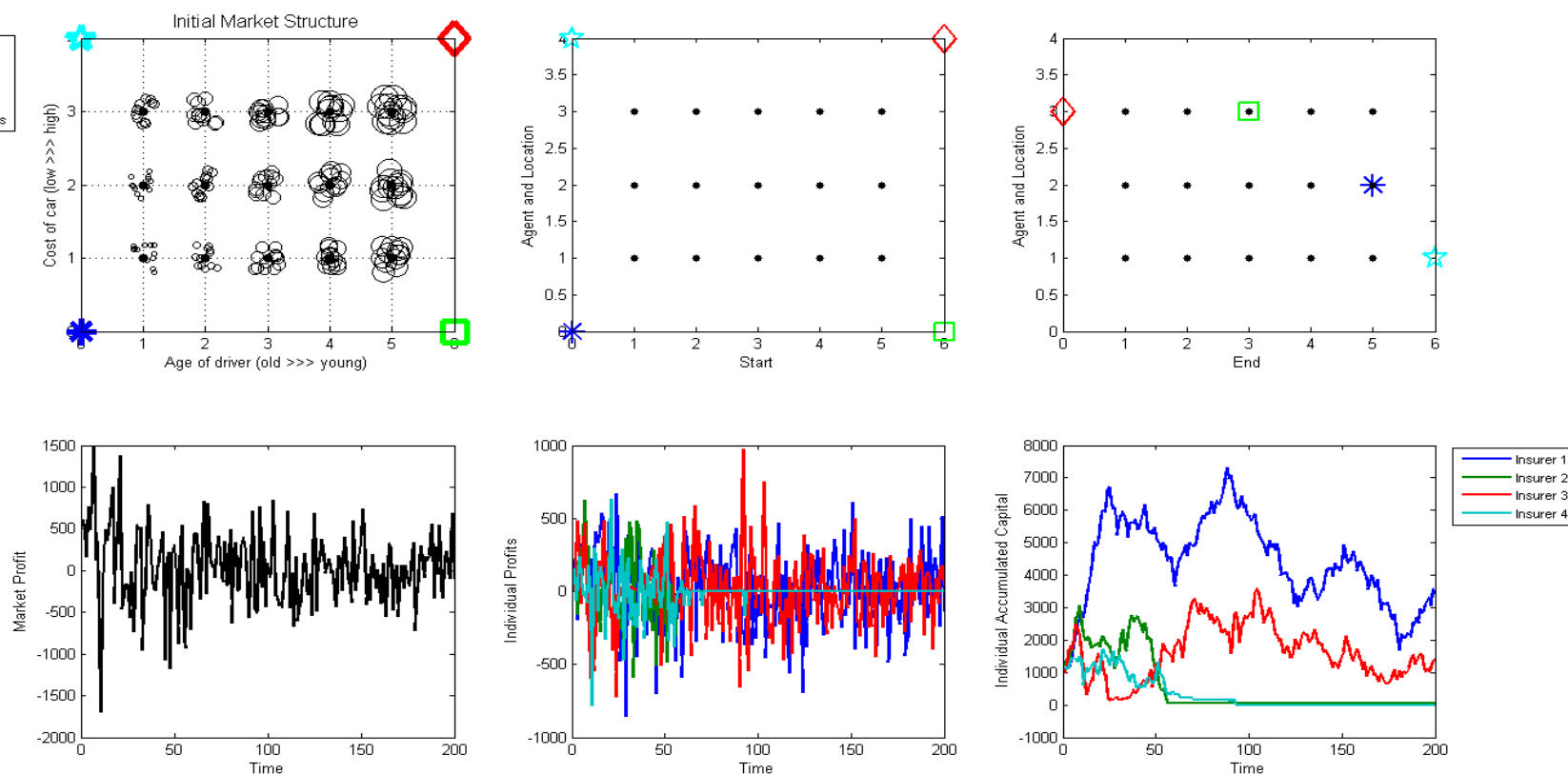
- Market and individual profits are volatile, due to a small sample size
- Insurers exposed to the large-claim customer group are more likely to become insolvent
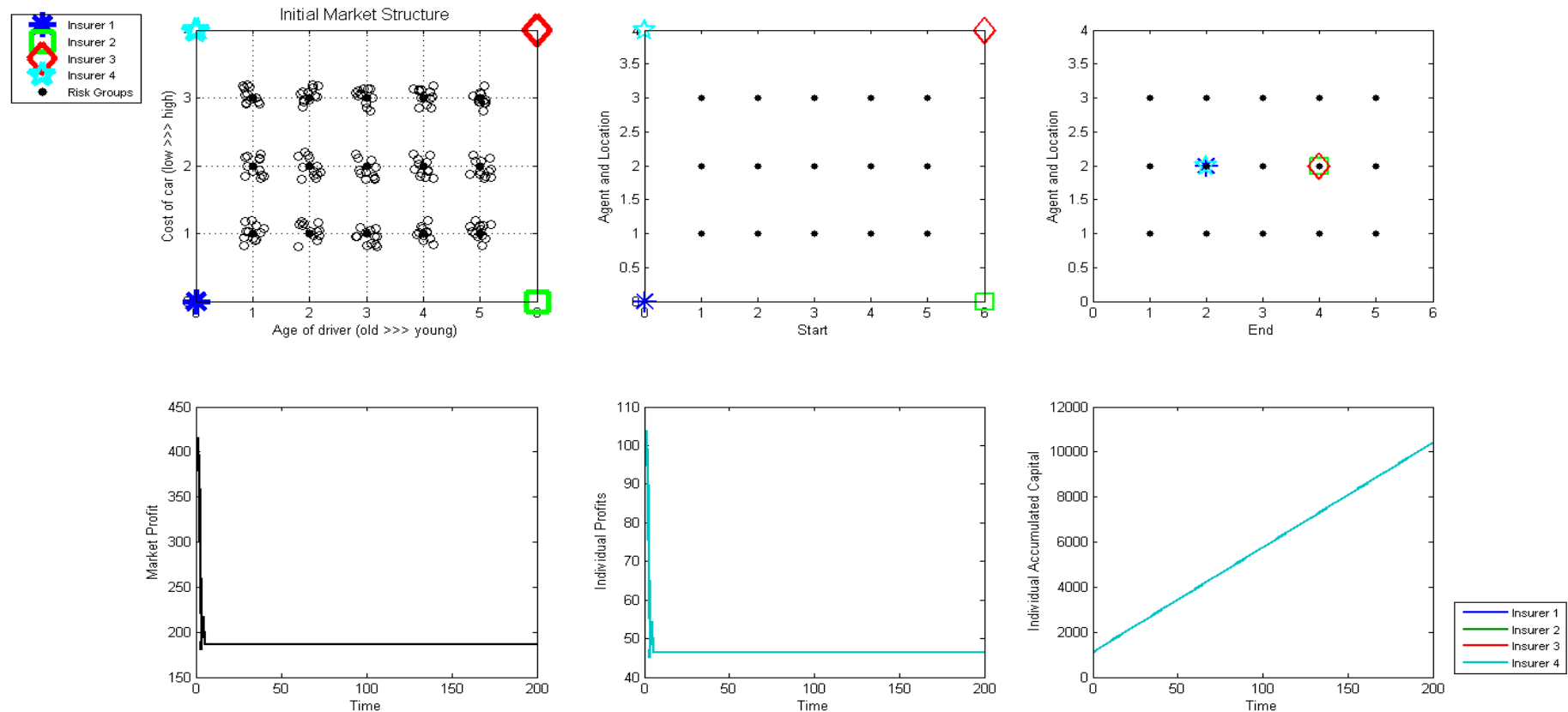
A Simplified Example: Profits and Price Cycles
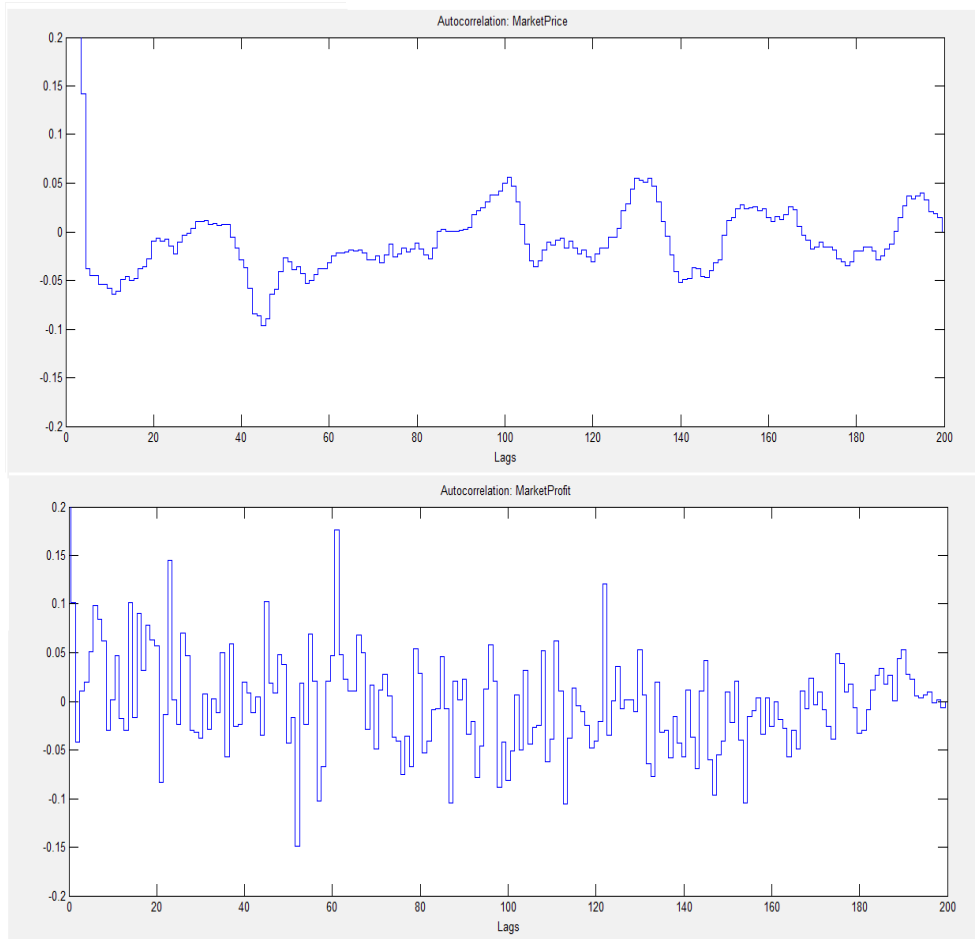
> As market stabilises, average price exhibits cycle.
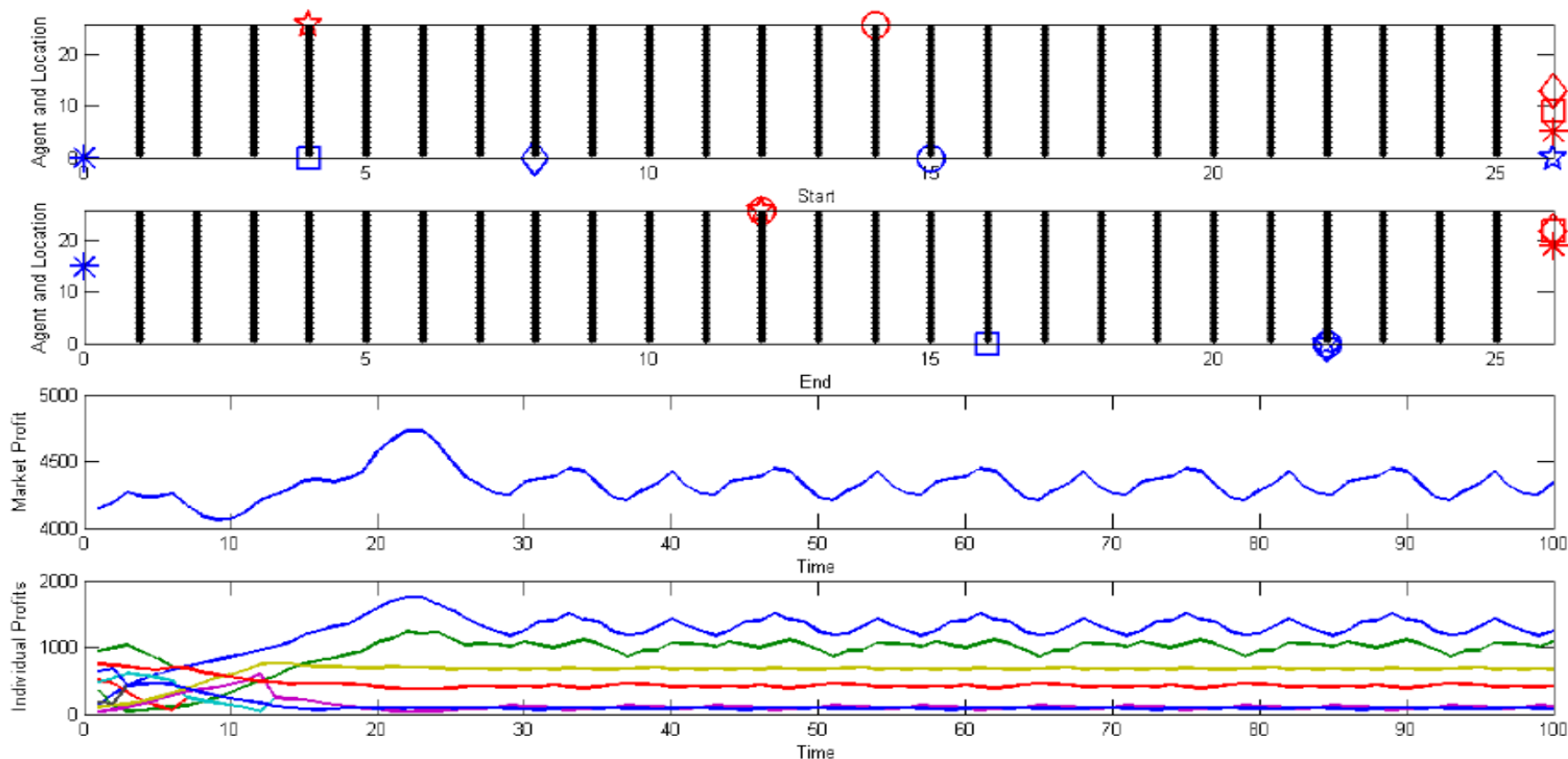> Average market profit is effected by random claims.

Remove uncertainty in the market, insurers reach the equilibrium.

Increase the number of insurers in a larger system, these diagrams show some insurers may form groups. Their behaviors as large groups casue market movements.
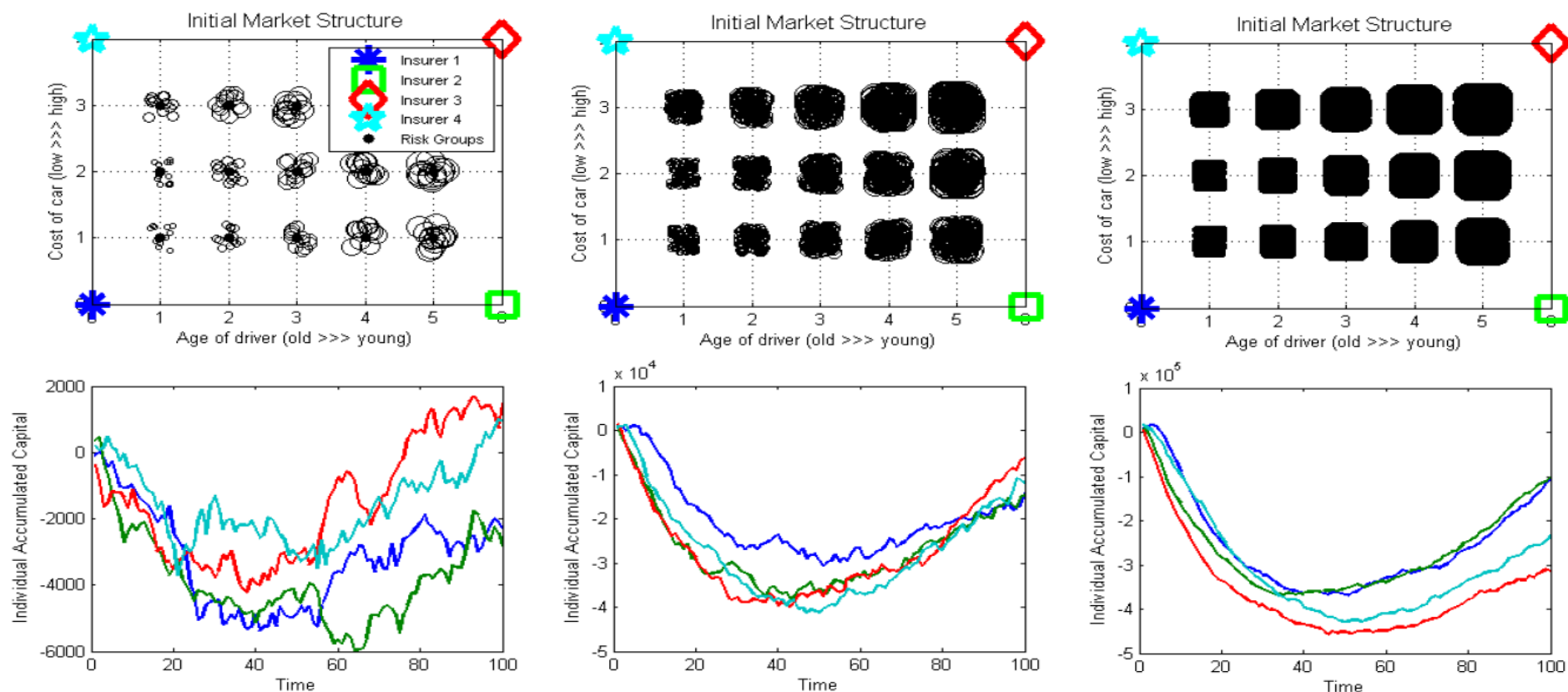
If we increase the number of customers in each risk group, this will smooth the results.

The number of customers: 12 -> 120 -> 1200 in each risk group.

Cycle Explanation: An ABM Approach

Key elements (factors) that create cycles in our model:

- **Local interactions:**

    - insurers only compete with "neighbors" (herding behaviors);

- **Competitive uncertainty:**

    - competitive pressures force insurers to increase uncertainty;

- **Strategic resistance:**

    - both time lag and opportunity cost delay insurer's action;

- **Entry and exit:**

    - capital out/in flows promote the cyclical market movements.

(Competitive uncertainty and strategic resistance are particularly relevant to insurance market!)

# Cycle Explanation: Seesaw Movements
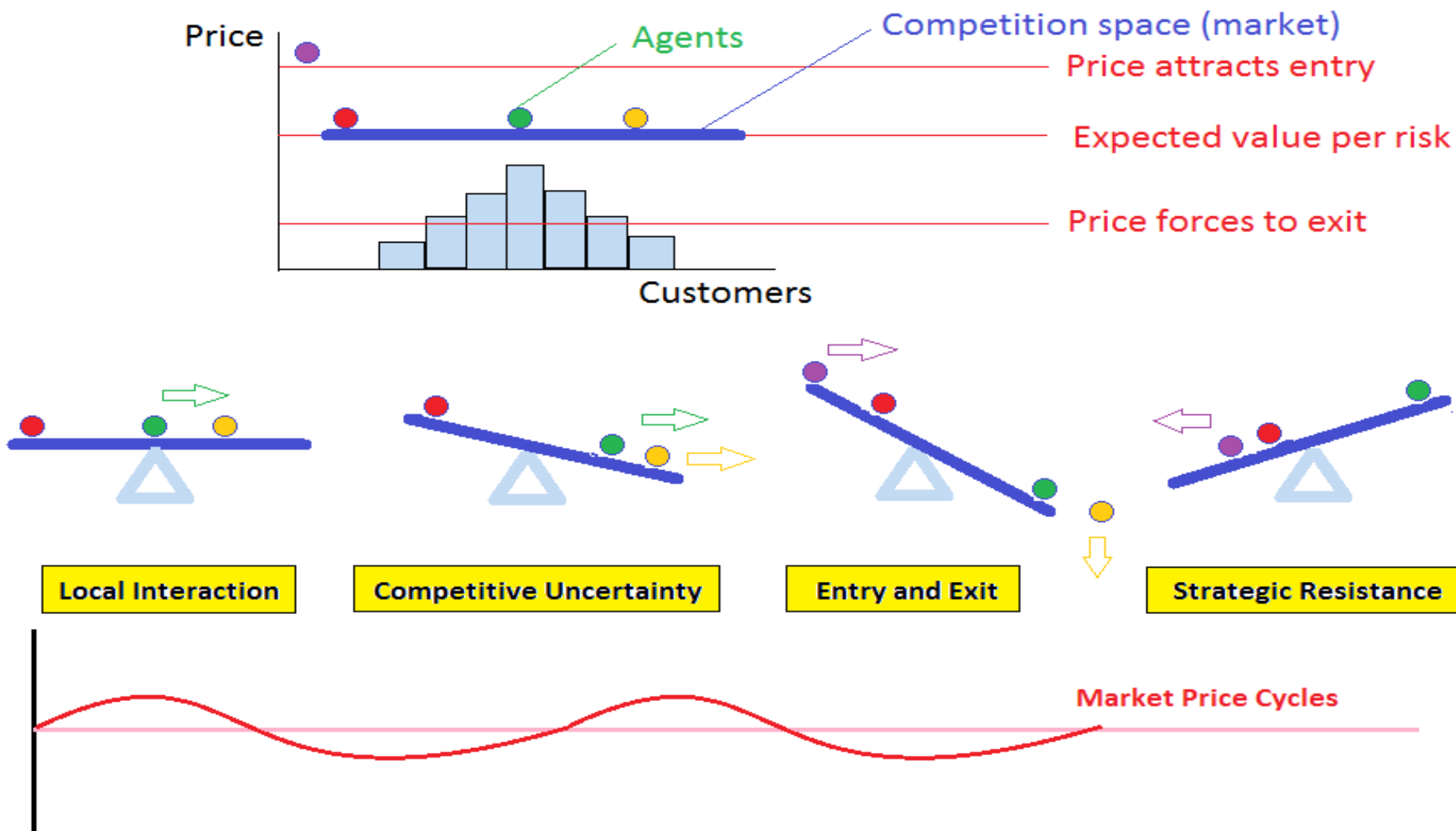
Conclusion: Applications and Risk Managements

We can test parameters and scenarios (real world examples):

- **The different ways of agents' interactions:**

  - M&A activities, the role of market association (ABI), etc.

- **Different histogram of customer distributions:**

  - Different sectors, such as from Motor Property to Liability Insurance

- **The speed of changing business strategy:**

  - Development of latest IT system, comparison websites, etc.

- **The barriers to entry and exit (capital market):**

  - Recent innovations of ILS, and regulatory requirements, etc.

Questions or comments?
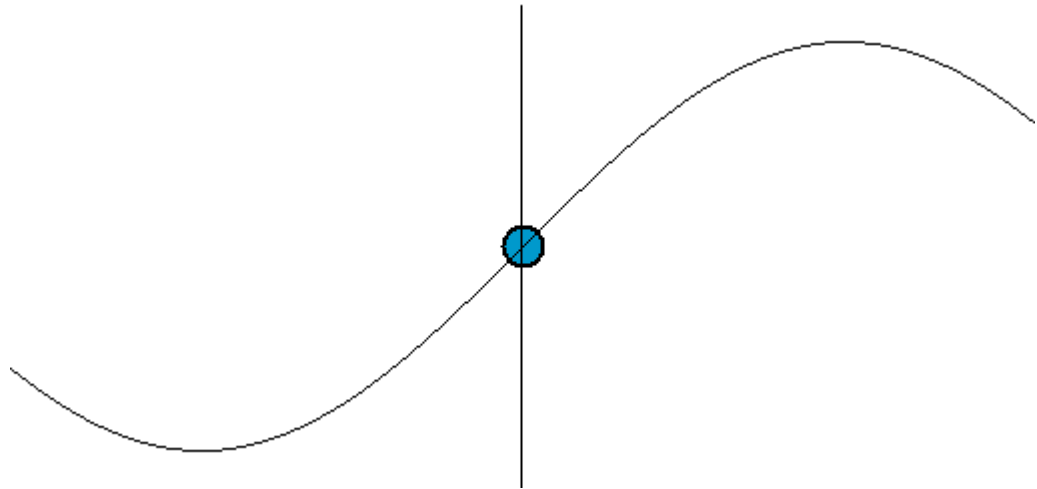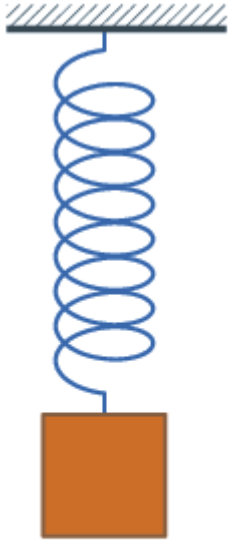
Cycles are created by the interactions of forces...

and **forces are effected by individual agents!**

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