The Actuarial Profession
making financial sense of the future

GIRO conference and exhibition 2011

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Understanding Insurance Cycles

An agent-based modelling approach

Workshop session B13: Wed 12 Oct 2011 14.45-15.45

Introduction: Purpose of research

- Insurance cycle is a phenomenon that been recognised since 1920s, it has a pattern but unpredictable nature.
- Daykin et al. (1994) argue that cycles are hard to be analysed by any individual explanation alone. It is a dynamic phenomenon that involves many interactions among different agents and contributing factors.
- Agent-based Modelling (ABM) tries to simulate the dynamic interactions of agents in a complex system. It provides a method to better understand the complexity of real world.
- We apply some basic real-world behaviour rules of insurers in the market. Despite its simplicity, the model produces many stylised facts of the market: we will focus on cycles.

Introduction: Existing Explanations of Cycles

Major existing explanations of insurance cycles:

- Market competitions cause structure fluctuations;
- Irrational forecasting errors cause pricing cycles;
- Time delays and reporting lags cause accounting cycles;
- Interest rate movements cause "cashflow underwriting" cycles;
- Cycles in line with "Mass psychology" of the underwriters;
- Other contributing factors: capital constraints, reserving errors, price regulations and insolvency risks, etc.

Reference: *Feldblum, 2001; Venezian, 1985; Cummins and Outreville, 1987; Balzer and Benjamin, 1980; Berger, 1988; Doherty and Garven, 1995; Gron, 1990; Fitzpatrick, 2004; Ligon and Thistle, 2007.*

Introduction: Agent-based Simulation Models

ABM models complex systems from the bottom-up:

- Actions and interactions of heterogeneous agents through time
- Agents are continually adopting new strategies and be adaptive
- Bounded rationality, with capacity to gather/process information
- Agents as local players, interacting within closed "neighbours"
- Feedback loops and externalities between agents and system
- Modeler only decides agents' initial resources, rules, objectives

Recent contributions: Arifovic (*JPE*, 1996); Arthur (*AER*, 1991); Banal-Estaol and Ruperez-Micola (*Management Science*, 2009); LeBaron et al (*JoF*, 1992); Kirman (*QJE*, 1993); Hart (*Econometrica*, 2005); Noe et al (*JoF*, 2003 and 2006).

Our ABM Model: Potential Benefits

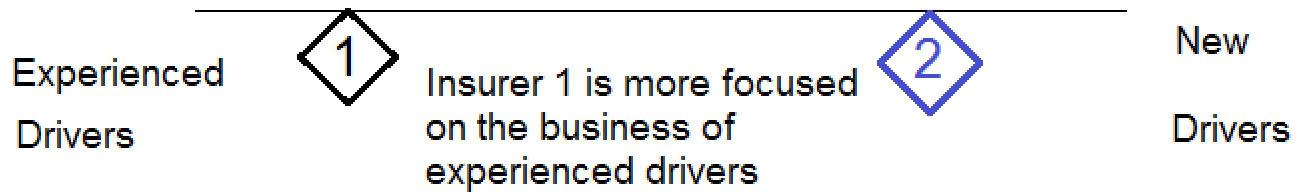
- A cheap way to experiment different scenarios of contributing cycle factors, and test relations
- Studies dynamic interactions of micro-behaviours (the insurers) and macro-dynamics (the market)
- Useful complement to traditional top-down approach of market price analysis
- Beyond explanation and prediction: guide data collection, discover new questions, demonstrate real world tradeoffs, understand complexity, train staffs, etc.

Our Model: ABM application to Insurance Market

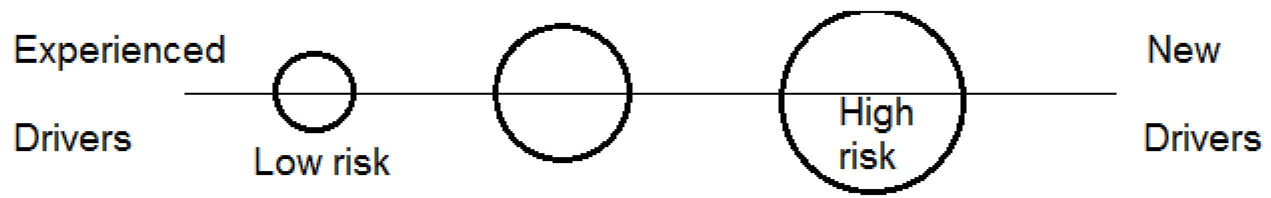
- System: Insurance market with its unique features
  - Insurance: horizontal product differentiation (Location models)
  - Contract: price now but exchange goods future (Cobweb models)
  - Competition: on business strategies and information process
- Agents: Underwriters and/or insurance companies
  - Behaviour: obey simple rules to be adaptive in complex systems
  - Objective: earn more profits and balance risk to return
  - Interaction: competition with “neighbours” through prices
- Targets: Customers and/or future claims
  - Customers decision rules: cheapest price and past experience
  - Future claims: model several specific cases (claim distributions)

Our Model: An example of simplified real world

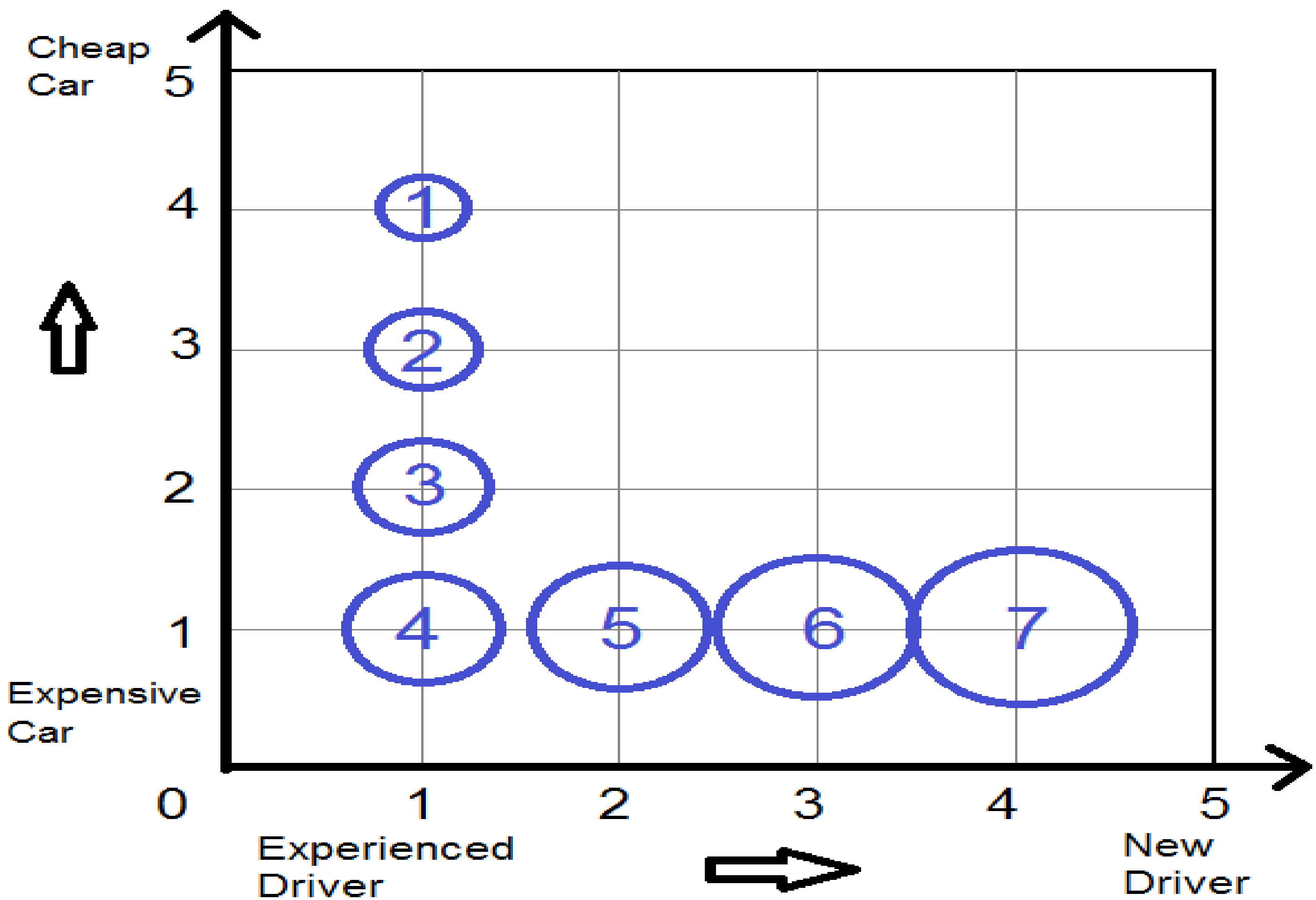
- A closed Motor Insurance sector
- Two rating factors (age of driver and cost of car)
- A few individual (or group) insurance companies



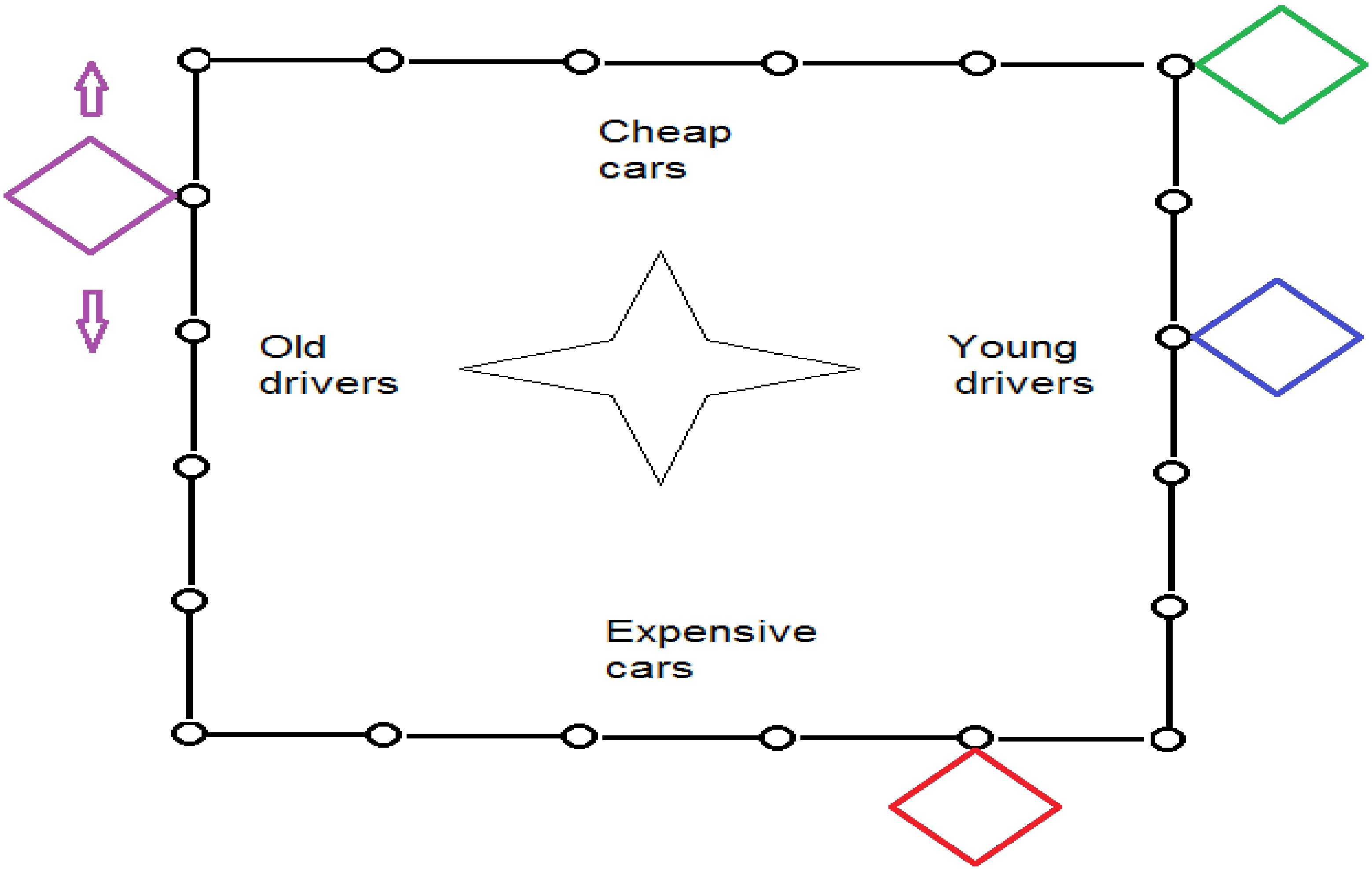
- Many customers with different risks (depend on expected future claim, past data or experience, etc.)



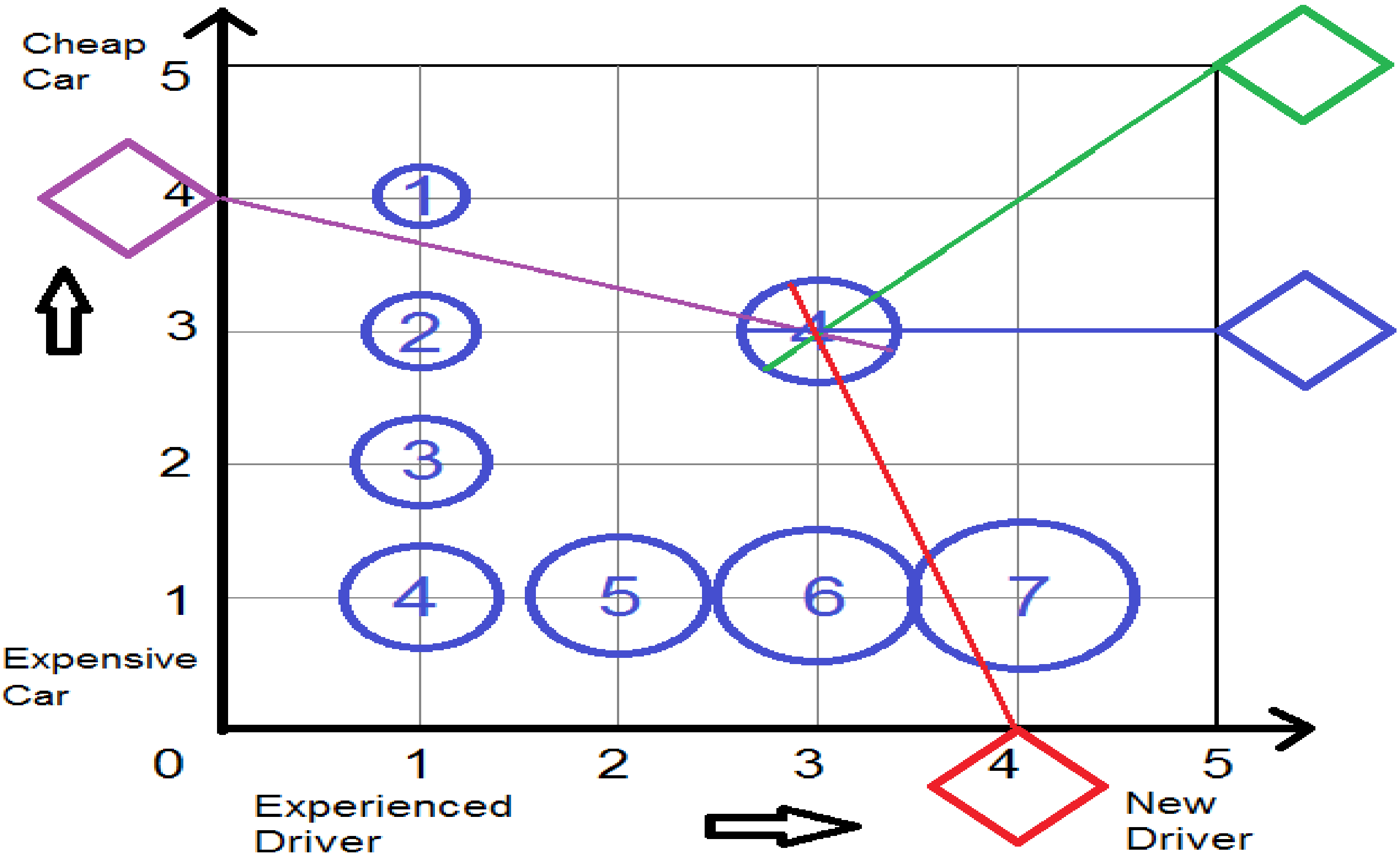
Our Model: An example of customers



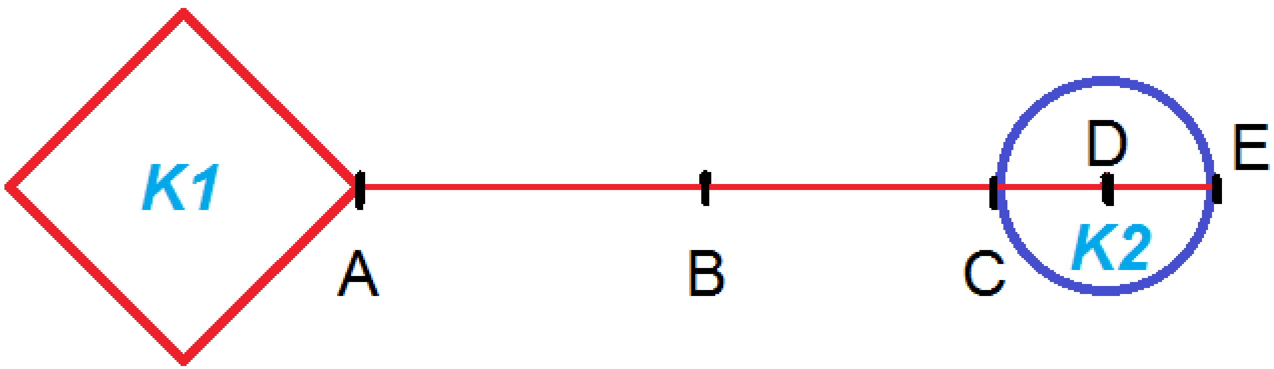
Our Model: An example of insurers



Our Model: An example of the system



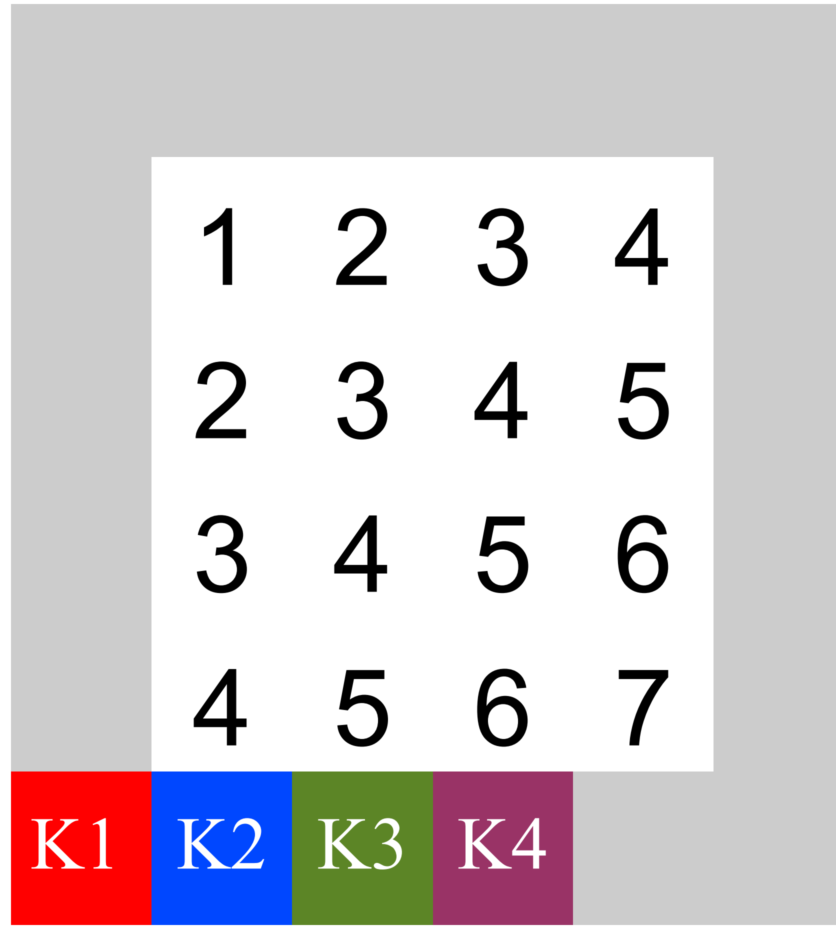
Our Model: Price, profit, capacity



- The above snapshot is from the early system, it shows:
  - 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)
  - **BC** measures the information set about this customer (longer BC, more uncertainty)
  - **AB** measures the market competition level (longer AB, less competition)
  - Therefore: Price **AE** = function (**AB, BC, CD, DE**)

Model element (1): Market Structure

- Demand Side (white space)
  - Customers' risk classification
  - Define expected average claim
  - Define required capacity
  - Define profitability (risk vs return)
- Supply Side (gray space)
  - Insurers as agents move in space
  - Define existing capacity K
  - Define business strategy
  - Define “neighbourhoods”



Our Model: Basic Rules of Agents (insurers)

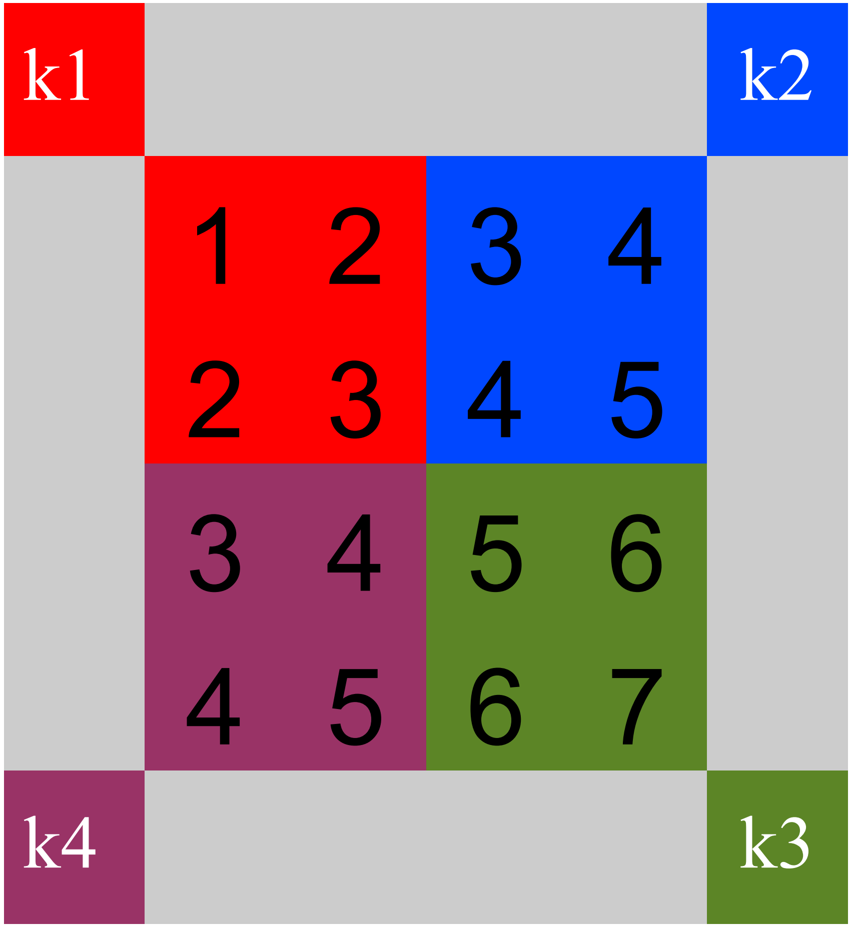
The beauty of ABM, it is based on simple rules from real world.

- Rule 1: Insurers offer different prices, customers select lowest
- Rule 2: Select the more profitable customers first (involve risk)
- Rule 3: If same profitability, then select the one with lower risk
- Rule 4: If capacity is full, it stops further potential customers
- Rule 5: If capacity is not full, increase competitions to neighbours
- Rule 6: If potential profit from neighbours, increase competitions
- Rule 7: If no potential profit/competition, refine existing business

Model element (2): Interactions of Agents

Rule 1: Insurers offer different prices, and customers select the lowest ones

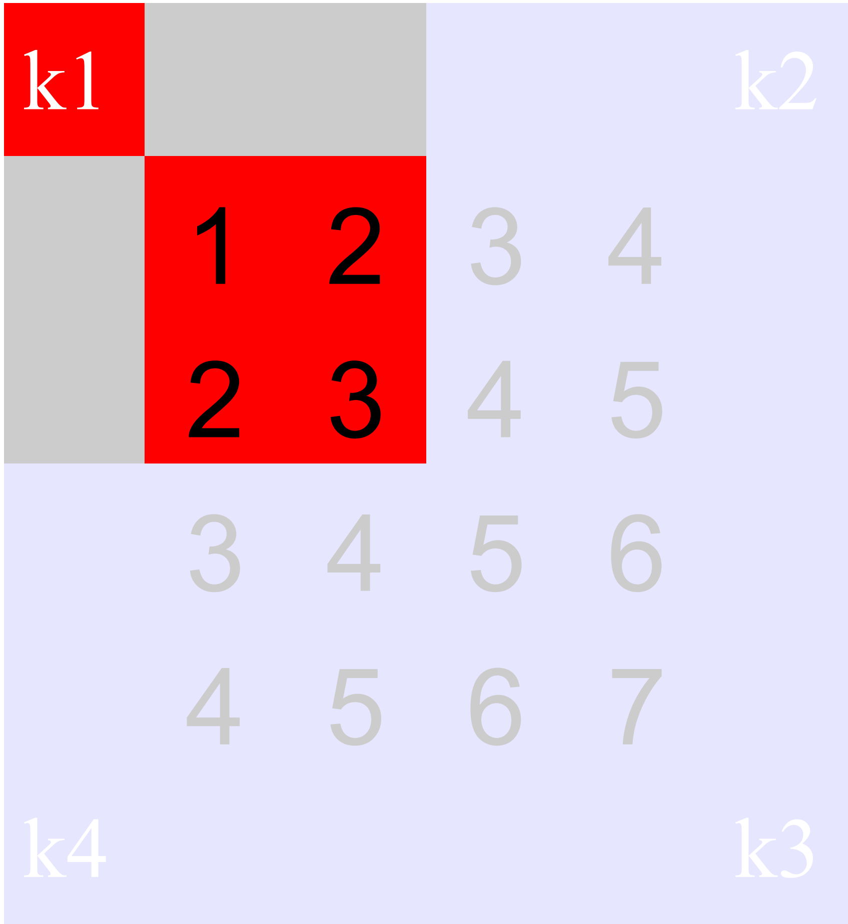
- As example
  - Four insurers offer different prices
  - Prices depend on customers' risks
  - AND depend on business focuses
  - Customers will select the lowest prices
  - On the diagram, the prices are measured by the distance from insurers to each customer, and customers' decisions are reflected in different color.



Model element (2): Interactions of Agents

Rule 2: Insurers select the more profitable customers first (involve risk)

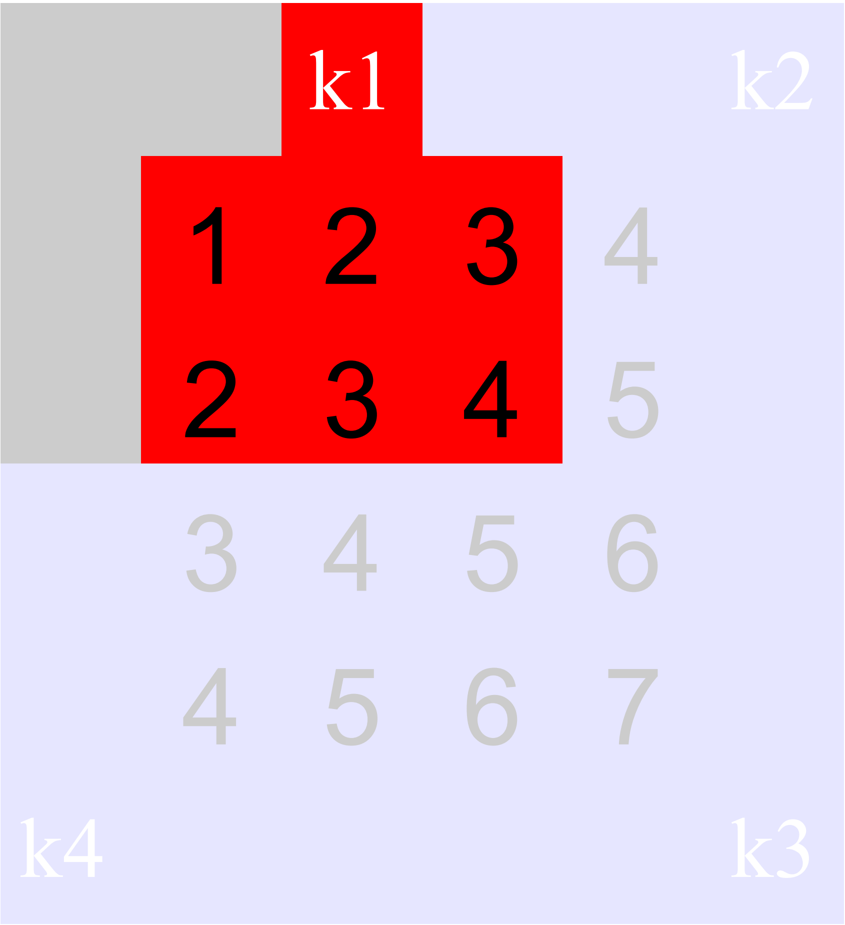
- As example
  - If RED insurer faces capacity constraint
  - It only selects a limited # of customers
  - It will select most profitable one first
  - Ranking selection
    - Customer 3 is better than others
    - Customers 2 are indifferent
    - Customer 1 is the last choice



Model element (2): Interactions of Agents

Rule 3: If same profitability, then select the one with lower risk

- As example
  - If RED insurer faces capacity constraint
  - If it moves to another location
  - There are six potential customers
  - Same profitability customers
    - Customer 3 (right) vs. Customer 1
    - It selects 1 instead of 3
    - Customer 2 (left) vs Customer 4
    - It selects 2 instead of 4



Model element (2): Interactions of Agents

Rule 4: If capacity is full, it stops further potential customers

- As example

◆If RED insurer faces capacity constraint

◆It only selects total capacity of 5 units

◆The selection depends on overall profit

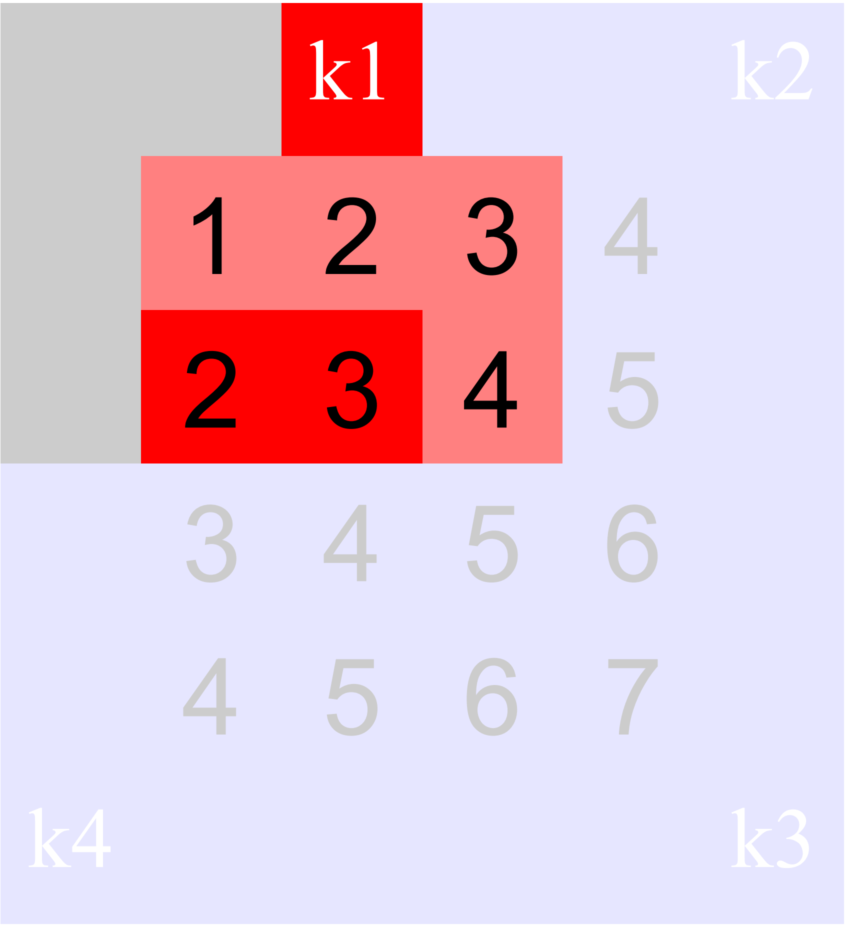
◆Higher risk require higher capacity

◆In following case,

1) Select bottom 2 and 3; OR

2) Select 4 and 1

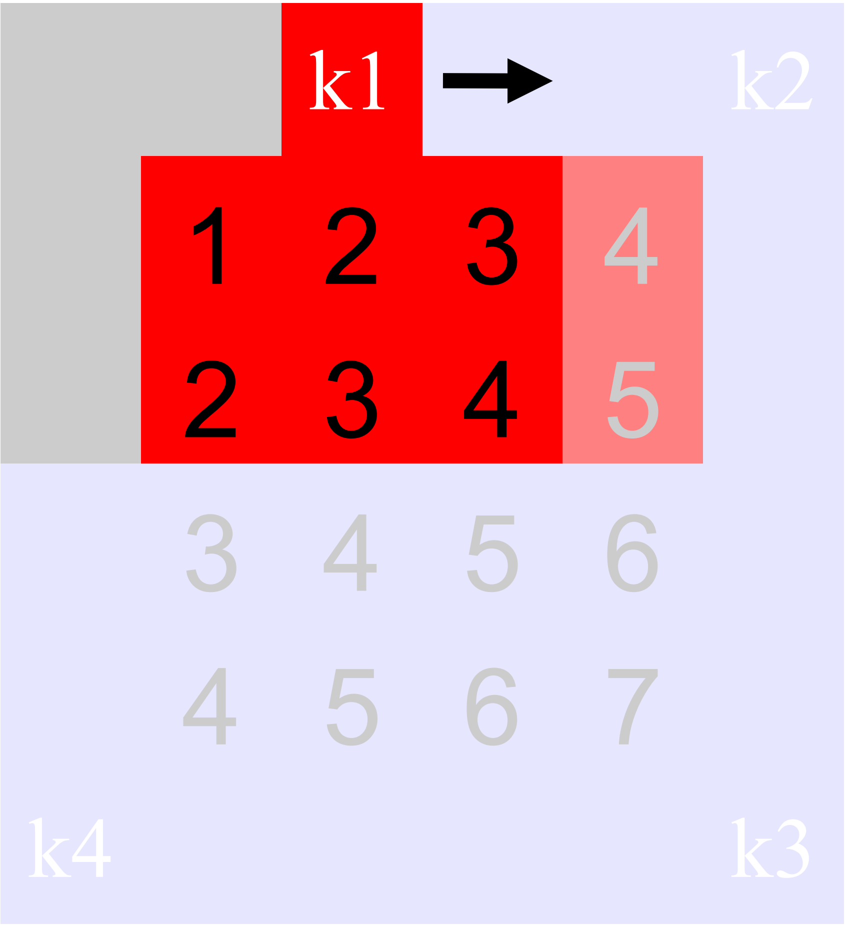
◆It will choose option (1) and stop others



Model element (2): Interactions of Agents

Rule 5: If capacity is not full, increase competitions to neighbors

- As example
  - If RED insurer has extra capacity
  - It takes all its potential customers
  - It'll try to move closer to its neighbors
  - This increases competitions
  - Lower prices attract new customers
  - BUT higher prices on existing ones
  - In this case, 1 and 2 (left) will increase prices, since RED faces low competition

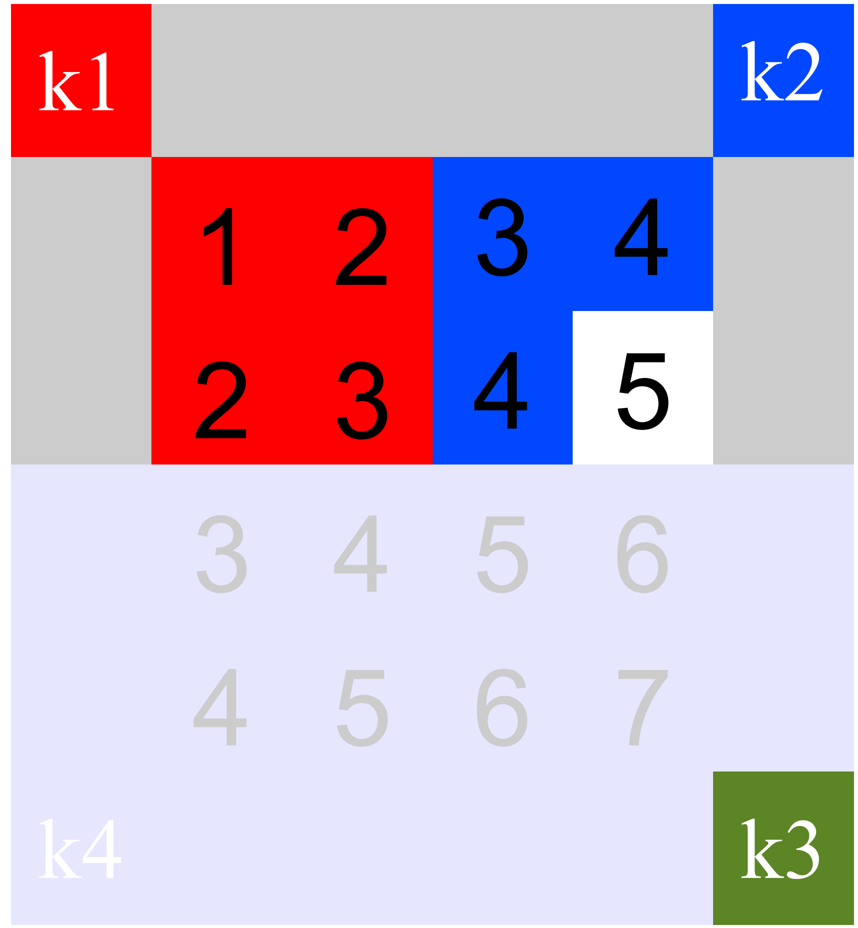


Model element (2): Interactions of Agents

Rule 6: If potential profit from neighbors, increase competitions

- As example

- If **RED** insurer has enough capacity
- But **BLUE** insurer has not
- Some customers of **BLUE** rejected
- In case of Customer 5 rejected
  - **BLUE** insurer cannot take this risk
  - **RED** insurer like it but has a low competitive advantage to **GREEN**
  - So **RED** move closer to 5, even it has no enough capacity to take it now

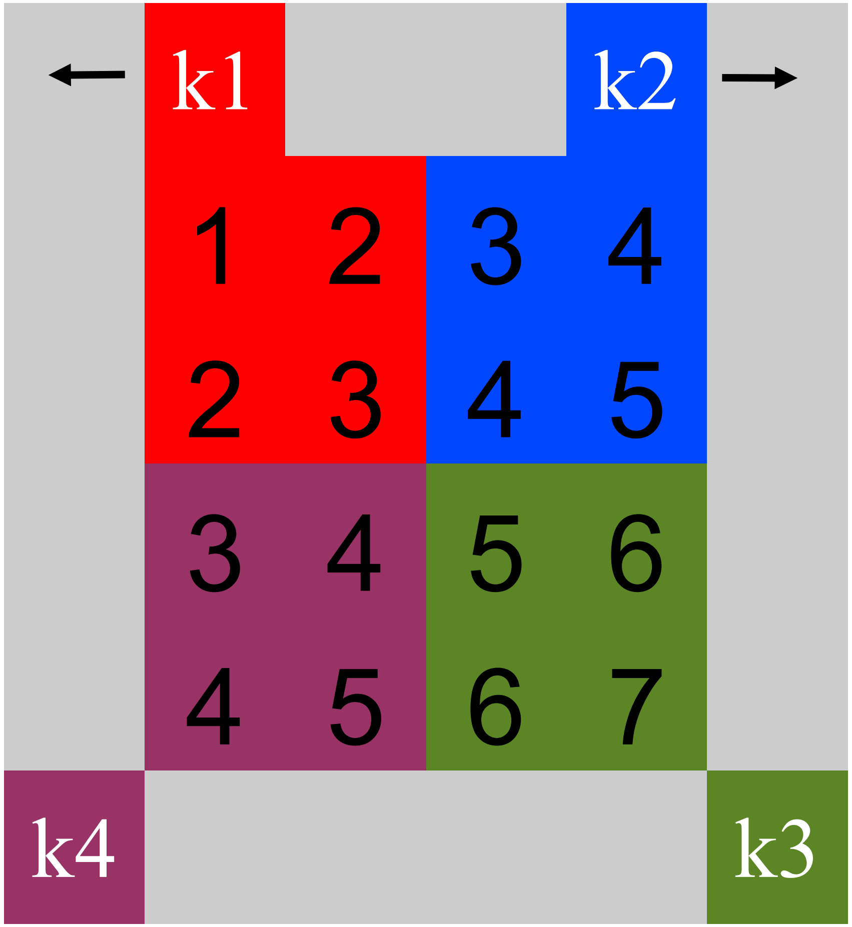


Model element (2): Interactions of Agents

Rule 7: If no potential profit or competition, refine existing business

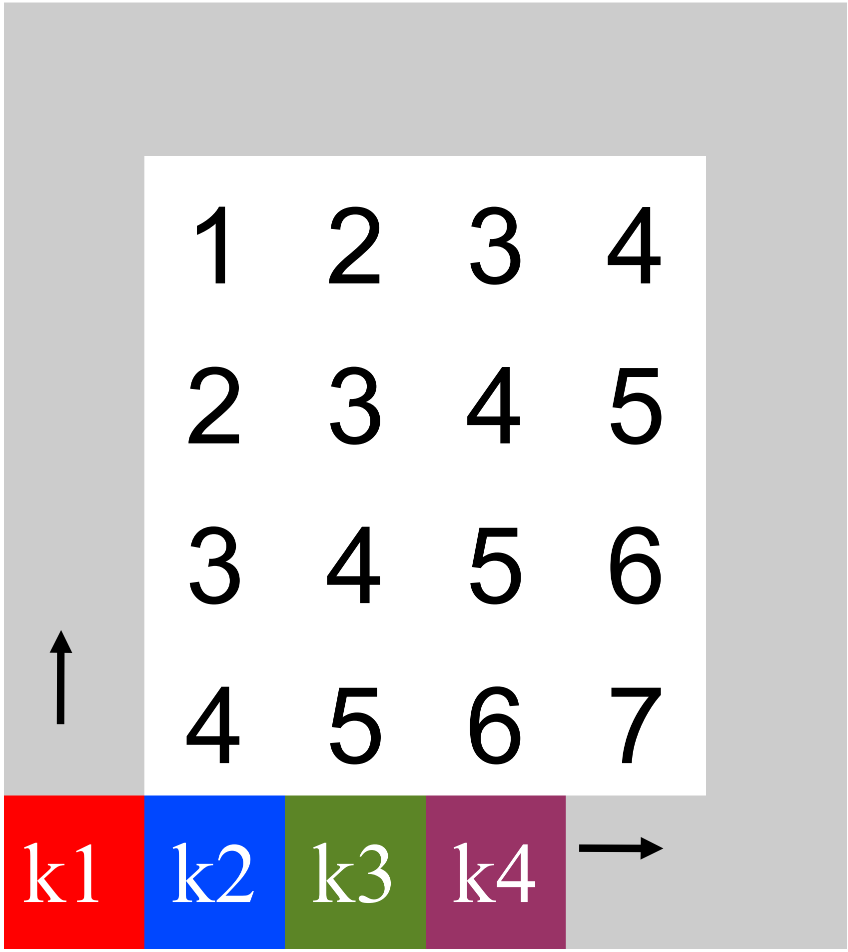
- As example

- Every customers are occupied
- No potentials for Insurer **RED** or **BLUE**
- But they can increase profit still
- Increase prices on existing customers
- Since low competition on existing ones
- **RED** moves left and **BLUE** moves right
- In this case, one of them will move only when the other does it at the same time

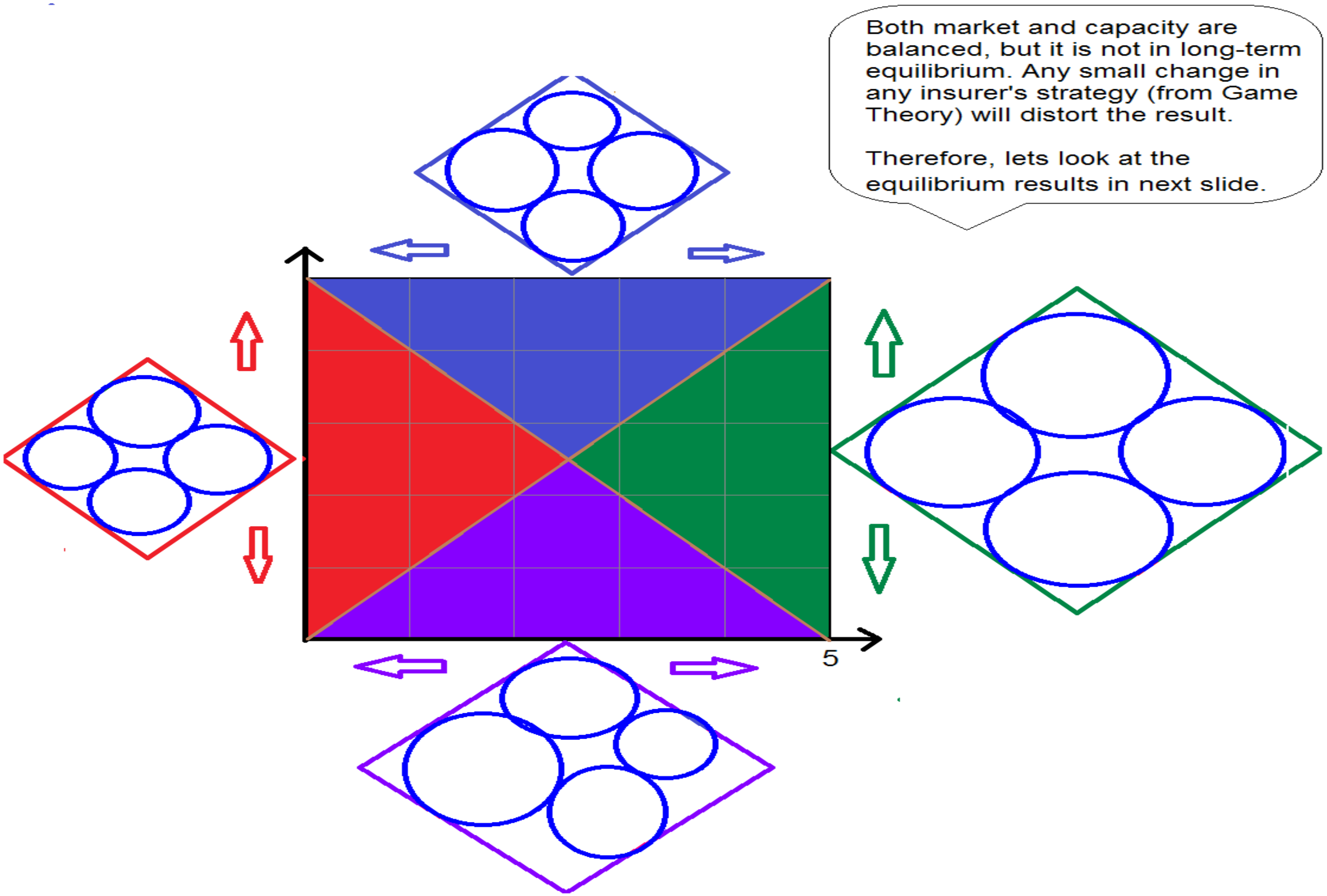


Model element (3): Real World Constraints

- Customers
  - Risk classifications cannot change rapidly
  - In a short run, they are fixed (i.e.: cells in white space are unchanged)
- Insurers
  - They can move along the gray area, this means changing business strategy
  - But it only moves one step in each time period, since business strategy cannot change rapidly (time lags)

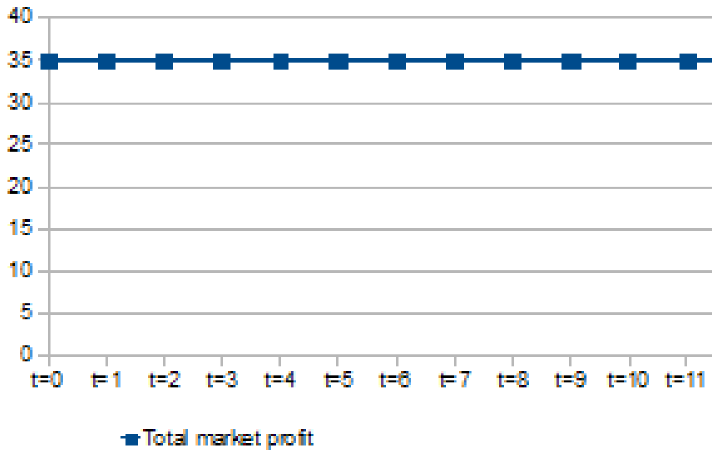


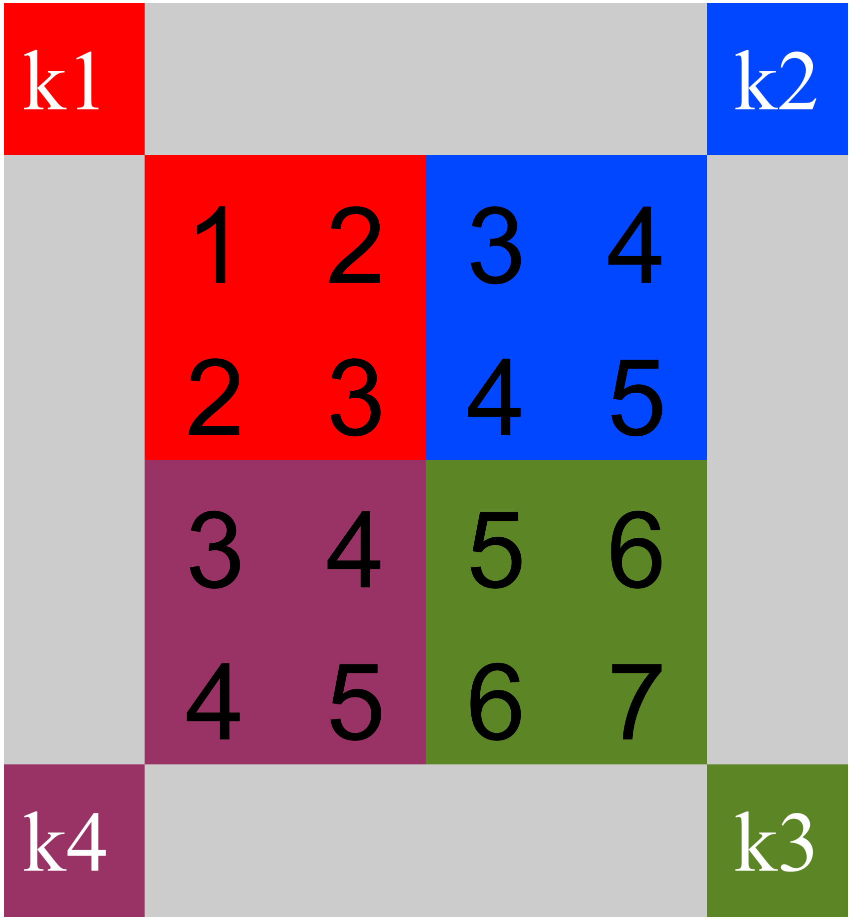
Model element (4): Emergence



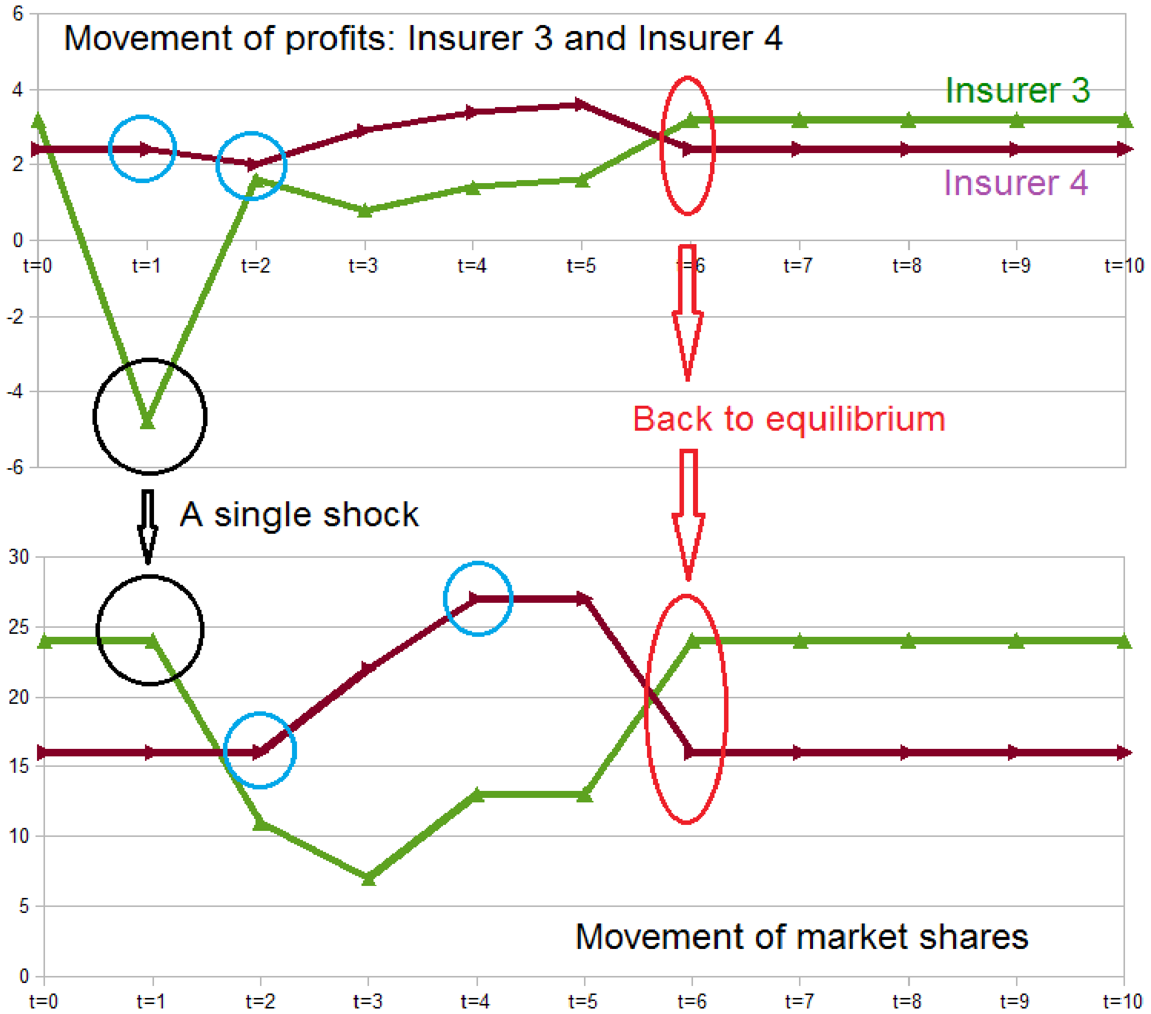
Model result (1): Equilibrium Scenario

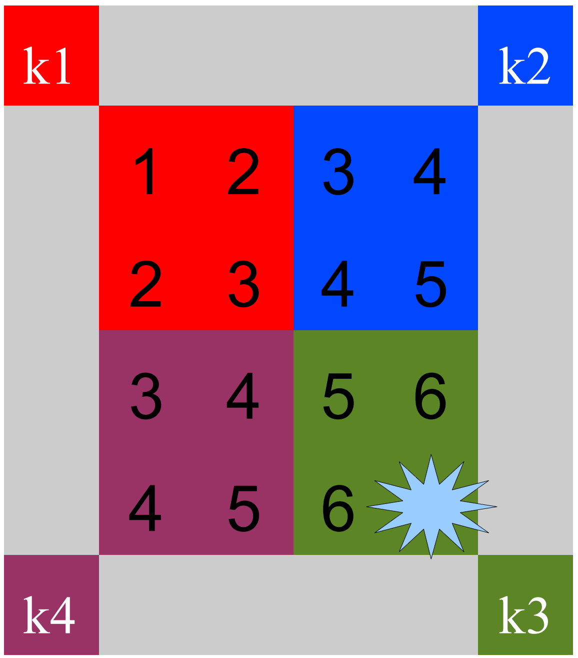
- Under following conditions
  - Expected claims always equal actual results
  - No shocks or mis-priced
  - Profit Maximization





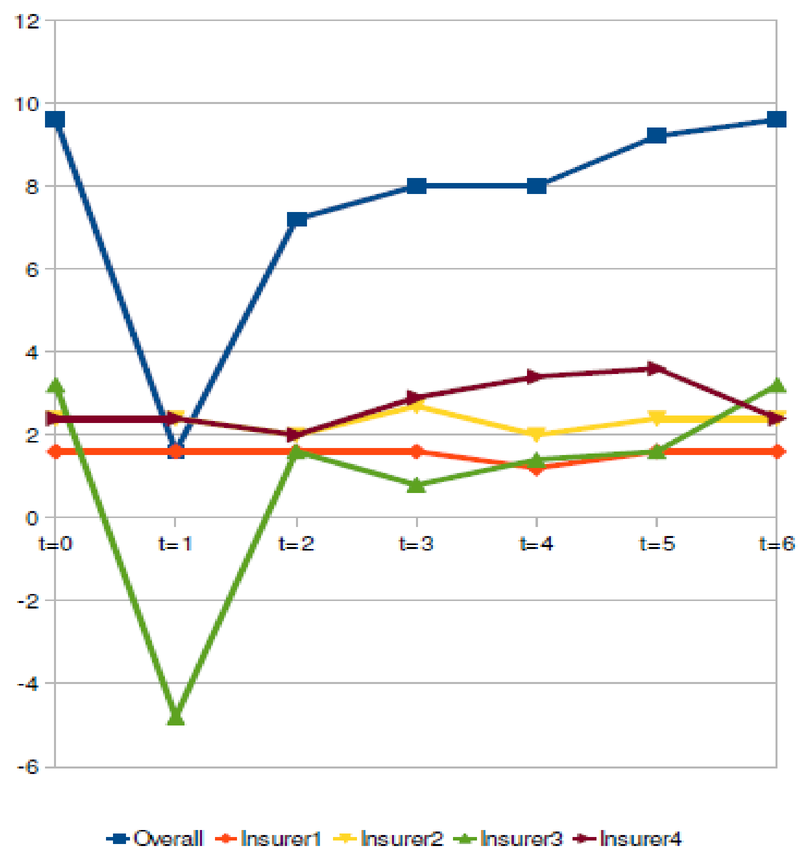
Model result (2): A case of single large shock



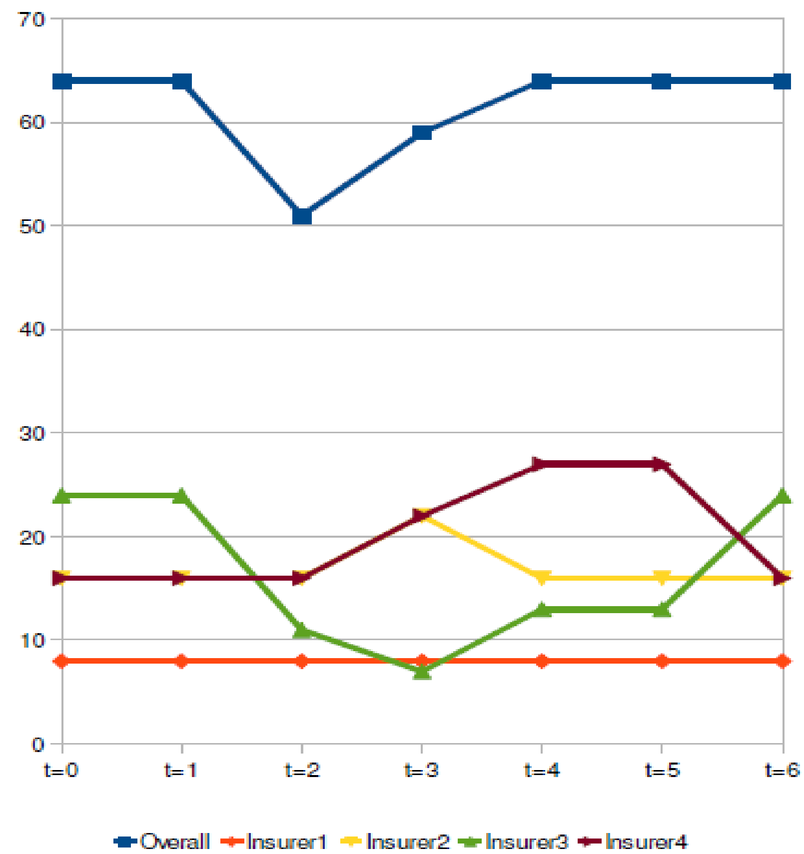


Model result (3): A case of single large shock

Profit movements after a large shock

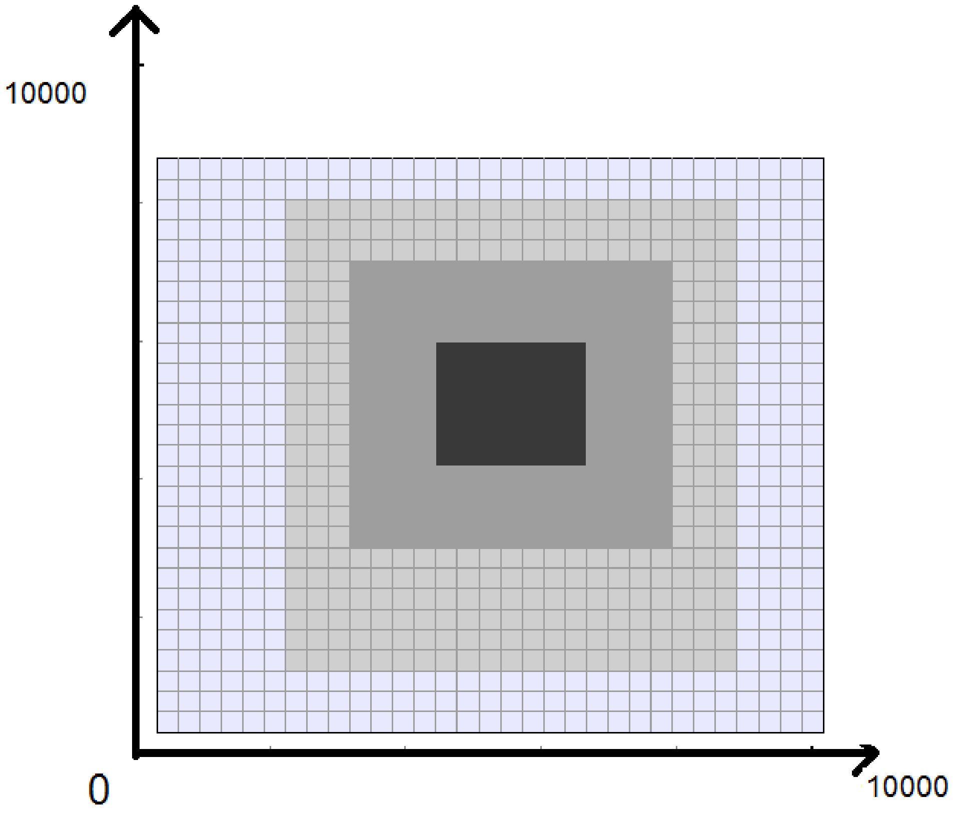


Market share changes after a large shock



Model proposal: Model Expansion

- Expansion
  - More customers
  - More classifications
  - More Insurers
  - Add density of groups
  - Risk distributions
  - Non-linear relations in pricing
  - Even more dimensions of risk factors



Our Model: Key Conclusions

Despite its simplicity,

- The model produces a market with a similar structure to real world: some insurers are large, others are small. Even though all of them start with the same size;
- It shows that the larger insurers are willing to take more risky customers and compete general business, while smaller insurers focus on their specialised areas;
- Niche business are emerged. Some insurers are specialised in one particular sector or a group of targeted customers, because their competitive advantages;
- Those unique features of Non-life insurance market create systemic movements of the market, cycles are emerged.

Future research: Some Improvements

- External capitals
  - New entry and exit
  - Dividends and other financial investment opportunities
  - Investor capital injection
  - Loan, reinsurance, co-insurance
- Different Insurers learning algorithms
  - Reactive reinforcement learning (Backward looking)
  - Anticipatory learning (Forward looking)
  - Evolutionary learning (GA: Genetic Algorithm)
  - Network learning (ANN: Artificial Neural Networks)

Question to think: Actuarial models

Alan Mills FSA ND (2010)* states that, "*Although traditional actuarial models take many forms, in essence they simply project historical aggregate patterns into the future.*" No matter if the model type employed is a micro-simulation, a statistical model, risk analysis model, the essential methodology is a top-down approach.

He argues, "*By contrast, ABM is bottom-up. It seeks to understand and model the behaviour of a system's fundamental units, its agents. System-side attributes and behaviour, such as the aggregate patterns of actuarial models, are then a by-product, an emergent result.*"

Exercise: From your experience, suggest a counter-example to the above statement on the view of traditional actuarial models.

*Reference: Mills (2010), a report to the Society of Actuaries, "*Complexity Science: an introduction (and invitation) for actuaries*".

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