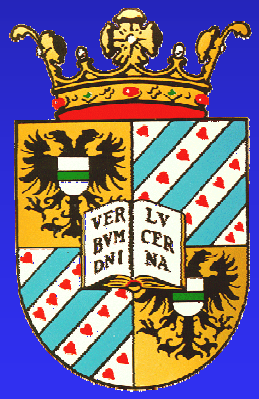
Multi agent simulation of human behaviour using psychological theory



Wander Jager

University of Groningen (NL)

Dept. of Marketing

Projects involving the use of simulation

Market dynamics and innovation diffusion

Stock market dynamics

Crowd and riot control

Opinion dynamics

Self organisation in teams

Agricultural production

Today a focus on market dynamics and innovation diffusion

Many markets display characteristics of complex systems:

- many interacting components
- non-linear behaviour
- path-dependent developments
- No long term equilibrium
- limited predictibility


Mables.com


PHILIPS


MAGNUM
CLASSIC


Slim
Fast

Market dynamics

- A main source of this complexity resides in consumer behaviour: heterogeneous and moving preferences, social exchange of norms and information, social relevance of consumption
- Also producers compete for market share by developing and marketing new products

Market dynamics and social simulation

- General Linear Models (GLM) have a fundamental problem in modelling complexity in markets
- Social simulation provides a suitable tool to study such complex market dynamics

GLM versus Social simulation

Goals of market simulation

Identification of the market dynamics emerging from individual consumer behaviour

Experimentation with policy measures/interventions to change behaviour

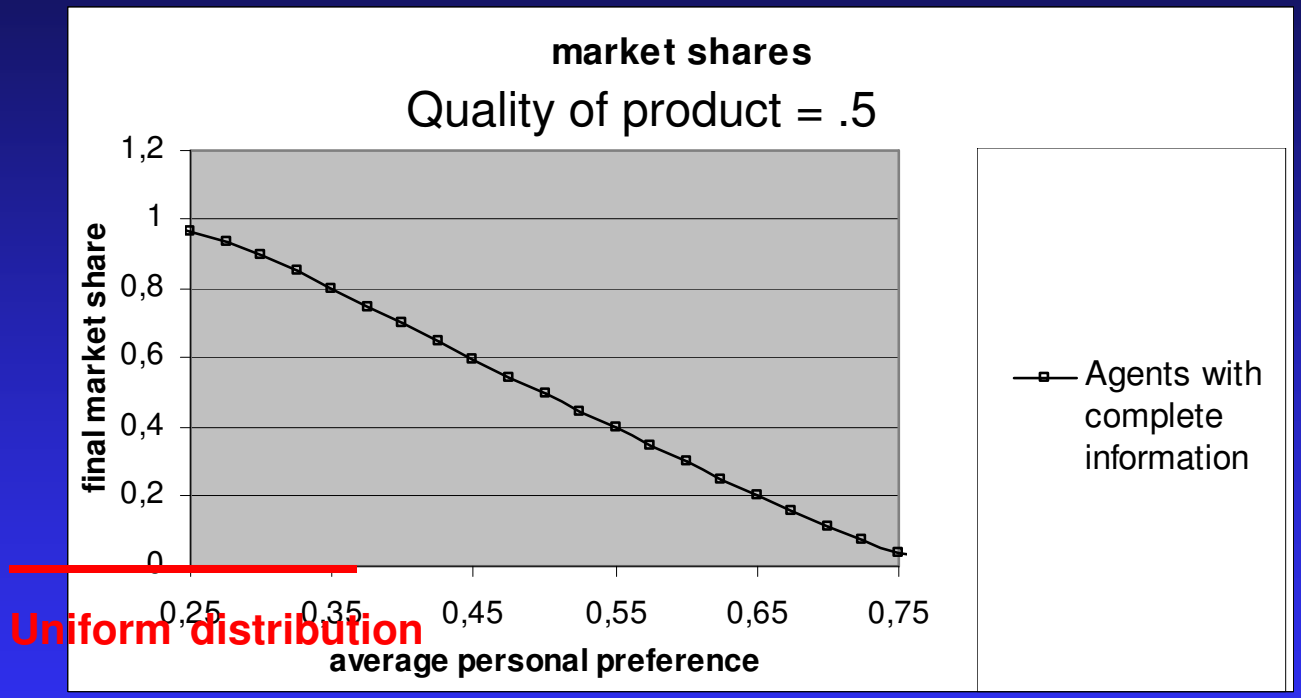
A better understanding of the complex nature of systems contributes to shaping the future rather than predicting it

Market dynamics and social simulation

- Several simulation models have been developed to model market dynamics
- Econophysicists were among the first in developing percolation models of diffusion dynamics
- These models often consider individuals as identical particles communicating with their local neighborhood in trying to optimise their outcomes (theoretically empty)

Diffusion of innovation

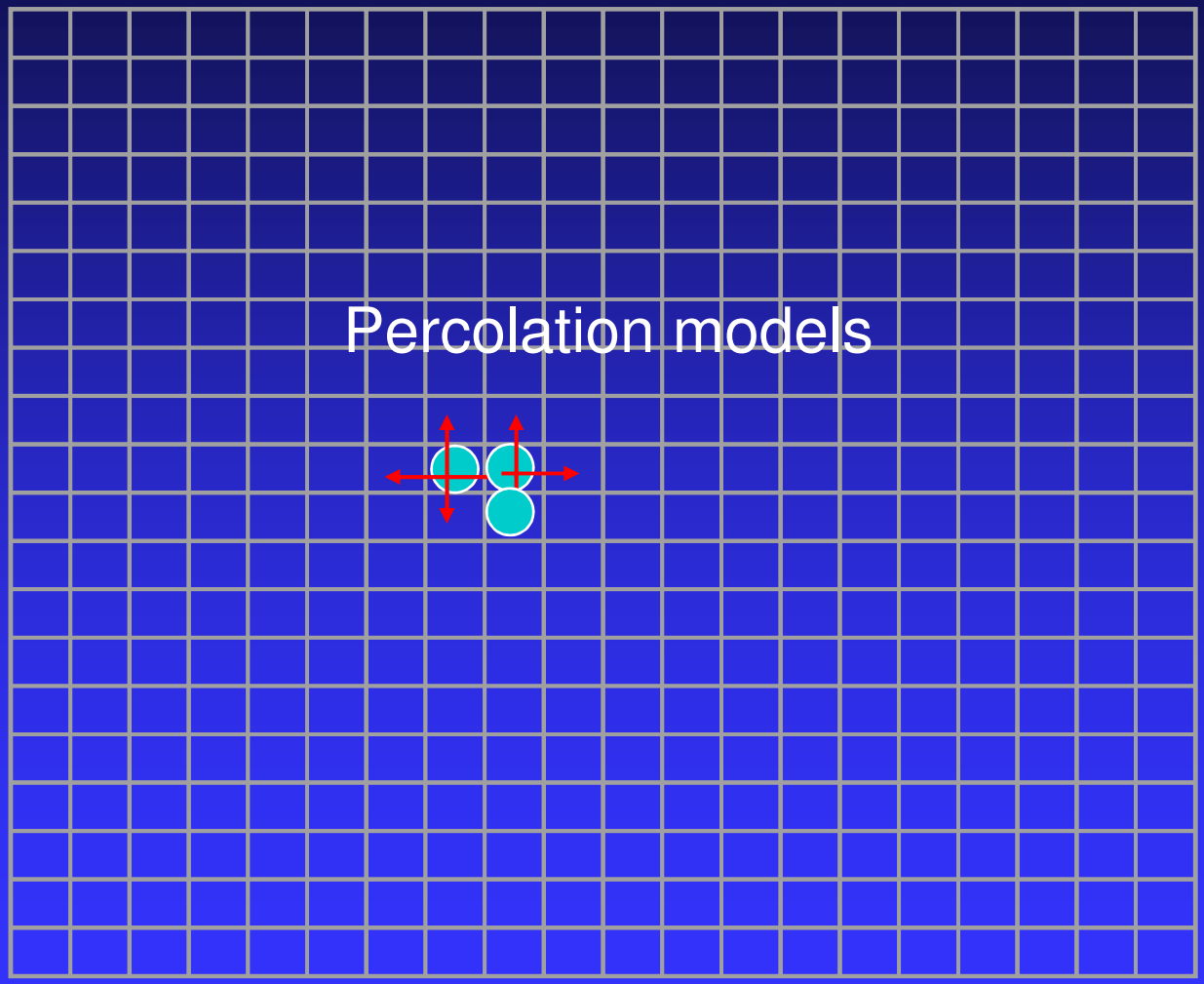
The agents rule: Is the quality (q) of this product higher than my preference (p), then adopt – perfect information



Physicists: atoms communicate, translate to humans!

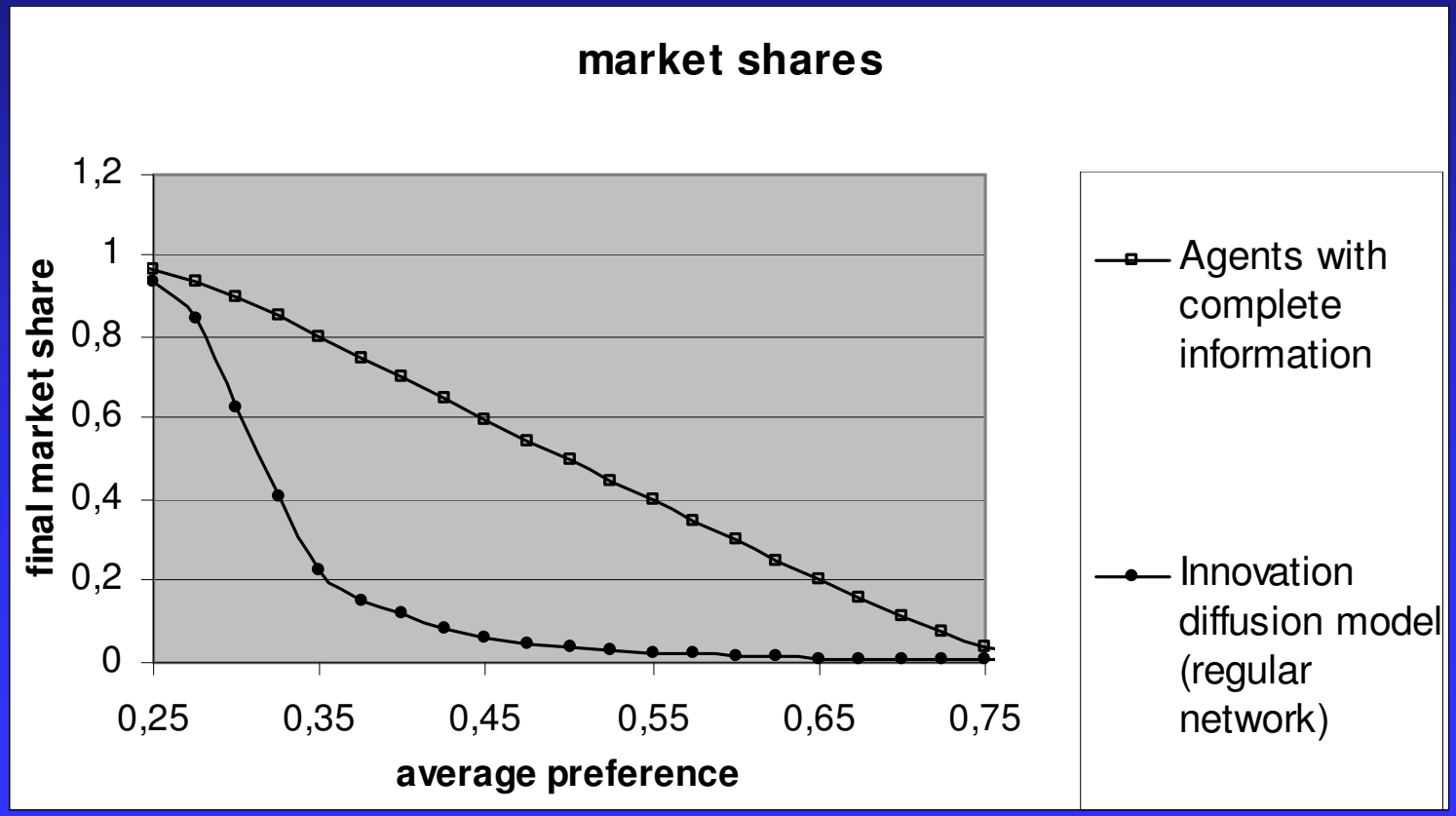
Diffusion of innovation

The agents rule: Is the quality (q) of this product higher than my preference (p), then adopt and inform my 4 neighbours



Diffusion of innovation

The agents rule: Is the quality (q) of this product higher than my preference (p), then adopt – perfect information



Diffusion of innovation

The problem:

- People do not optimise their outcomes according to the rational actor approach
- People are connected in various ways (social networks)

The challenge:

- Representing human decision-making and social networks in a multi agent based model

What theories of behaviour?

Social comparison theory

Conformity

Elaboration Likelihood Model

Theory of Reasoned Action

Balance theory

Social cognition

Social Judgment Theory

Cognitive Dissonance Theory

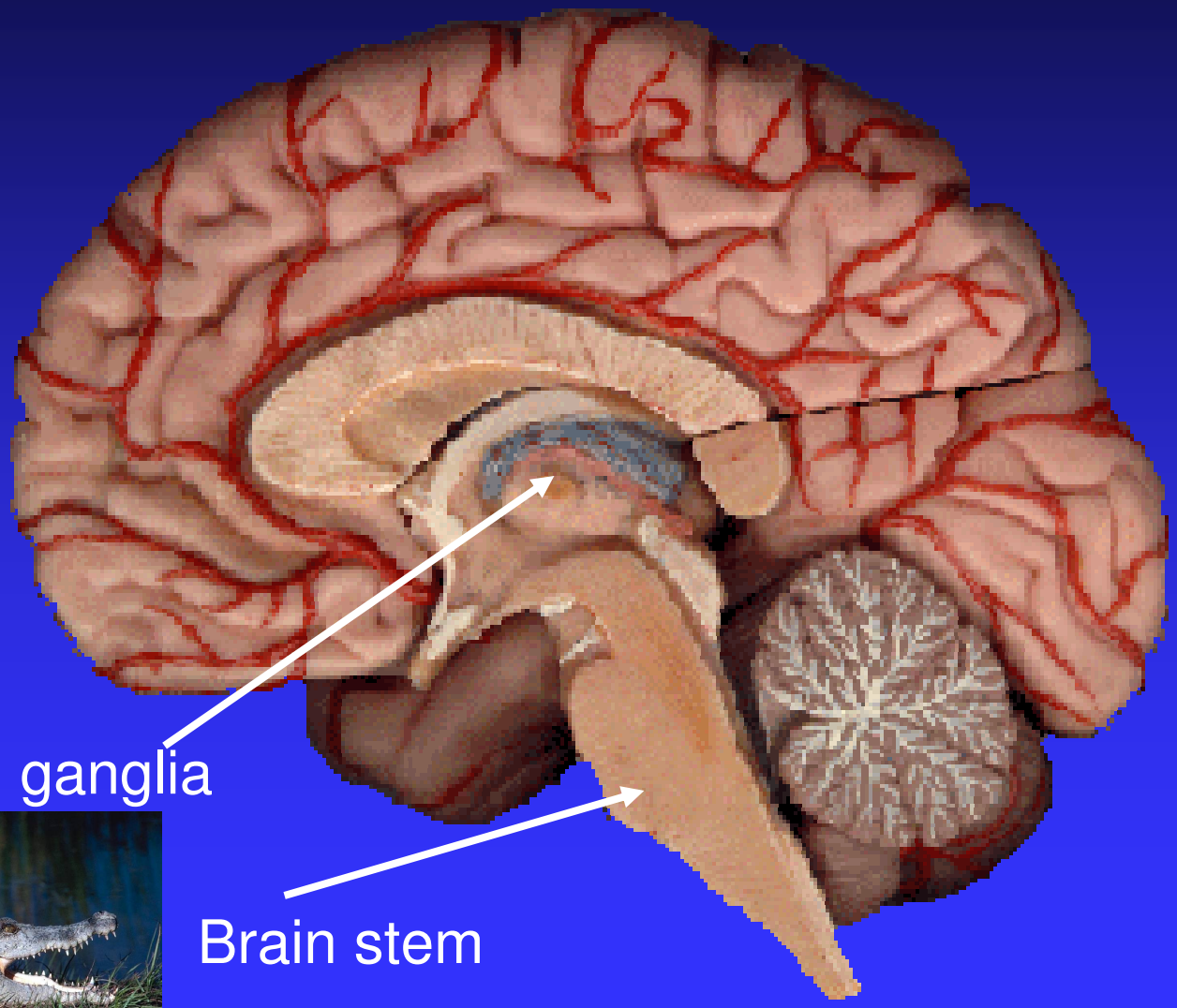
Habit formation

Theory of Normative Conduct

A model of consumer behavior

Brain systems

Evolutionary origins of need



The reptile brain (brain stem, cerebellum)

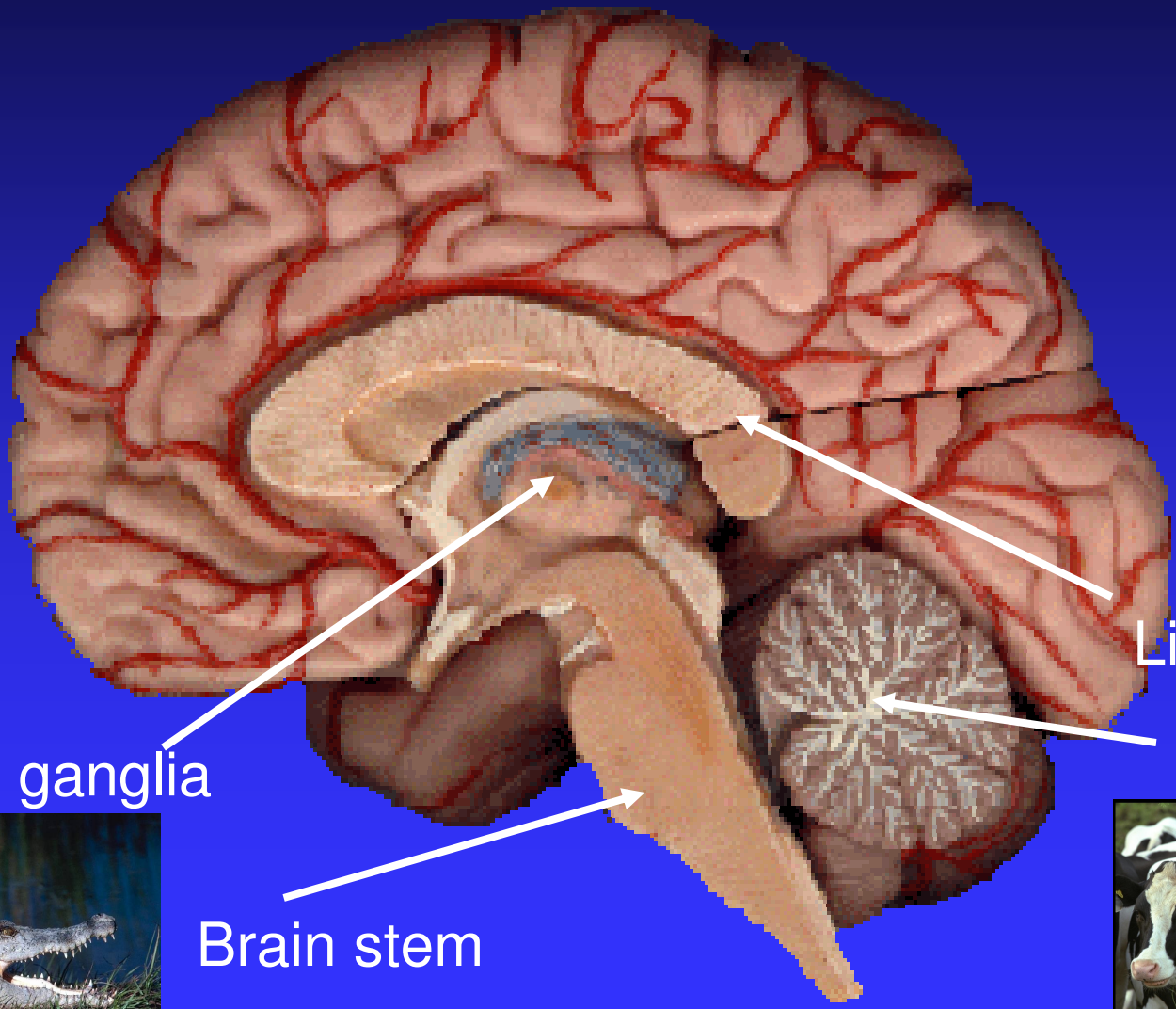
The reptile wants:

- order
- physical safety
- repetition
- security

The reptile fears:

- change
- dislocation
- novelty

Evolutionary origins of need



The mammalian brain (limbic system)

The limbic system wants:

- Affiliation
- celebration
- emotional involvement
- recognition

The limbic system abhors:

- alienation
- emotional threats
- lack of communication

Evolutionary origins of need

Neo cortex

Limbic system

Cerebellum

Basal ganglia

Brain stem

The primate brain (neo-cortex)

The neo cortex wants:

- activity
- challenge
- novelty
- stimulation

The neo cortex deplores:

- boredom
- deprivation
- stagnation

A model of consumer behavior

Brain systems

Neo cortex

Limbic system

Brain stem

Mind that these systems often operate quite independently

Mind that questionnaires and interviews mainly address the Neo Cortex

A model of consumer behavior

Brain systems

Needs

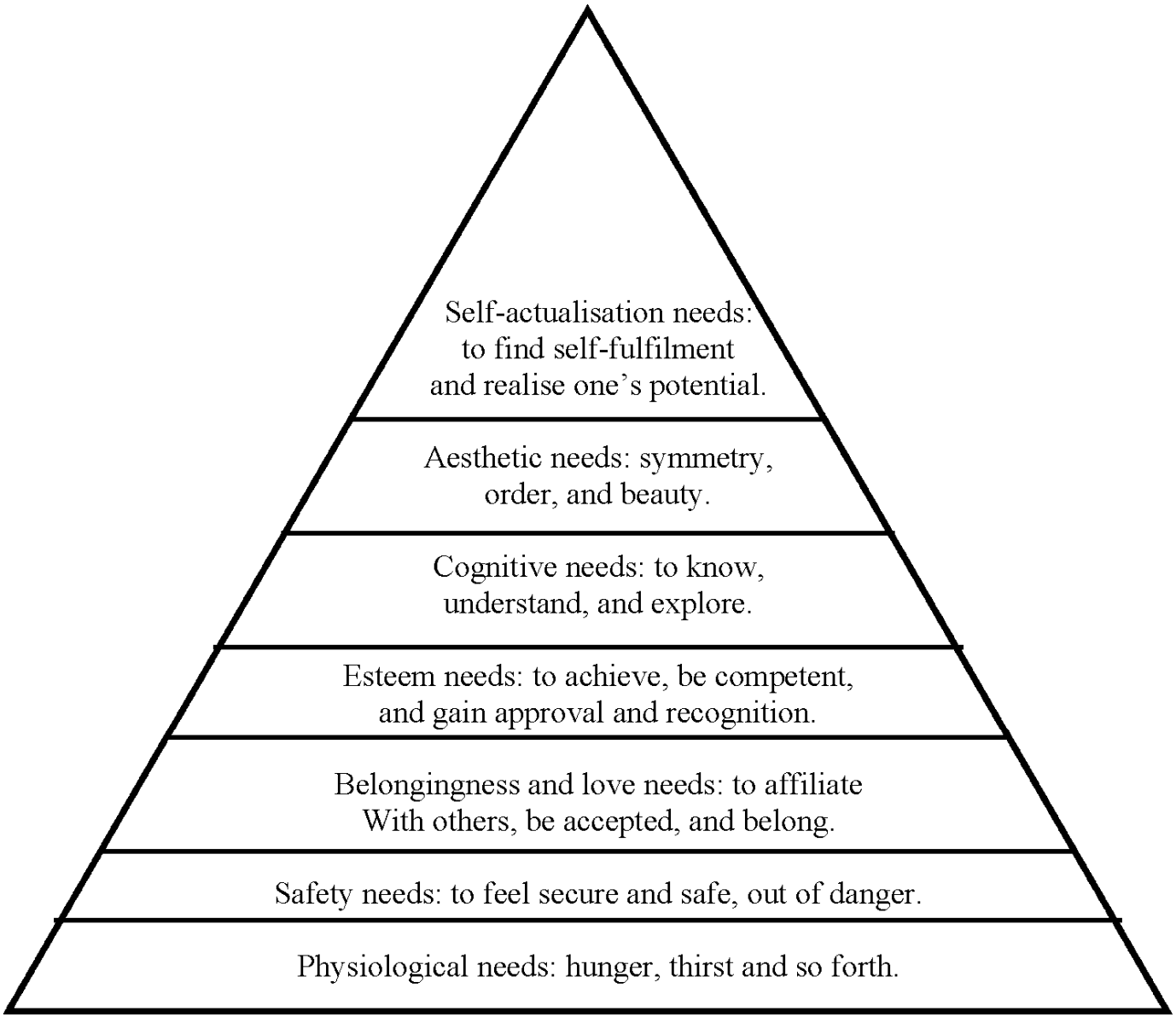
Neo cortex

Limbic system

Brain stem

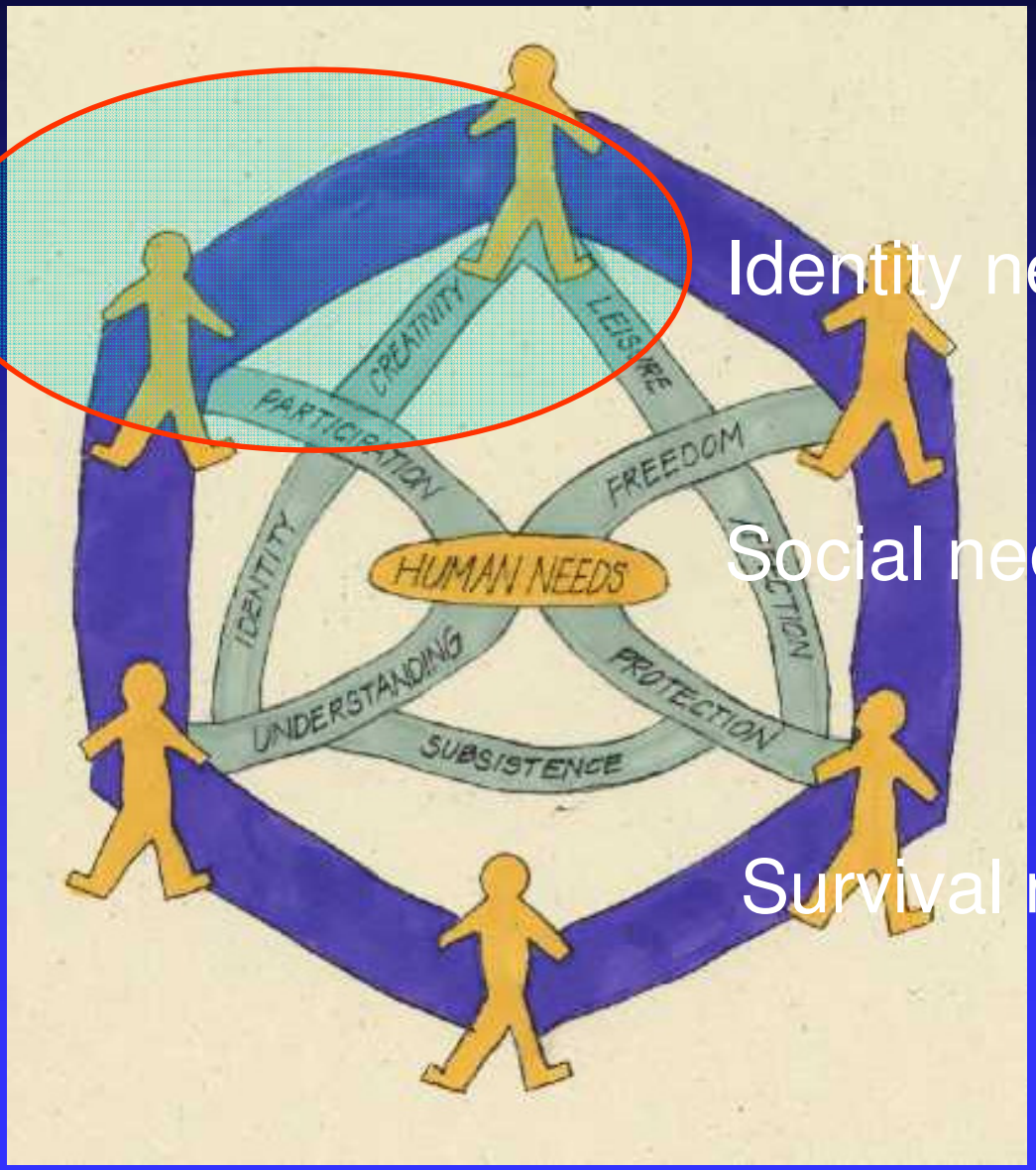
What needs do consumers have?

Maslow (1954)



What needs do consumers have?

Max-Neef (1992)



Identity needs

Social needs

Survival needs

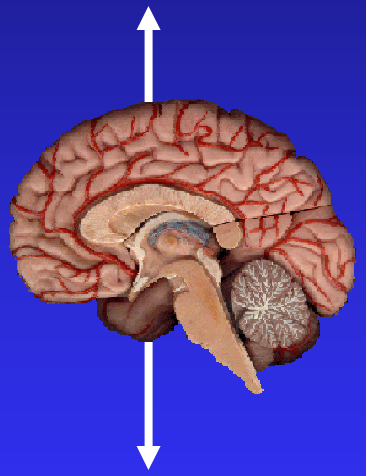
A model of consumer behavior

Brain systems	Needs
Neo cortex	Identity
Limbic system	Social
Brain stem	Survival

Involvement:
The more important behaviour is for the satisfaction of (several) needs, and the lower needs satisfaction is, the higher involved the consumer will be

Decision strategies

Long term



Short term

Individual heuristics
-Compensatory
-Non compensatory

Social heuristics
-Social comparison
-Imitation

Automatical heuristics
-Habits
-Reflexes

A model of consumer behavior

Brain systems	Needs	Deciding
Neo cortex	Identity	Individual heuristics
Limbic system	Social	Social heuristics
Brain stem	Survival	Automated decisions

Individual heuristics

When?

- High involvement
- Individual needs

How?

- Compensatory heuristics
- Non-compensatory heuristics

Innovative behaviour

Social heuristics

When?

- Uncertainty
- Complex decisions

How?

- Social comparison
- Norms
- Imitatation
- Observation

Who to compare with? Similarity

Herding

Automated decisions

When?

- Stable situation
- Frequent behaviour

How?

- Habits
- Reflexes

Automated behaviour

Conclusions on modelling consumer behaviour

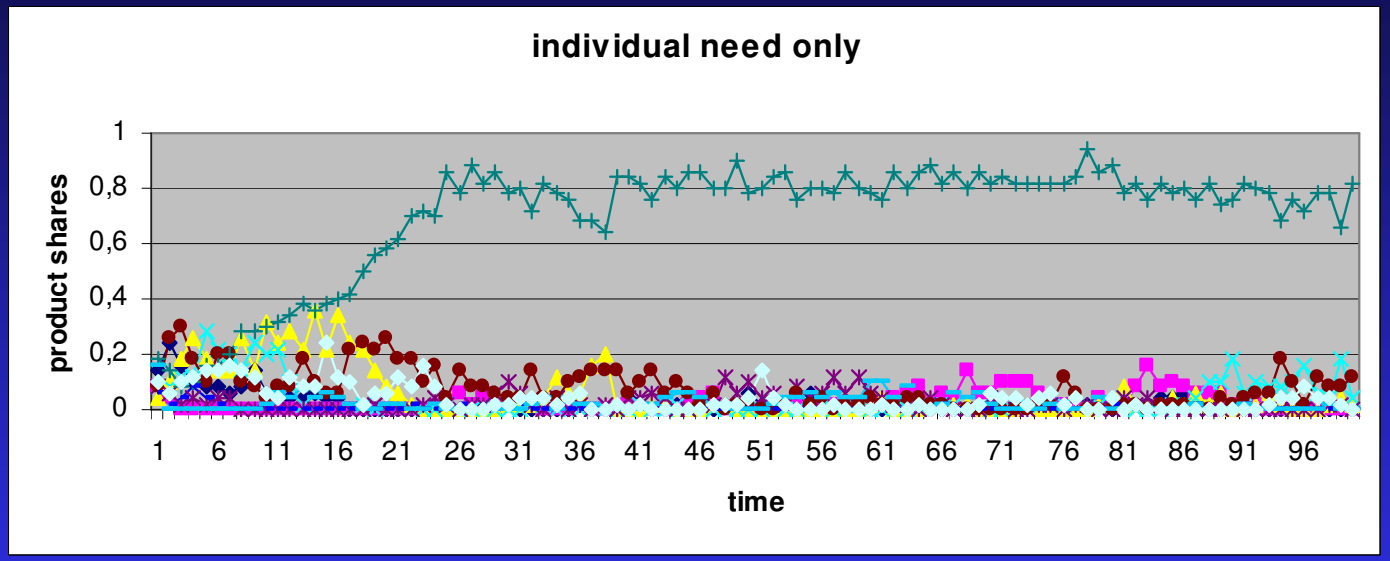
- Needs as motives of consumer behaviour
- Consumer decision making: cognitive effort & individual and social dimensions

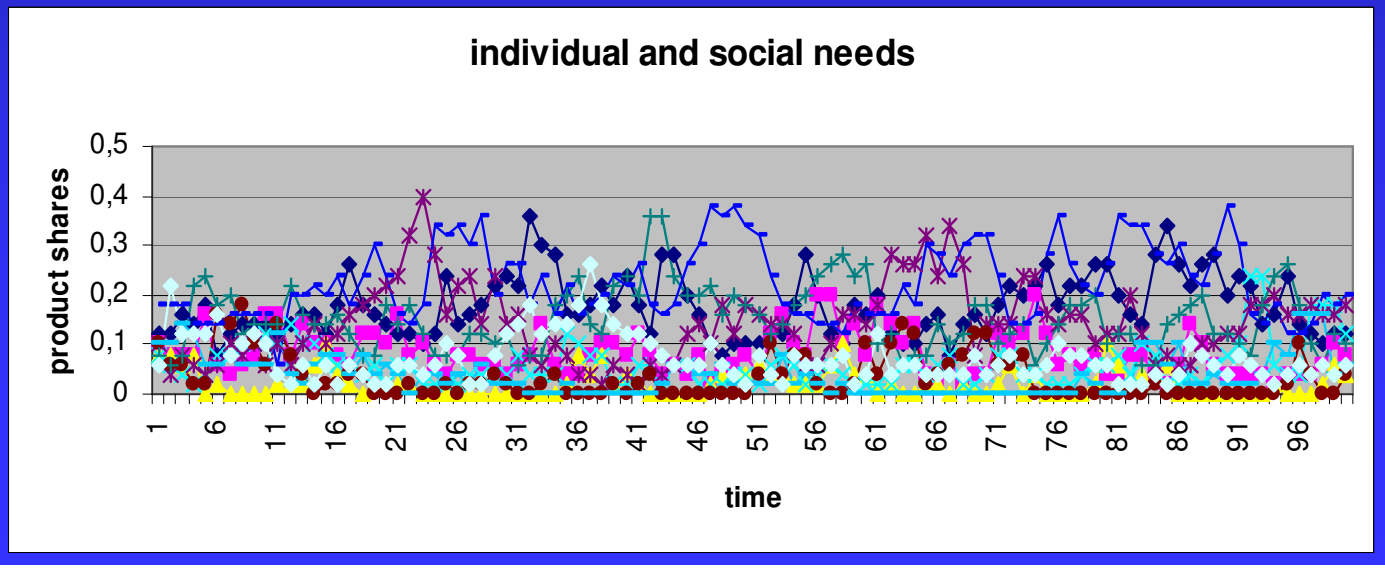
Why do we try to formalise this?

- Behavioural drivers,such as needs and decision strategies:
  1:Lay at the foundation of many behavioural dynamics
  2:Provide points of application for policy measures

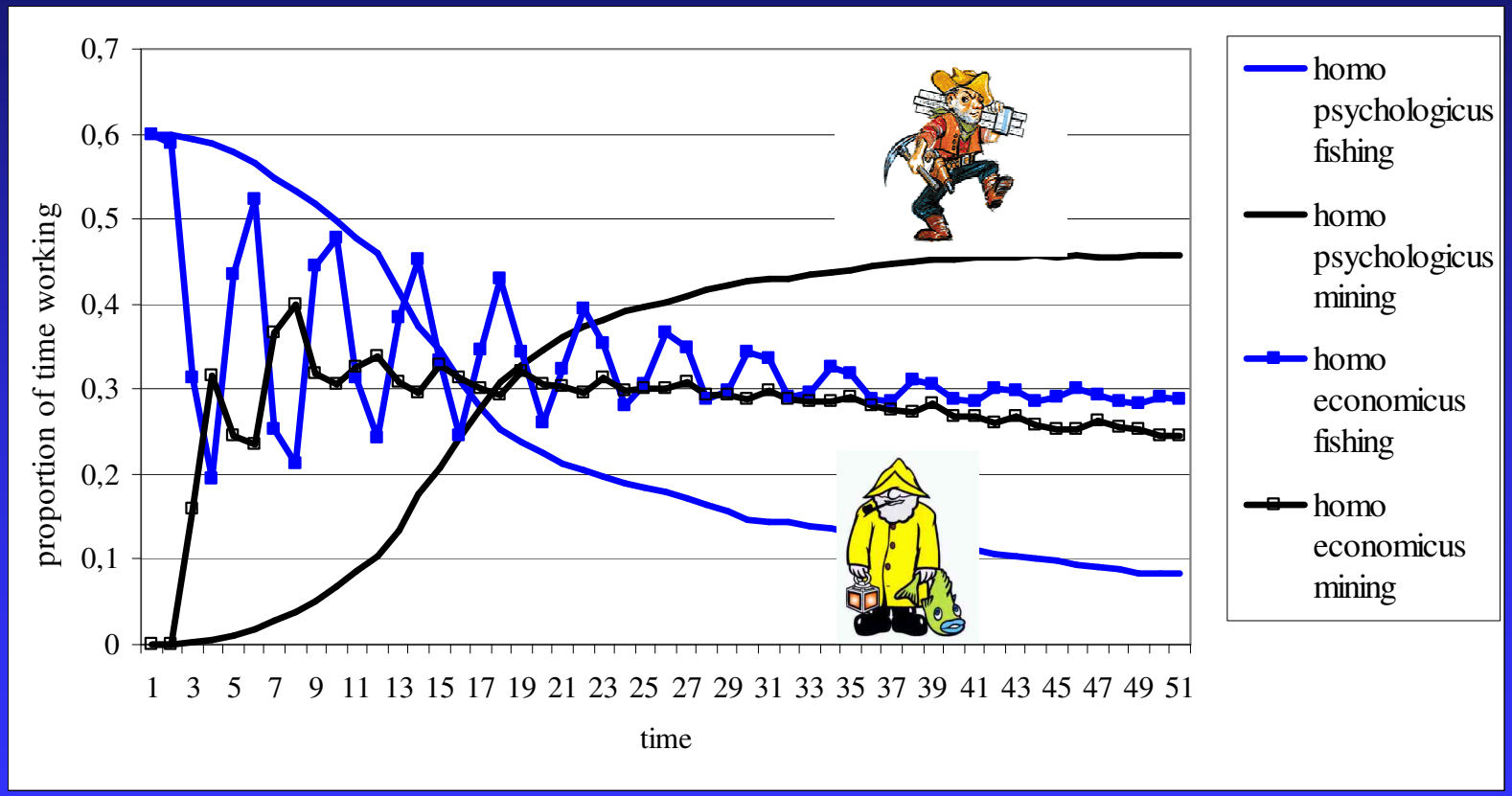
Mimicking just doesn't do the job!

Including behavioural drivers. An example of needs





Including behavioural drivers. An example of decision-making



Back to the diffusion of innovations

- The problem: people attach a social value to products (conspicuous consumption)
- The challenge: representing conspicuous consumption in a multi agent based model

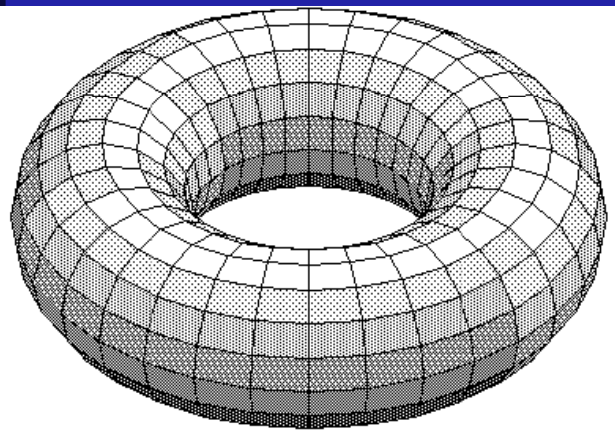
Diffusion of innovation, a simple extension with social needs

$$N_i = \beta_i \cdot N_{s,i} + (1 - \beta_i) \cdot N_{p,i}$$

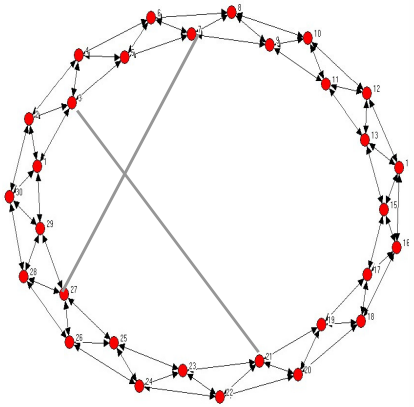
Ni = Need satisfaction agent i
Ns,i = Social need satisfaction
Np,i = Personal need satisfaction

Diffusion of innovation, a simple extension with social needs

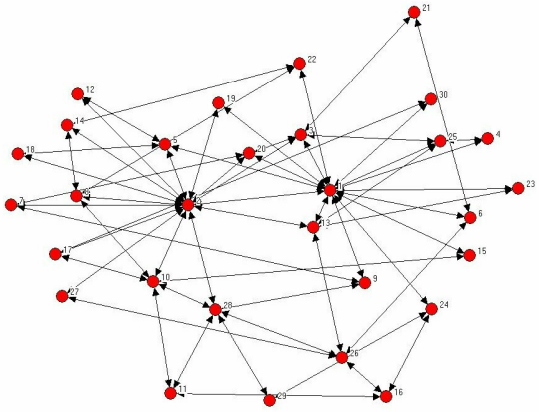
-Network effects are critical



Regular lattice

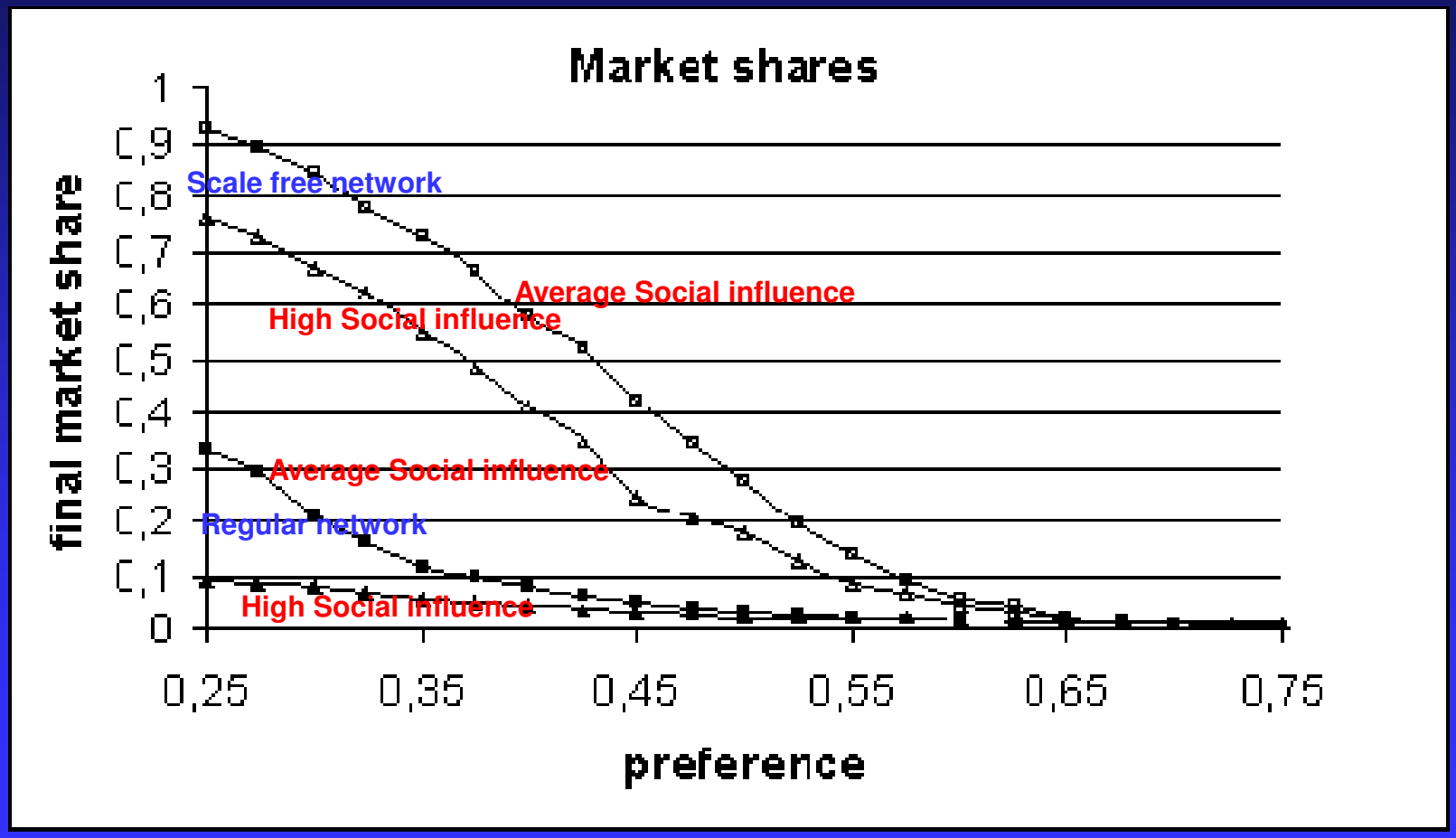


Small World



Scale Free

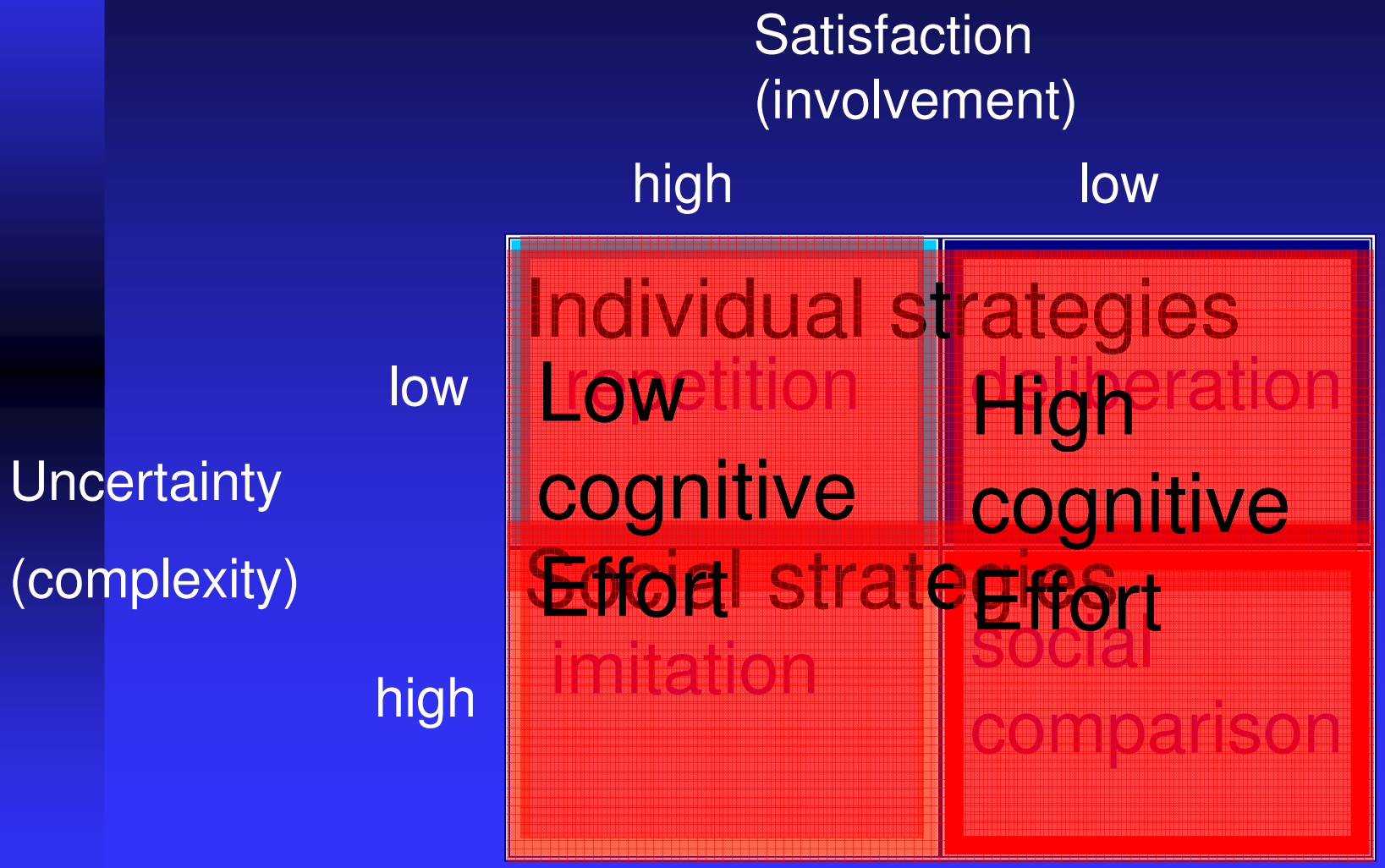
Diffusion of innovation



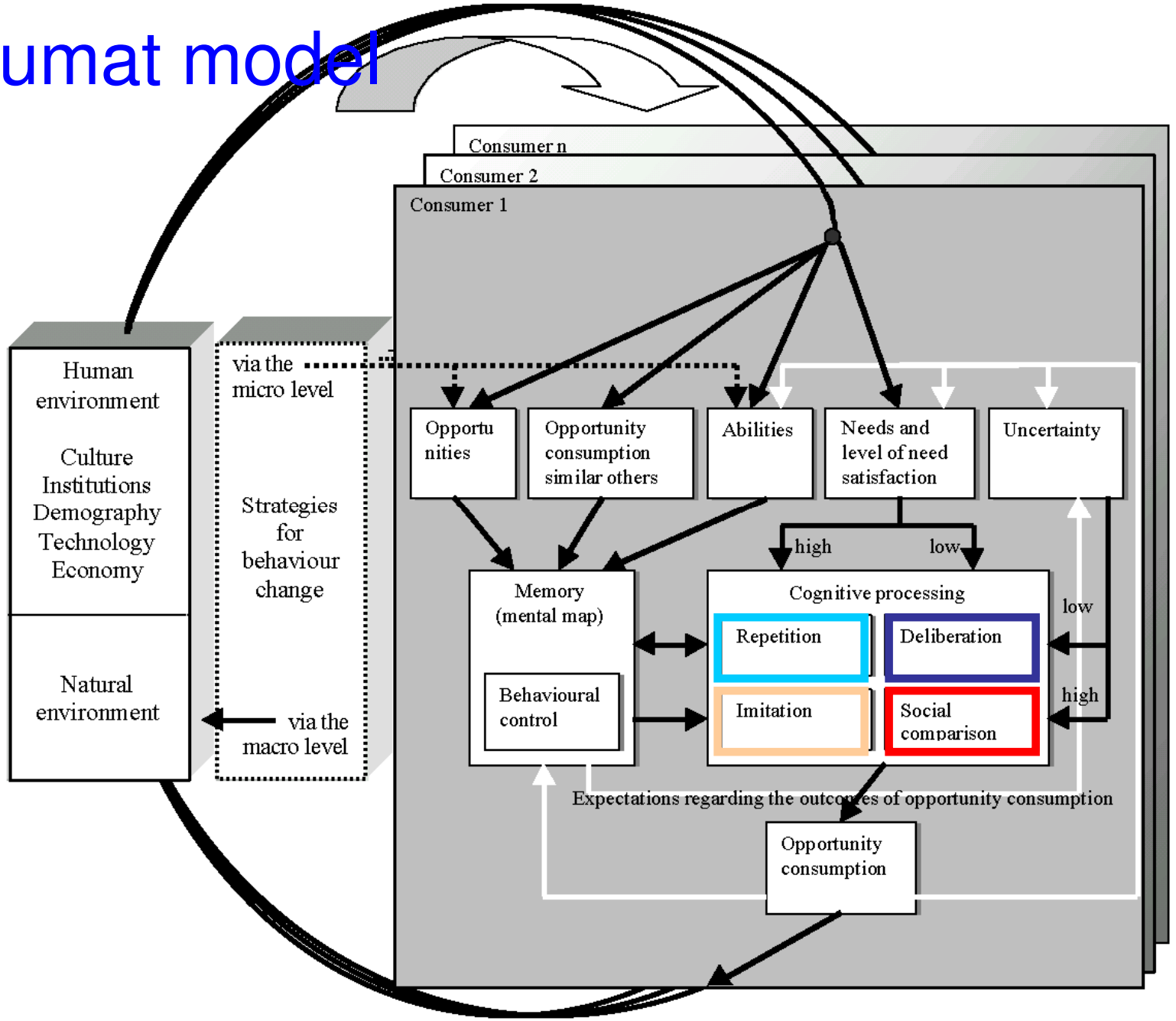
Towards more complex agents

- We want to address basic behavioural drivers in the agent rules
- Needs and decision making strategies

Consumer decision-making: the consumat (1999)



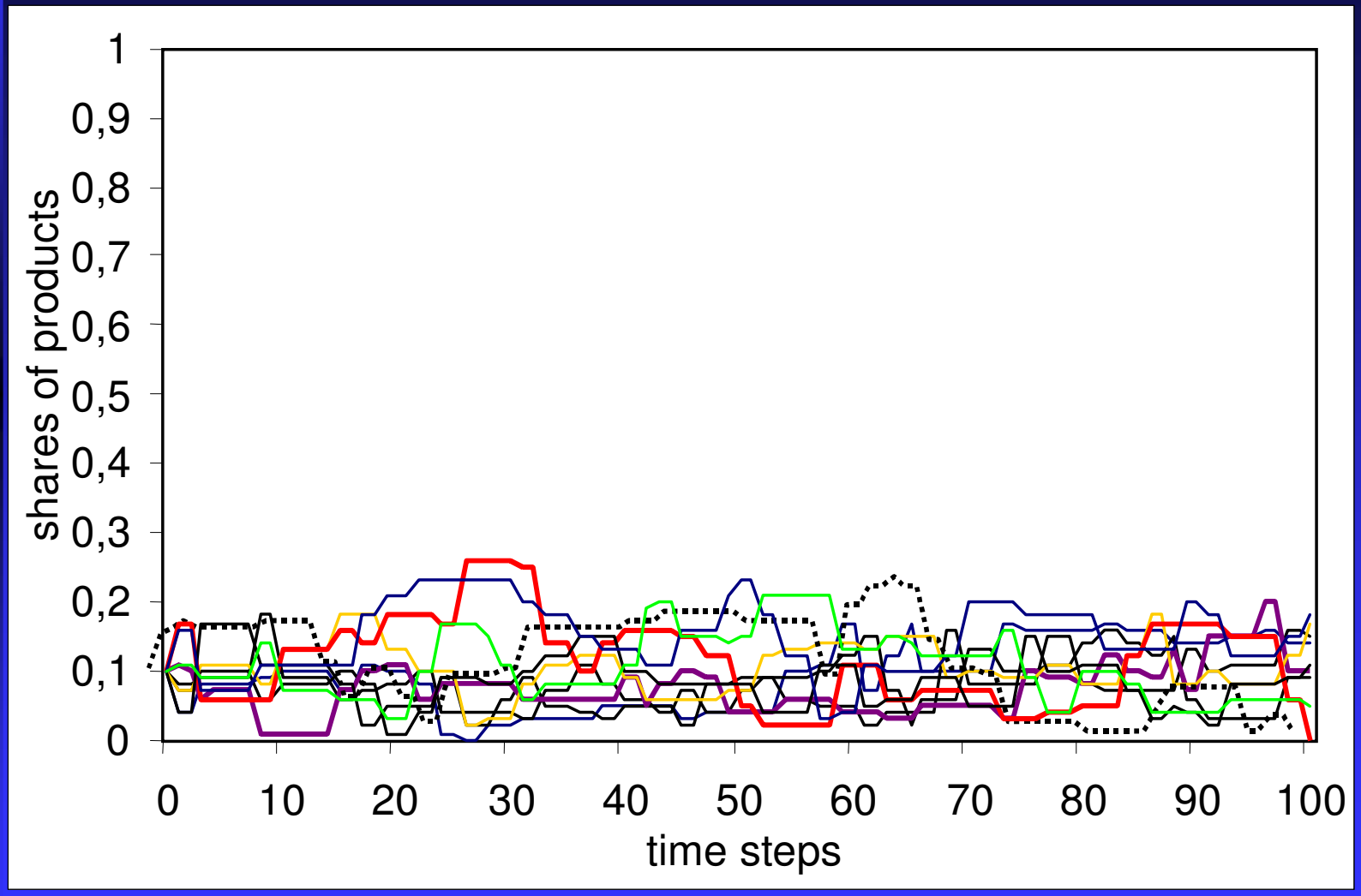
Consumat model



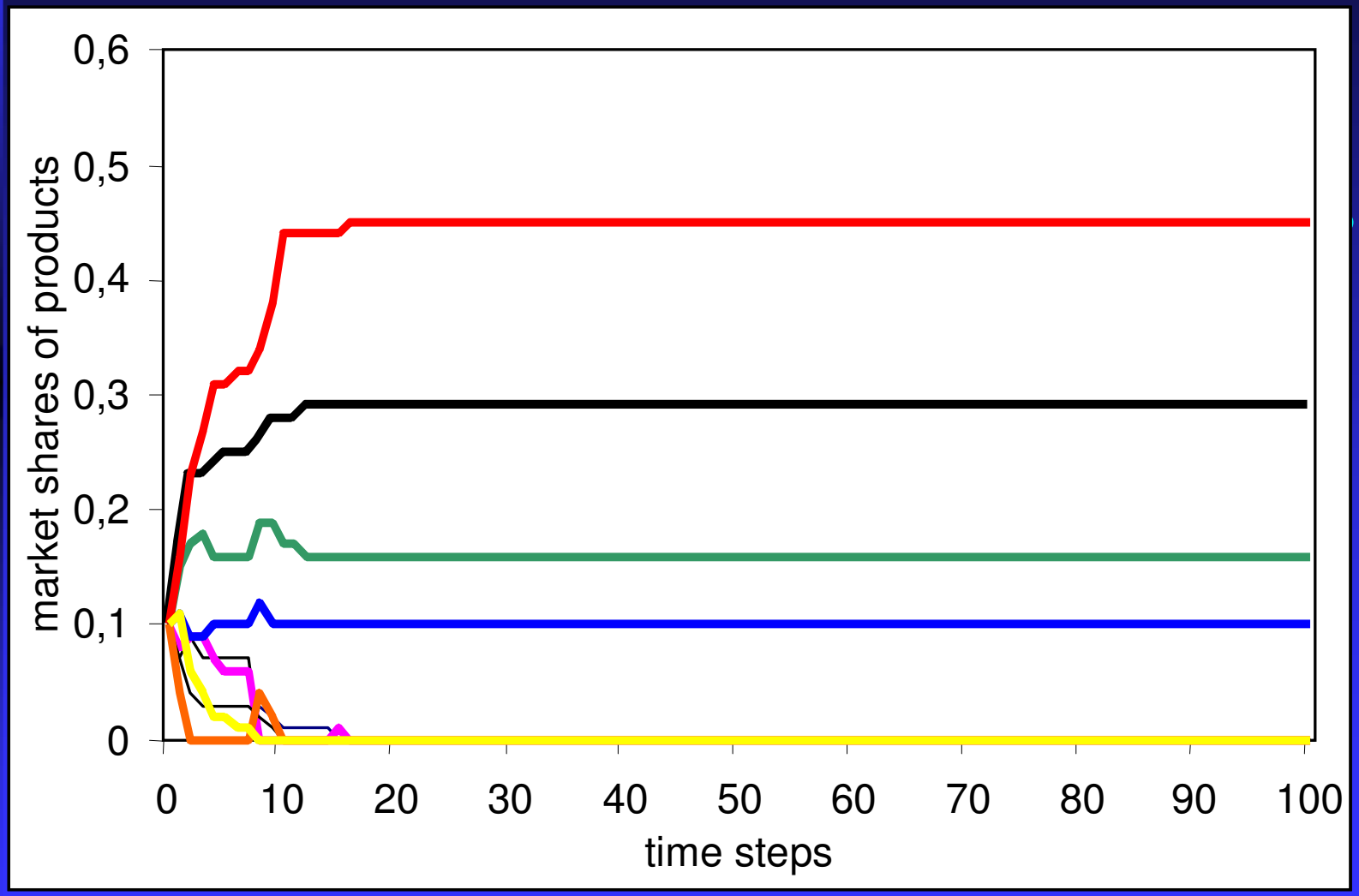
Market dynamics (2001)

- Varying the tendency of agents to (1) invest cognitive effort in the decision making process, and (2) using individual versus social strategies
- 10 products, removed if share remains low
- Different types of consumer markets:
  - involved individualists (much deliberation)
  - low-involved social oriented (much imitation)
  - involved social oriented (much social comparison)

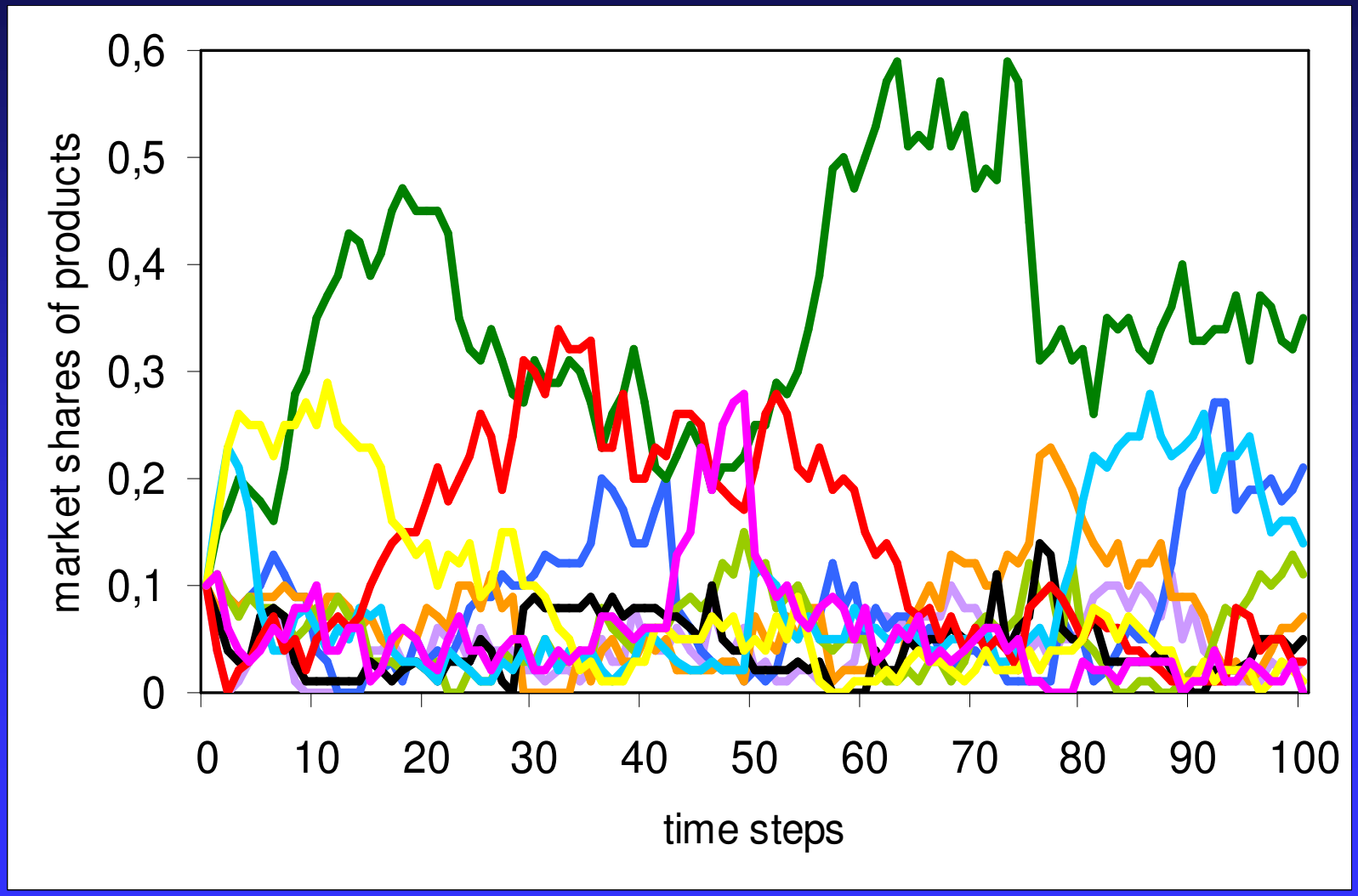
Market dynamics: Deliberators



Market dynamics: Imitators



Market dynamics: Social comparers



Balancing between simplicity, complexity and applicability: redefining a behavioural model

- Agent architecture has to reflect the key-drivers of consumer behaviour
- Marketing strategies can be implemented as affecting these key drivers
- The conceptual & formal model should serve to program simulation models of varying complexity – simple models can be extended using this model.

The four P's of Marketing (McCarthy, 1960)

product

pricing

placement

promotion

Formalising the four P's (2007)

- Formalising all the factors just mentioned would – if possible – result in a model not accessible for research
- A simplification is required for developing a transparent simulation model
- The formalisations as presented are meant as a framework, simpler models can (and should) be used, and if necessary extended using the framework

Product

- Product characteristics relate to individual preferences (related to needs)
- Vector model of preferences: the more, the better (quality, service)

$$Uinj = Ajn$$

With:
Uinj = Utility of consumer *i* on attribute *n* for product *j*
Ajn = Score of product *j* for attribute *n*

Product

- Ideal point model of preferences: relative position on a scale (design, colour, taste)

$$Uinj = 1 - |Ajn - Pin|$$

With:
Uinj = Utility of consumer i on attribute n for product j
Ajn = Score of product j for attribute n
Pin = Preference of consumer i for attribute n

Product

- Besides individual preferences, consumers also have social preferences for products
- Networks play a critical role in social effects, and much can be said about preferential attachment

$$Uinj = Nj/N$$

With:

Uinj = Utility of consumer *i* on attribute *n* (here the social attribute) for product *j*

Nj = Number of neighbours consuming product j

N = Number of neighbours

Product

- The utilities (vector, ideal point and social) are summed to construct a total utility. Beta indicates the relative weight of each utility in the total utility

$$U_{ij} = \frac{\sum_1^n (\beta_n * U_{ijn})}{n}$$

With:

Uij = Utility of consumer *i* for product *j*, ranging from 0 to 1

ßn = Weighting of attribute n, ranging from 0 to 1

Uijn = Utility of consumer *i* for product *j* for attribute n

Product

- The weighting of utilities can be different for different agents, thus including heterogeneity (segments!) in the consumer population

$$U_{ij} = \frac{\sum_1^n (\beta_{in} * U_{ijn})}{n}$$

With:

Uij = Utility of consumer *i* for product *j*, ranging from 0 to 1

ßn = Weighting of attribute n, ranging from 0 to 1

Uijn = Utility of consumer *i* for product *j* for attribute n

Product

- Needs can be represented as the type of (conflicting!) preferences satisfied by the attributes belonging to a product
- The decision process of consumers can be represented by the values of the betas
  - Cognitive effort: the number of product aspects taken into account (involvement)
  - Social v.s individual orientation: weighting of social utility

Product

- Note! The formulation of utility has the lay-out of a regression formula
- But: for each simulated consumer this formula may be different. Moreover, the utilities and their weigting are subject to change

Price

- The concept of value-for-money is being used to link price to utility
- the value for money will be closer to the utility of the product the lower its price and the higher the consumers budget

$$V_{ij} = U_{ij} * B_i * (1 - P_j)$$

With:

Vij = Value for money of product *j* for consumer *i*

Uij = Utility of consumer *i* for product *j*

Pj = Price of product *j*, ranging from 0 to 1

Bi = Budget of consumer *I*, ranging from 0 to 1

Placement

First a focus on distance:

- Simple formalization: distance as additional attribute in the model
- Heterogeneity in distance score expresses the distance to a buying location.
- Weighting the distance attribute (with a ß) distinguishes between markets where distance is important (e.g., groceries) versus unimportant (e.g., e-commerce)

Promotion

- Promotional activities by ***producers*** (i.e., mass media, viral techniques) and other stakeholders (government, NGO's)
- Interaction between ***consumers***, such as Word-of-Mouth (normative & informative)

Promotion – by producer

- Convince consumers to attach more weight to a product attribute on which the product scores well (increasing the ß)
- Convincing the consumers that their utility for attribute *n* would be higher than they currently believe (increase Uinj).
- Inform consumers about other consumers (famous role models) that already use a product, thus affecting the social attribute.

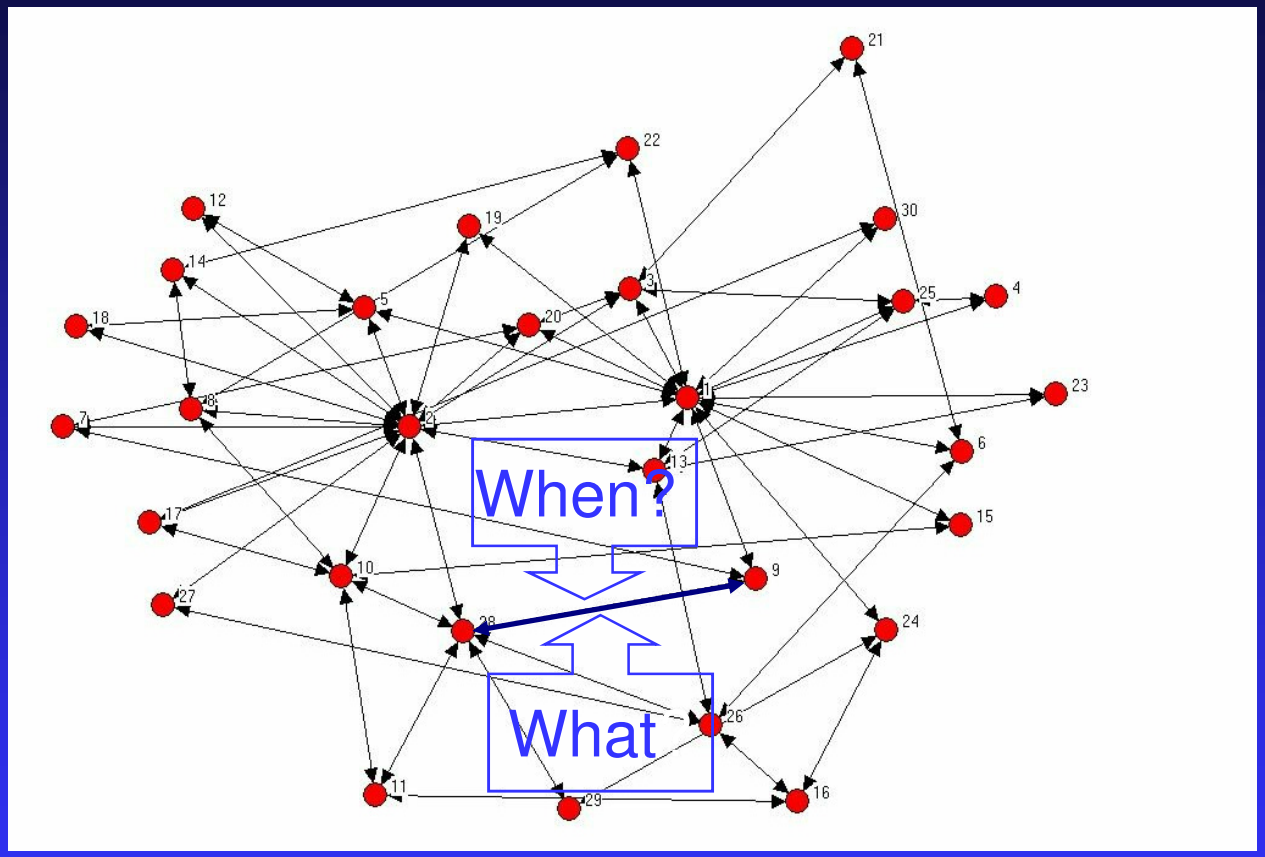
Promotion – by producer

- Who to address?
  - Mass media
  - Random consumers
  - Consumers with particular characteristics (segments)
  - Clusters of connected consumers
  - A mix of strategies?

Promotion – consumers: word-of-mouth

- Specific information: exchange information concerning the product utilities (Uinj), e.g. fuel consumption of a car
- Generic information: discuss the importance of certain attributes (weighting of attributes), e.g. the importance of safety of a car.
- Norms: consider the number of neighbours consuming a particular product without considering further information (social attribute as defined in product)

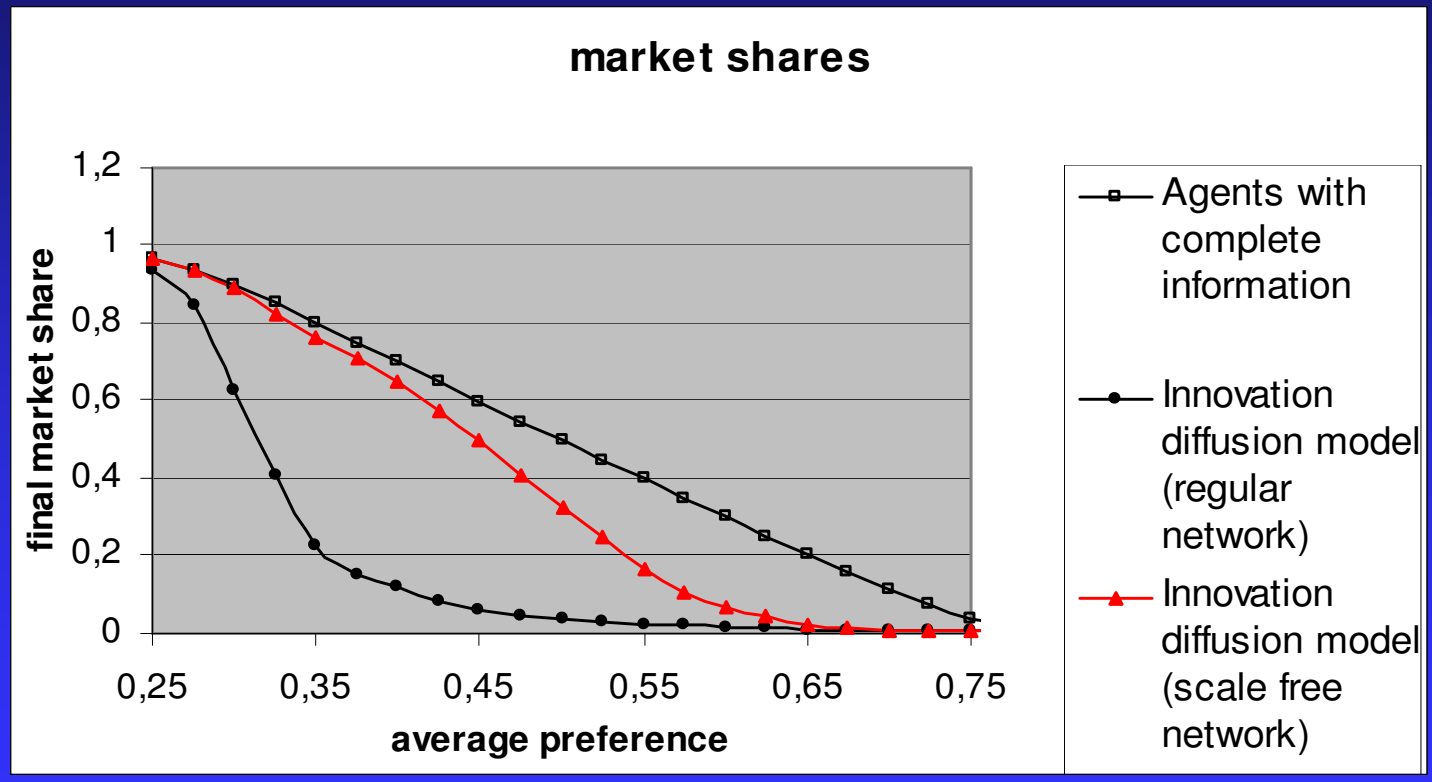
Promotion – consumers: word-of-mouth



Scale free network connecting individual agents

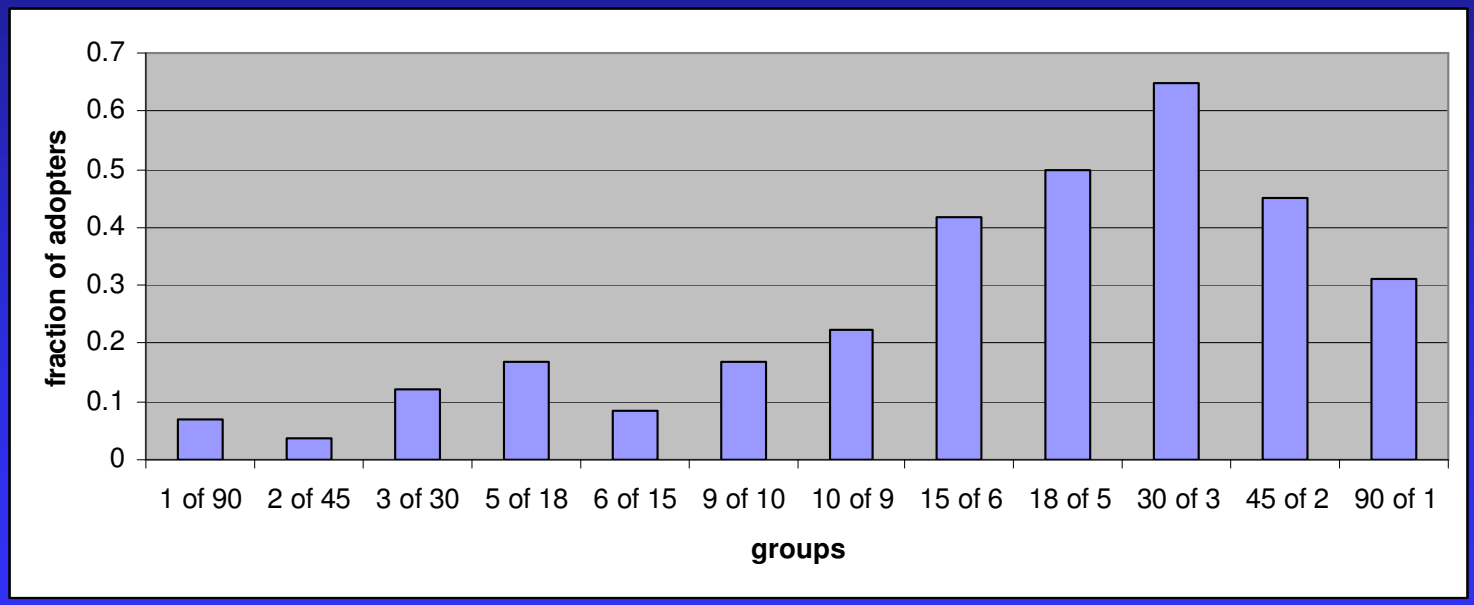
(Barabasi & Albert)

Again, back to the diffusion of innovation



Some preliminary results on promotion

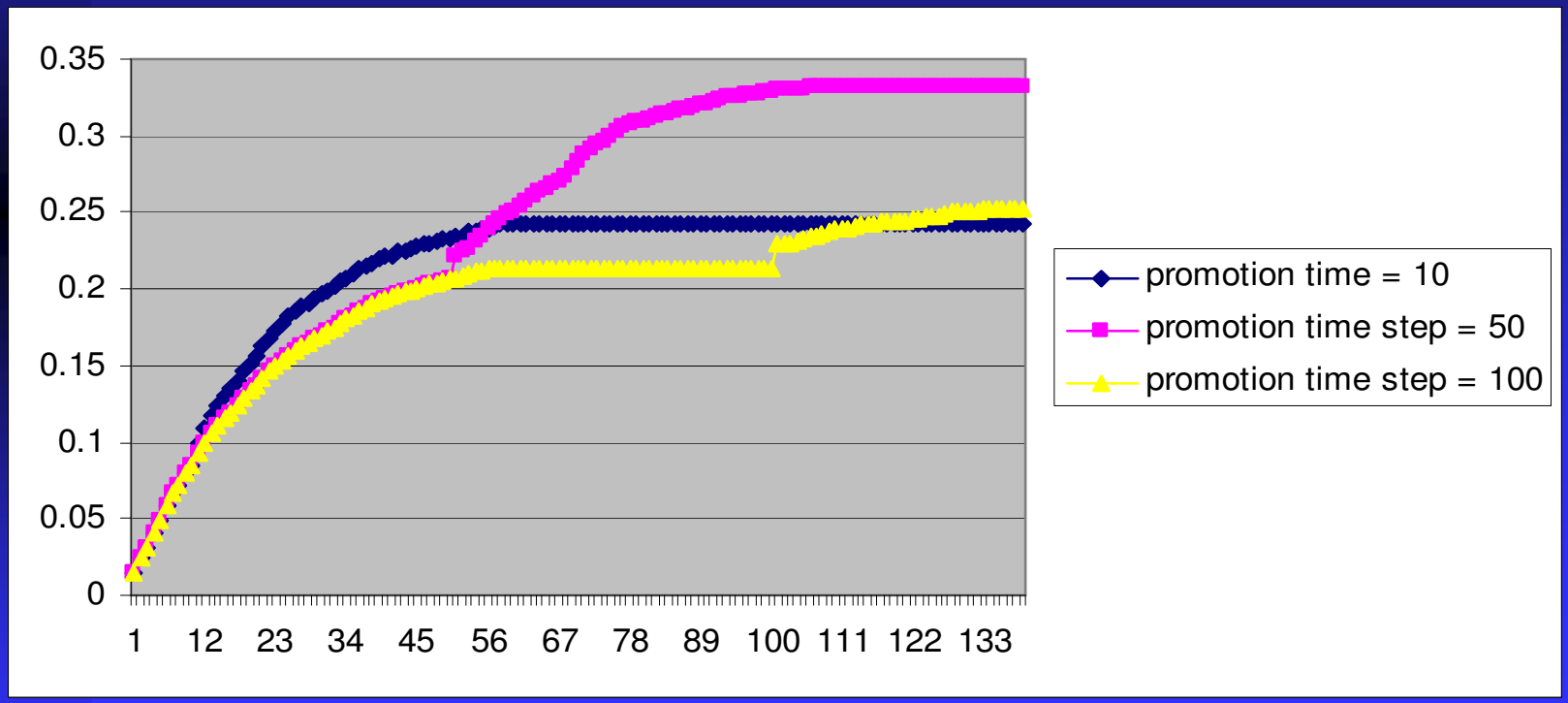
The problem: who should we address in a promotion campaign:
a cohesive group, or random people?



1 of 90 means targeting 1 group of 90 agents
90 of 1 means targeting 90 groups of 1 agent

Some preliminary results on promotion

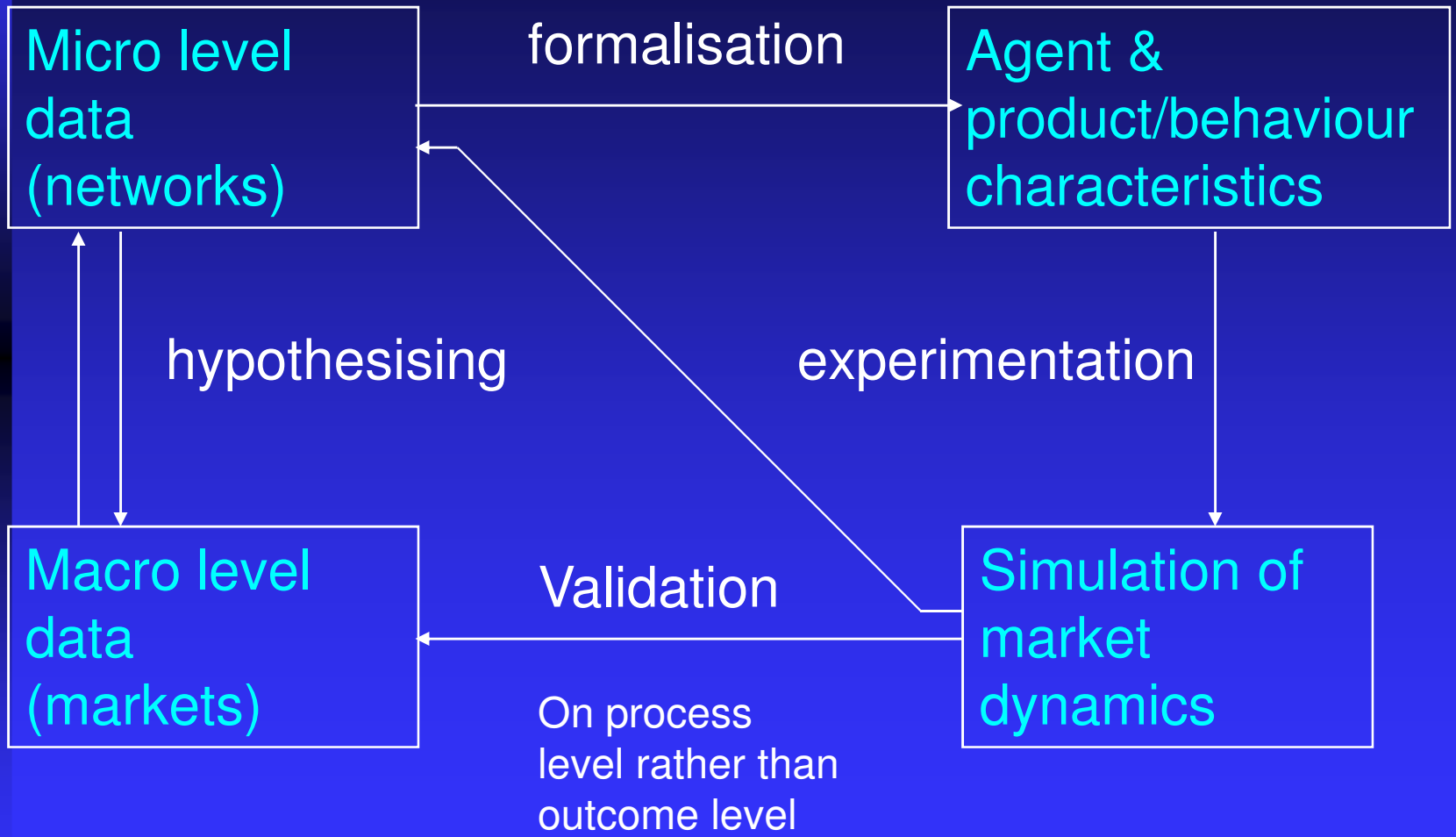
The problem: when should we start a promotion campaign



Empirical data

- Macro level sales data (& timing of marketing strategies) – development of market shares over time and indication of marketing effects
- Micro level sales data (loyalty card data) – how do consumers behave in a market
- Micro level data on decision-making – getting grip on the decision-making process of consumers (attributes & weights)

Research organisation



Conclusions

- It is essential to capture behavioural processes and drivers in simulation models of consumer behaviour
- Formalising the four P's provides a perspective on:
  - modelling complexities in markets
  - implementing and testing marketing strategies in complex markets
  - The linkage of simulation models to empirical data on both the micro and macro level

Simulating market dynamics:

It's not aimed at predicting the future,
It's about shaping it!

The European Social Simulation Association

Special interest group on market dynamics