Emergence and Evolution of Coalitions in Buyer-Seller Networks

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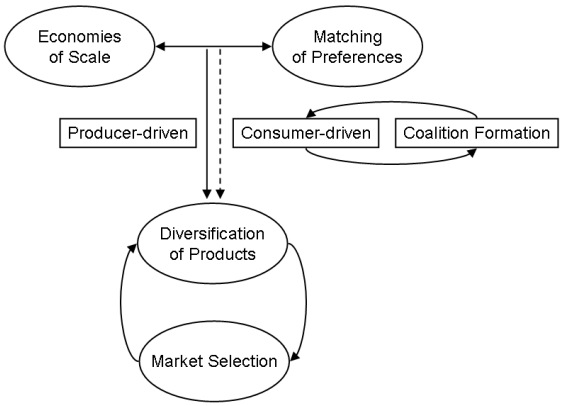
Agenda

Motivation

- Internet: opportunity to form *spontaneous, location-independent communities*
  - emergence of services based on *social networking*
- Application: electronic markets
  - "Buying clubs" for e-commerce have been around for several years, but the concept itself has not really become popular.
  - advantage: economies of scale
    increase in quantity → decrease in cost-per-item
  - Tsvetovat & Sycara (2000): formation of groups of buyers to obtain volume discounts from sellers

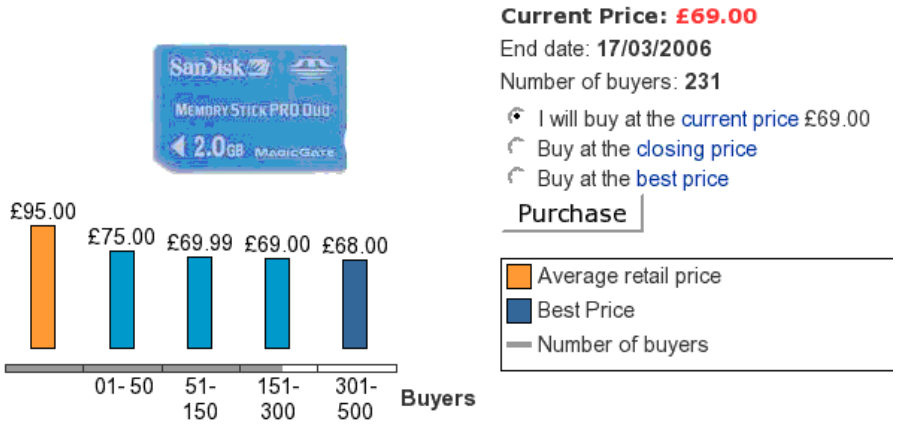
Coalition Formation:

- alternative to achieve trade-off between *economies of scale* and *matching of preferences*:



Examples

- buying clubs for food: few self-organised groups
- co-buying web sites such as *www.letsbuyit.com*:



Drawbacks and Incentives

- "more buyers, lower cost" principle based on limited selection of products ⇒ buyers have to *compromise*
- "buying clubs": waiting time and risk of not concluding a deal (additional overhead)

Buyers
- volume discount
- customised items: match of preferences
- sharing of search cost
- "bundle search"

Sellers
- better predictability of sales volumes
- customized items: increase of sales
- reduction of transaction costs

Related Work

- Tsvetovat and Sycara (2000): Incentive analysis for the formation of "buying clubs".
- Yamamoto and Sycara (2001): Coalition formation scheme; stability and efficiency analysis.
- He and Ioerger (2004): Coalitions as a means of minimising the cost of "bundle search".
- Sarne and Kraus (2005): Coalitions as a means of sharing the cost of searching specific sellers.

Model for Coalition Formation

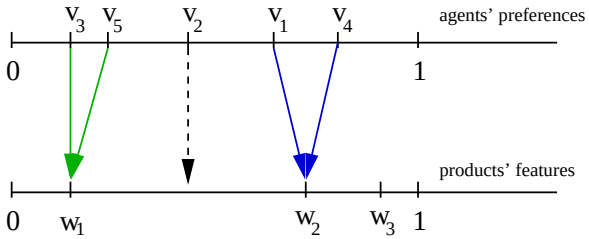
- agent-based model ⇒ buyers B and sellers S (represented by their products)
- focus: dynamics of *creation*, *evolution*, and *breakup* of coalitions of buyers
- emphasis on:
  - effect of *heterogeneity* of agents' preferences ⇔ *size*, *number* and *lifetime* of coalitions
  - existence of *stationary* and *non-stationary regimes* (stable and unstable coalitions), *transition* from one regime to the other

Heterogeneity:

- products j: vector of *features* $[w_{j,1}, ..., w_{j,k}]$
- buyers i: *preferences* for product features $\Rightarrow [v_{i,1}, ..., v_{i,k}]$

Example:

- buyer $i \longrightarrow v_i$, seller/product $j \longrightarrow w_j$, distributions $\mathcal{F}(v)$, $\mathcal{G}(w)$
- each agent buys only one product
  - different buying modes: individually, in coalitions, new demand



Utility

- agents: *rational* and *self-interested* $\longrightarrow$ maximise their private utility over time
- benefit of agent i from purchase of product j depends on:
  - distance between features w_j and preferences v_i: $\Delta_{ij} = |w_j - v_i|$
  - price of product j, which depends on quantity sold: $p_j = P/N_j^{\beta}$ (price elasticity: $\beta = 0.5$)
- agent's utility: compromise between cheap price and match of preferences

$$U_i = \frac{1}{p_j}\left[1 - |w_j - v_i|\right]$$

  - *indirect cost* for joining a coalition $\Rightarrow$ commitment unsuccessful coalition: $U_i = 0$ (risk of failure)

Agent's actions and decisions

1. purchase product j individually
   - advantage: get product immediately
   - disadvantage: pay higher price $p_i = P$

$$k_i^{\mathrm{ind}}(t) \propto \frac{1}{P}\left[1 - \Delta_{ij}\right]$$

2. join existing coalition j with a set of other buyers N_j
   - advantage: pay lower price $p_i = P/\sqrt{N_j}$
   - disadvantage: (i) waiting time until coalition has reached critical size $N_j \geq N_{\mathrm{thr}}$, (ii) risk of coalition failure

$$k_i^{\mathrm{coal}}(t) \propto \frac{\sqrt{N_j}}{P}\frac{N_j}{N_{\mathrm{thr}}}\left[1 - \Delta_{ij}\right]$$

1. initiate new coalition k and wait for other buyers to join
   - advantage: get product k according to preferences: $\Delta_{ik} = 0$
   - disadvantage: (i) risk of coalition failure: $N_k(t_0) = 1 \ll N_{\mathrm{thr}}$, (ii) waiting time until coalition has reached critical size

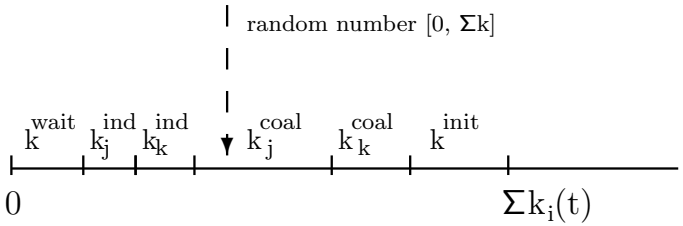
$$k_i^{\mathrm{init}}(t) \propto \frac{\sqrt{1}}{P}\frac{1}{N_{\mathrm{thr}}}$$

2. postpone decision
   - advantage: no commitment, open for future possibilities
   - disadvantage: (i) wait for product, (ii) uncertainty of future

$$k_i^{\mathrm{wait}}(t) \propto \exp\left(-\alpha t\right)$$

Stochastic decision dynamics

- each possible action has a certain weight k_i
- *decision:* stochastic draw among the weighted possibilities
  - path dependence: symmetry break
  - positive feedback: decision affects weights k_j of other agents
  - consequences for utility at $t \to t_{\rm end} \Rightarrow$ affects strategy in repeated games



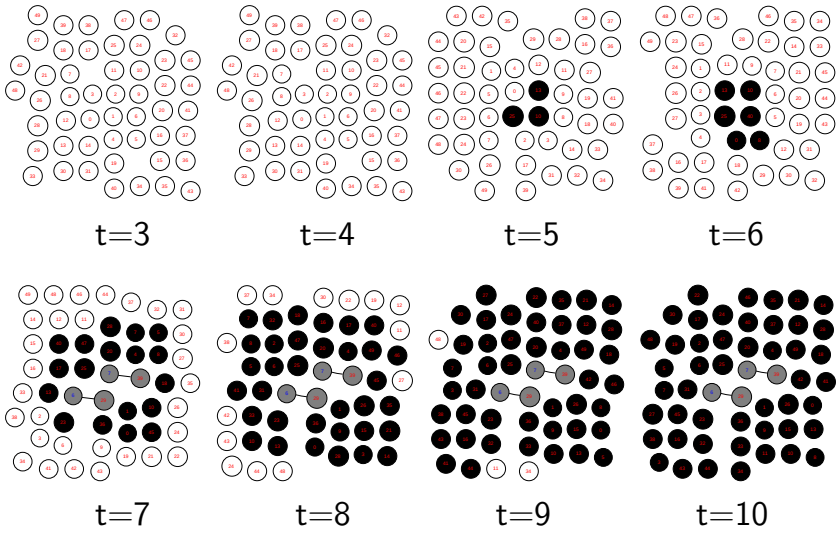
Scenarios of coalition formation

1. individual purchasing behaviour, i.e., no buyer-seller network exists among the agents,
2. formation of several heterogenous coalitions, i.e., a number of buyer-seller networks which are not connected,
3. condensation to a single giant coalition, i.e., a buyer-seller network involving all agents.

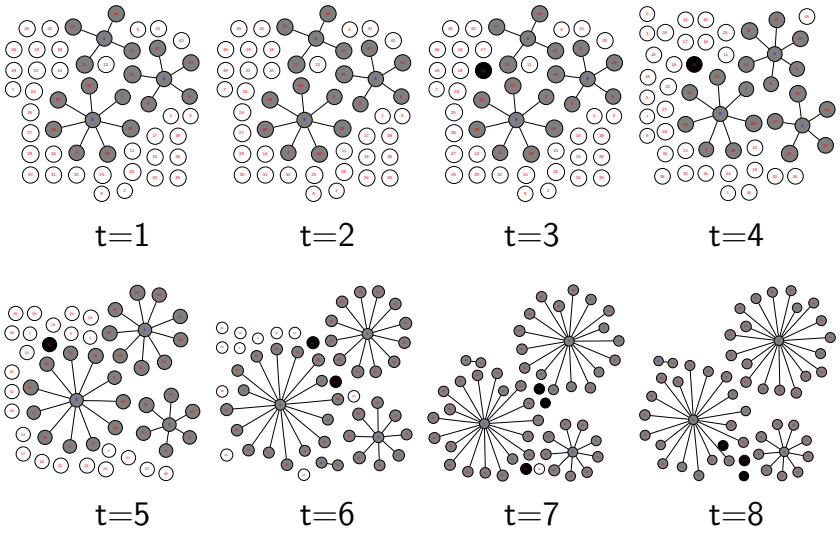
The transition between these scenarios is governed by

- heterogeneity of agents' preferences, η
- threshold for successful coalitions, $N_{\rm thr}$

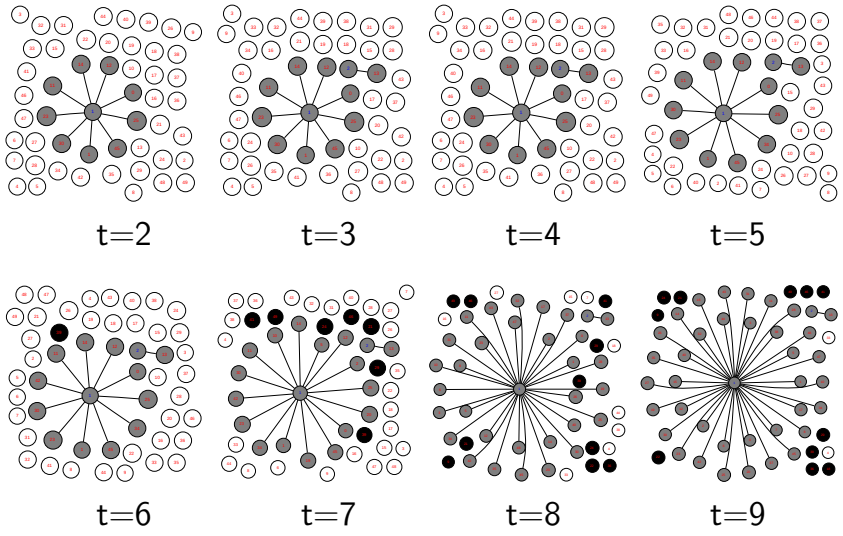
Individual purchasing ($N_{\rm thr} = 50$)



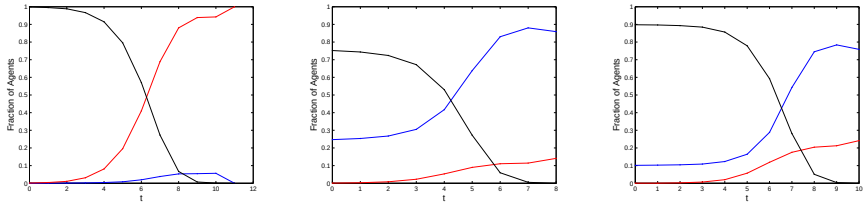
Several heterogeneous coalitions ($\varepsilon = 0.04$, $N_{\rm thr} = 5$)



Single giant coalition ($\varepsilon = 0.05$, $N_{\text{thr}} = 20$)

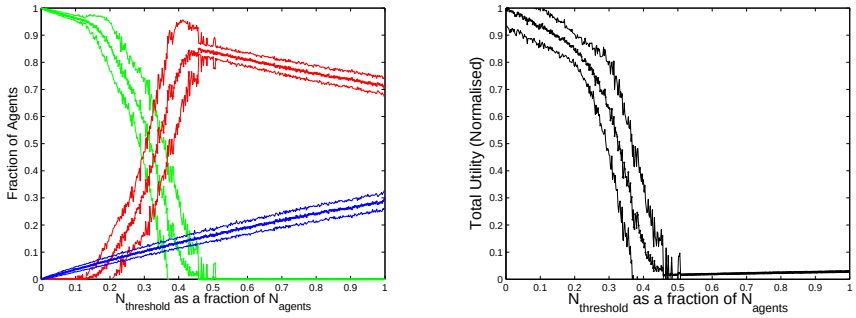


Fraction of agents in coalitions vs. time



Utilities	indiv.p.	several c.	giant c.
Avg	0.43	1.25	1.01
StDev	0.04	0.24	0.36

Influence of coalition threshold N_{thr}



Extensions

- buyer's dynamics
  - different preferences (multidimensional case)
  - incomplete, bounded in time information about products
  - buy different products with limited budget → competition
- seller's dynamics
  - products with different features (multidimensional case)
  - offer more than one product
  - limited production ressources → competition
- repeated games
  - buyers: memory about the failure/success of coalitions
  - sellers: memory about agents ⇒ loyalty reward
  - stationary/non-stationary coalitions

Conclusions

- *coalition*: social network of agents to reach certain goal
  - get customized products at a lower price
  - *compromise* between preferences and price
  - *risk* of failure
- modeling framework: formation of coalitions vs. individual buying
  - focus: heterogeneity of agents/producs, threshold for success
  - three different scenarios $\Rightarrow$ utility maximization at several heterogeneous coalitions
- extensions towards multiple products/preferences, learning effects, competition scenarios
- *consumer driven economies of scale*
  - match of preferences, predictability of sales, reduced costs