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# *Do Consumers Shift from Private to Shared Ownership?*

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# Problem setting

- **Starting questions**
  - How many goods do we own? For how long do we use them? And, what about our neighbours?
    Vacuum cleaners; drills
    Internet connection
    Private cars
  - Wouldn’t it be more convenient to organise and make a common purchase and share utilisation?

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  - Do consumers shift from individual consumption and ownership to shared consumption and shared ownership?
  - Under which conditions/characteristics/preferences?

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  - Do consumers shift from individual consumption and ownership to shared consumption and shared ownership?
  - Under which conditions/characteristics/preferences?

- **Policy implication**
  - Unequal access to essential goods (too expensive for individual purchase): internet, transport, energy
  - Reduce not-sustainable individual consumption and ownership

# More equal model in sharing economy

| | Sharing Economy | Fractional Ownership |
|---|---|---|
| | Increase access<br>Sustainable consumption | |
| | "consumers granting each other temporary access to under-utilized physical assets ('idle capacity'), possibly for money" (Frenken & Schor, 2017) | |
| Ownership | Individual | |
| Consumption | Access-based (payment - short rental) | |
| Coordination | Market-based | |
| Good | Anti-common<br>Right of exclusion<br>Increases power concentration | |

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| | Increase access<br>Sustainable consumption | |
| | "consumers granting each other temporary access to under-utilized physical assets ('idle capacity'), possibly for money" (Frenken & Schor, 2017) | **True sharing:** "bottom-up community-led initiatives for shared consumption and ownership, to increase affordable access to goods for essential services" (Pasimeni, 2021) |
| Ownership | Individual | Shared |
| Consumption | Access-based (payment - short rental) | Access-based (group coordination) |
| Coordination | Market-based | Social rules |
| Good | Anti-common<br>Right of exclusion<br>Increases power concentration | Common-pool resource<br>Shared good (not private, not public)<br>Luxury goods (exclusive by nature) |

# Agent-Based Model

## Extends Pasimeni and Ciarli (2018) – SPRU WP

*Evolutionary game theory of coalition formation with the "best reply" type of adjustment dynamic*

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  - Agents tie links, communicate, evaluate options, establish stable groups and share

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- Agents interact to form a stable sharing groups:
  - Agents tie links, communicate, evaluate options, establish stable groups and share
  - Stability of sharing groups is necessary condition (purchase and share common good)
    - Agents establish a group when they reach stability (Pareto optimal)
      - all agents in group maximize individual utility (compared to other 2 options)
      - none of them has the incentive to move to another group or to purchase alone
      - no other agent wants to enter in this sharing group

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      - no other agent wants to enter in this sharing group
- Once the group is established, the decision to adopt the shared good is taken
- Replacement after certain period of time-use

# The utility functions (Cobb-Douglas)

**1)** Public provider (no purchase)

$$U_{i1} = \underbrace{[e_i - d_i p_1]^{\theta_i}}_{\text{1) Preference for income}} \underbrace{(d_i * K)^{1-\theta_i}}_{\text{2) Preference for consumption}}$$

**2)** Individual purchase:

**3)** Shared purchase:

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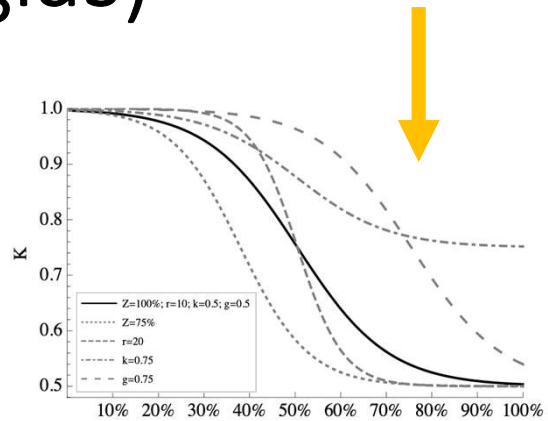


**2)** Individual purchase:

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# The utility functions (Cobb-Douglas)

**1)** Public provider
(no purchase)

1) Preference for income

2) Preference for consumption

**2)** Individual purchase: $U_{i2} = \overbrace{[e_i - (d_i p_2 + \frac{I}{L_2})]^{\theta_i}}^{\text{1) Preference for income}} \overbrace{(d)^{1-\theta_i}}^{\text{2) Preference for consumption}}$

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**3)** Shared purchase:

# The utility functions (Cobb-Douglas)

**1)** Public provider
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**2)** Individual purchase:

**3)** Shared purchase: $U_{i3} = \underbrace{[e_i - (d_i p_3 + x_i)]^{\theta_i}}_{\text{1) Preference for income}} \underbrace{\{(d_i + D_{-i})[\frac{\alpha_i d_i}{d_i + D_{-i}} + (1-\alpha_i)(\frac{\beta_i x_i}{x_i + X_{-i}} + \frac{1-\beta_i}{N})]\}^{1-\theta_i}}_{\text{2) Preference for consumption (in group)}}$

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1) Preference for income

2) Preference for consumption (in group)

a. Proportional division rule based on agent's demand
b. Proportional division rule based on agent's monetary contribution
c. Equal shared division rule based on group size

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1) Preference for income

2) Preference for consumption (in group)

a. Proportional division rule based on agent's demand
b. Proportional division rule based on agent's monetary contribution
c. Equal shared division rule based on group size

$$\sum d_i \leq S \quad \text{and} \quad L_3 = \frac{S}{\sum d_i} \quad \text{and} \quad \frac{I}{L_3} \leq \sum x_i \leq \frac{I}{L_3} * 1.1$$

# Model initialisation

| Parameter | Symbol (a) | Benchmark (b) |
|---|---|---|
| *Product features* | | |
| Capacity | $S{=}S_2{=}S_3$ | 600 |
| Investment | $I{=}I_2{=}I_3$ | 1300 |
| Price | $p{=}p_1{=}p_2{=}p_3$ | 1.5 |
| *Consumer features* | | |
| Demand | $d_{delta}$ | 30 |
| | $d_{mean}$ | 50 |
| Income | $e_{delta}$ | 450 |
| | $e_{mean}$ | 900 |
| Preference for income | $\theta_{delta}$ | 0.25 |
| | $\theta_{mean}$ | 0.5 |
| Preference for demand division rule | $\alpha_{delta}$ | 0.25 |
| | $\alpha_{mean}$ | 0.5 |
| Preference for contribution division rule | $\beta_{delta}$ | 0.25 |
| | $\beta_{mean}$ | 0.5 |
| *Public service features* | | |
| Lowest value of $K$ | $k$ | 0.5 |
| Steepness | $r$ | 10 |
| Sigmoid midpoint | $g$ | 0.5 |
| General provider capacity | $Z$ | 0.75 |

200 heterogenous agents

$d_{mean}$ : average demand in population

$d_{delta}$ : distance between min and max values of demand in the population

$d_i \in \text{UNIFORM}\ (d_{min}\ ;\ d_{max})$

$d_{min} = (d_{mean} - \frac{d_{delta}}{2})$

$d_{max} = (d_{mean} + \frac{d_{delta}}{2})$

# Finding the niche in the economy

**1. Global sensitivity analysis (full parameter space)** (Dosi et al., 2018)

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a. Elementary effect (EE) One-At-a-Time (OAT)
   - Identify the parameters most relevant to model output

b. Near Orthogonal Latin Hypercube (NOLH) DoE
   - Optimise the number of model sampling points to be observed for the selected parameters

c. Kirging meta-model estimation
   - Spatial interpolation method study the parameter space in which the number of sharing consumers is maximised

d. Sobol decomposition
   - Evaluate the individual and interaction effects of parameters on the variance of the model output.

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**3. Transition from individual ownership to shared ownership**

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- Which consumers drive it and to what extent it leads to a more sustainable model of consumption

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- Model configuration that produces the highest number of sharing consumers
- Which consumers drive it and to what extent it leads to a more sustainable model of consumption

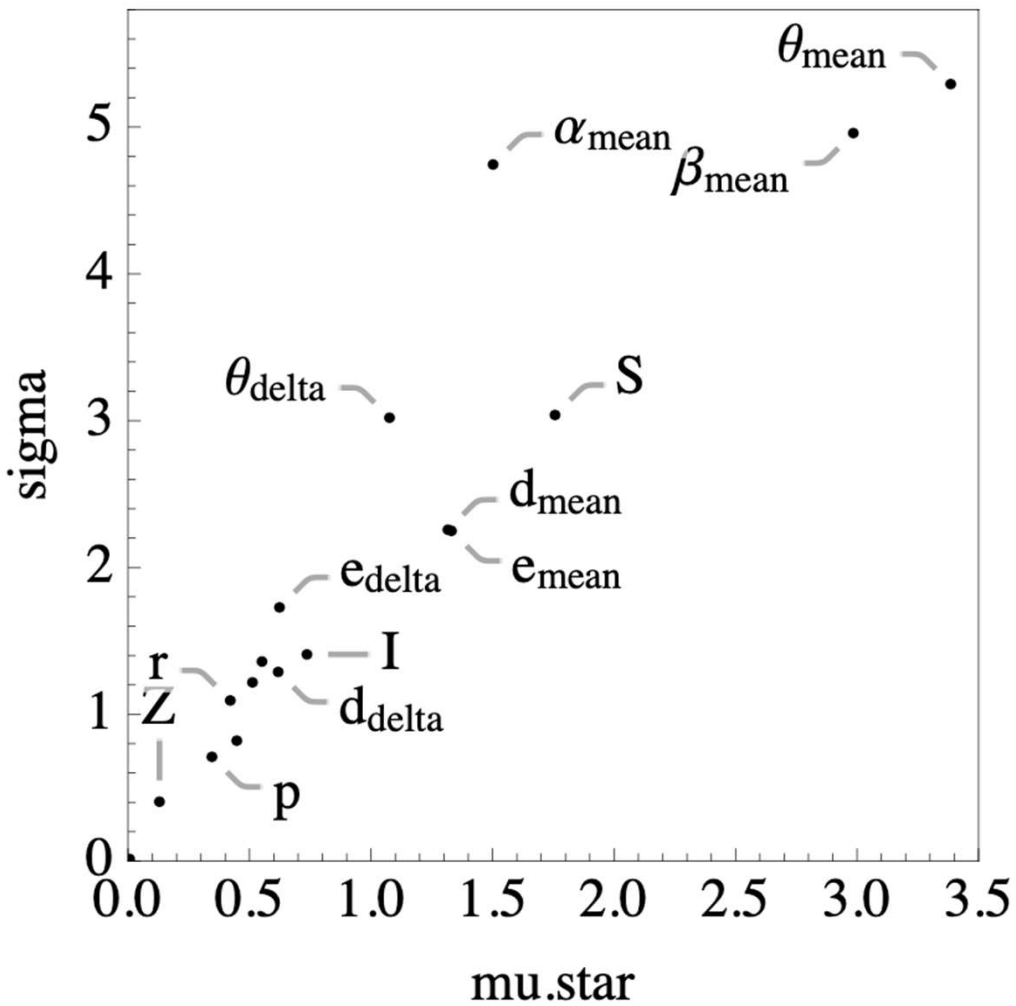
**4. Policy intervention**

- Unit price of the service/good
- Size and cost of the good

# Model initialisation (1/4) – EE (180 sim)

| Parameter | Symbol (a) | Benchmark (b) | Min. (c) | Max. (d) | OAT EE (e) |
|---|---|---|---|---|---|
| *Product features* | | | | | |
| Capacity | $S=S_2=S_3$ | 600 | 200 | 1000 | ✓ |
| Investment | $I=I_2=I_3$ | 1300 | 600 | 2000 | ✓ |
| Price | $p=p_1=p_2=p_3$ | 1.5 | 1 | 2 | ✓ |
| *Consumer features* | | | | | |
| Demand | $d_{delta}$ | 30 | 10 | 50 | ✓ |
| | $d_{mean}$ | 50 | 30 | 80 | ✓ |
| Income | $e_{delta}$ | 450 | 100 | 800 | ✓ |
| | $e_{mean}$ | 900 | 600 | 1200 | ✓ |
| Preference for income | $\theta_{delta}$ | 0.25 | 0.05 | 0.49 | ✓ |
| | $\theta_{mean}$ | 0.5 | 0.25 | 0.75 | ✓ |
| Preference for demand division rule | $\alpha_{delta}$ | 0.25 | 0.05 | 0.49 | ✓ |
| | $\alpha_{mean}$ | 0.5 | 0.25 | 0.75 | ✓ |
| Preference for contribution division rule | $\beta_{delta}$ | 0.25 | 0.05 | 0.49 | ✓ |
| | $\beta_{mean}$ | 0.5 | 0.25 | 0.75 | ✓ |
| *Public service features* | | | | | |
| Lowest value of $K$ | $k$ | 0.5 | 0.5 | 0.75 | ✓ |
| Steepness | $r$ | 10 | 10 | 20 | ✓ |
| Sigmoid midpoint | $g$ | 0.5 | 0.25 | 0.75 | ✓ |
| General provider capacity | $Z$ | 0.75 | 0.5 | 1 | ✓ |

# Elementary Effect



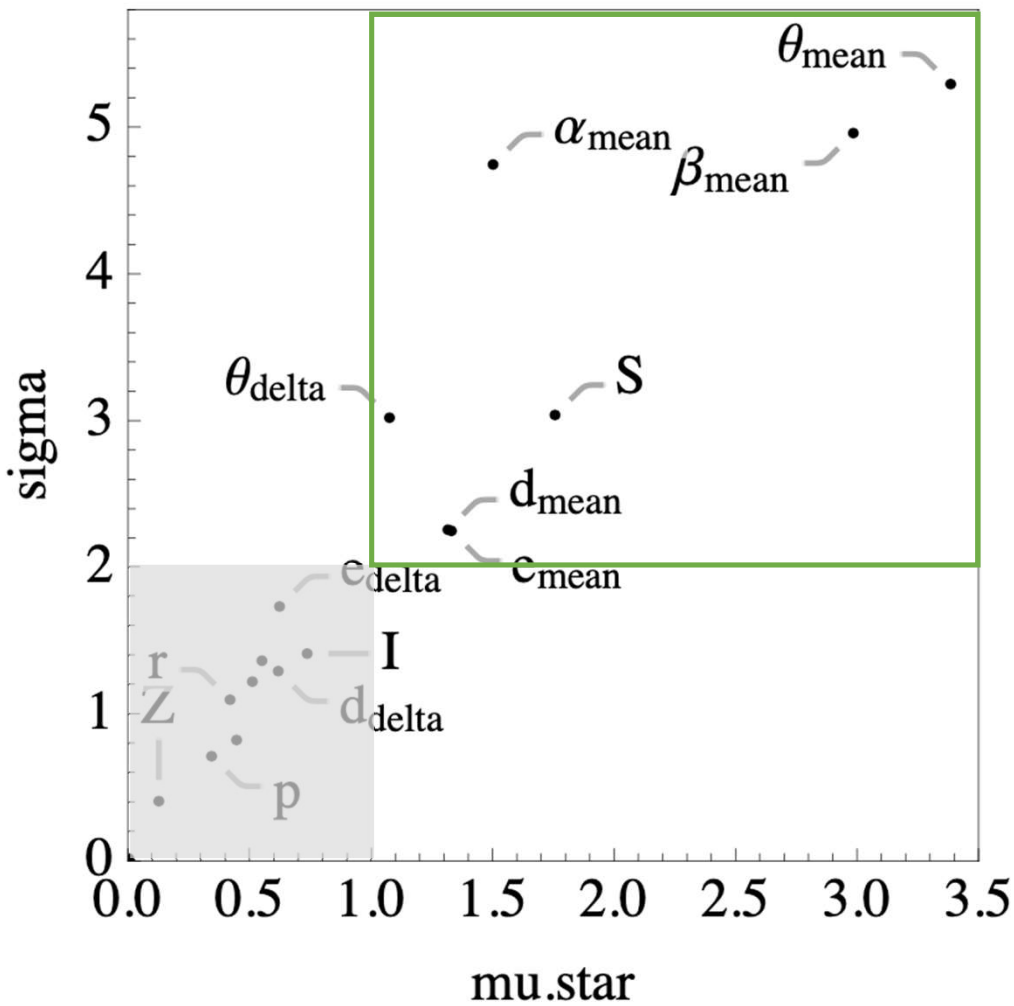

*sigma*:

Provides an estimate of the interaction effects with the other parameters (non-linear and non-additive effects of each parameter)

*mu.star*:

The overall effect of each parameter on the model outcome (shared purchase)

# Elementary Effect

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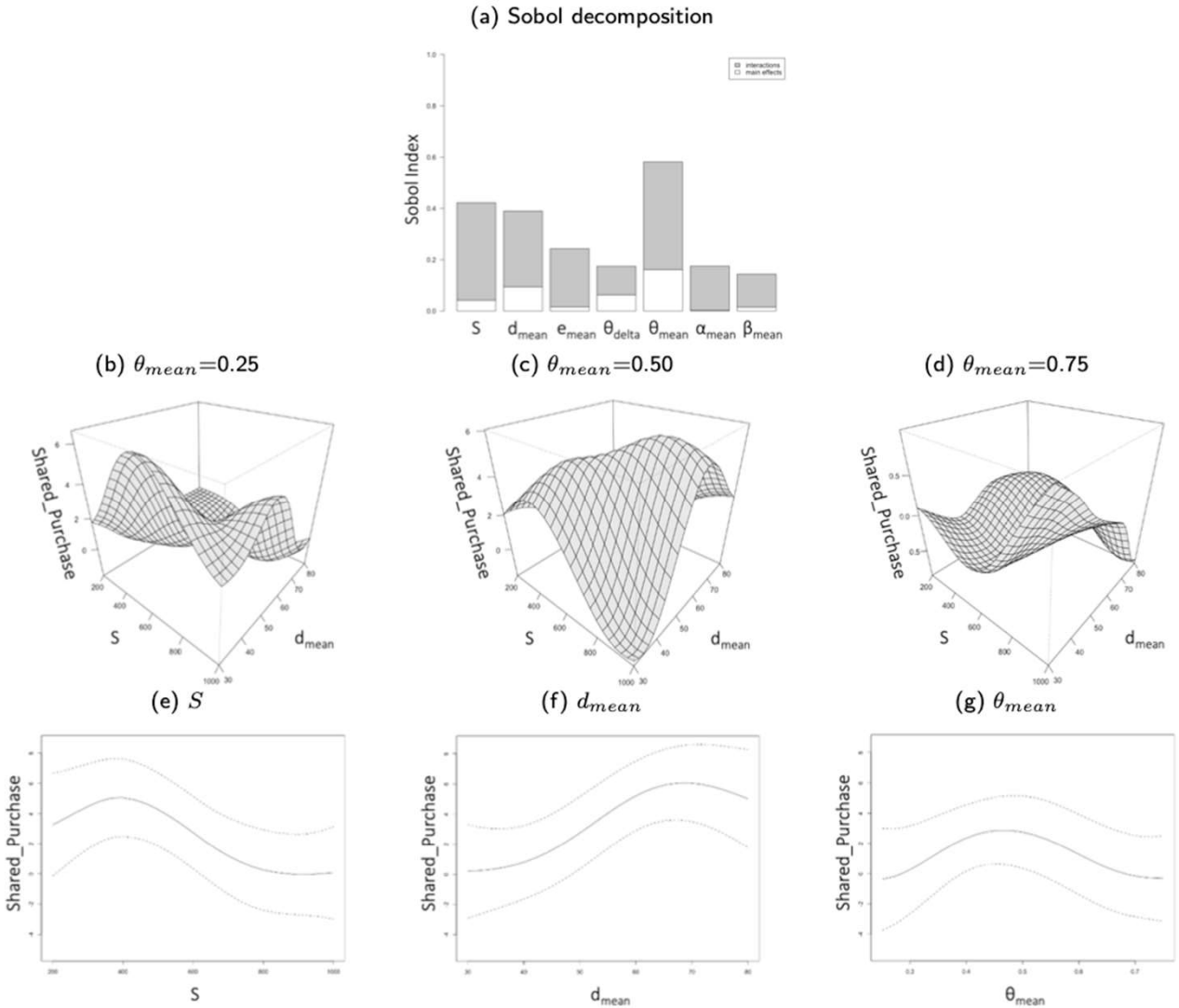
*mu.star*:

The overall effect of each parameter on the model outcome (shared purchase)

# Model initialisation (2/4) – NOLH (562 sim)

| Parameter | Symbol (a) | Benchmark (b) | Min. (c) | Max. (d) | NOLH Kriging (f) |
|---|---|---|---|---|---|
| *Product features* | | | | | |
| Capacity | $S=S_2=S_3$ | 600 | 200 | 1000 | ✓ |
| Investment | $I=I_2=I_3$ | 1300 | | | |
| Price | $p=p_1=p_2=p_3$ | 1.5 | | | |
| *Consumer features* | | | | | |
| Demand | $d_{delta}$ | 30 | | | |
| | $d_{mean}$ | 50 | 30 | 80 | ✓ |
| Income | $e_{delta}$ | 450 | | | |
| | $e_{mean}$ | 900 | 600 | 1200 | ✓ |
| Preference for income | $\theta_{delta}$ | 0.25 | 0.05 | 0.49 | ✓ |
| | $\theta_{mean}$ | 0.5 | 0.25 | 0.75 | ✓ |
| Preference for demand division rule | $\alpha_{delta}$ | 0.25 | | | |
| | $\alpha_{mean}$ | 0.5 | 0.25 | 0.75 | ✓ |
| Preference for contribution division rule | $\beta_{delta}$ | 0.25 | | | |
| | $\beta_{mean}$ | 0.5 | 0.25 | 0.75 | ✓ |
| *Public service features* | | | | | |
| Lowest value of $K$ | $k$ | 0.5 | | | |
| Steepness | $r$ | 10 | | | |
| Sigmoid midpoint | $g$ | 0.5 | | | |
| General provider capacity | $Z$ | 0.75 | | | |

# Few agents opt for shared purchase



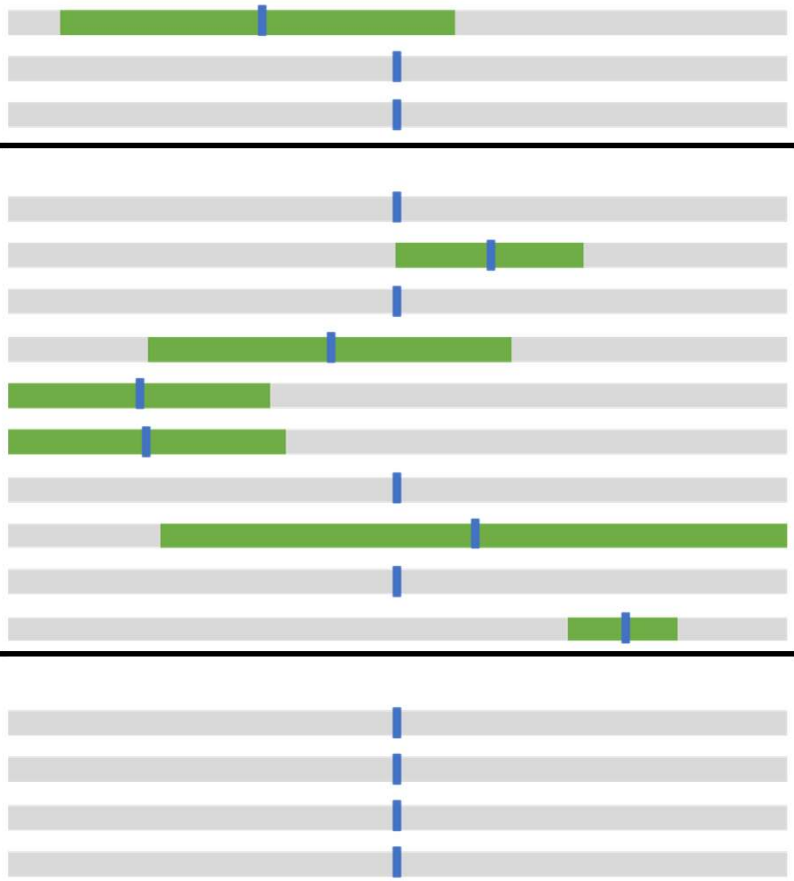

- Only a niche group of consumers chooses the shared purchase option

- Higher demand
- Medium-low average preference for income
- Small good are shared

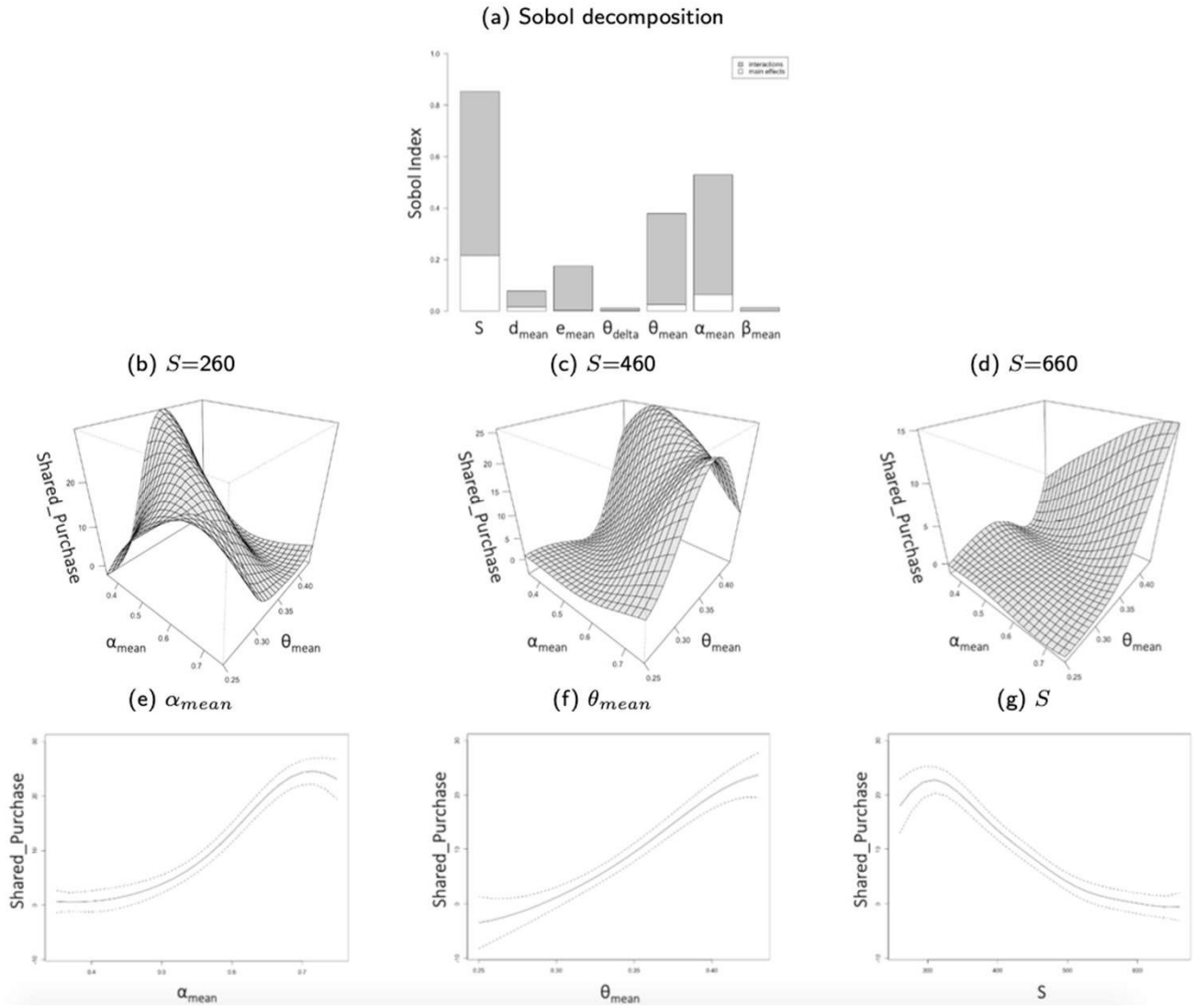
➢ Best three simulations to reduce the space

# Model initialisation (3/4) – NOLH small (562 sim)

| Parameter | Symbol (a) | Benchmark Niche (b) | Min (c) | Max (d) | NOLH Kriging (f) |
|---|---|---|---|---|---|
| *Product features* | | | | | |
| Capacity | $S=S_2=S_3$ | 460 | 260 | 660 | ✓ |
| Investment | $I=I_2=I_3$ | 1300 | | | |
| Price | $p=p_1=p_2=p_3$ | 1.5 | | | |
| *Consumer features* | | | | | |
| Demand | $d_{delta}$ | 30 | | | |
| | $d_{mean}$ | 61 | 55 | 67 | ✓ |
| Income | $e_{delta}$ | 450 | | | |
| | $e_{mean}$ | 850 | 710 | 990 | ✓ |
| Preference for income | $\theta_{delta}$ | 0.125 | 0.05 | 0.20 | ✓ |
| | $\theta_{mean}$ | 0.34 | 0.25 | 0.43 | ✓ |
| Preference for demand division rule | $\alpha_{delta}$ | 0.25 | | | |
| | $\alpha_{mean}$ | 0.55 | 0.35 | 0.75 | ✓ |
| Preference for contribution division rule | $\beta_{delta}$ | 0.25 | | | |
| | $\beta_{mean}$ | 0.645 | 0.61 | 0.68 | ✓ |
| *Public service features* | | | | | |
| Lowest value of $K$ | $k$ | 0.5 | | | |
| Steepness | $r$ | 10 | | | |
| Sigmoid midpoint | $g$ | 0.5 | | | |
| General provider capacity | $Z$ | 0.75 | | | |



# High shared purchase in the smaller space



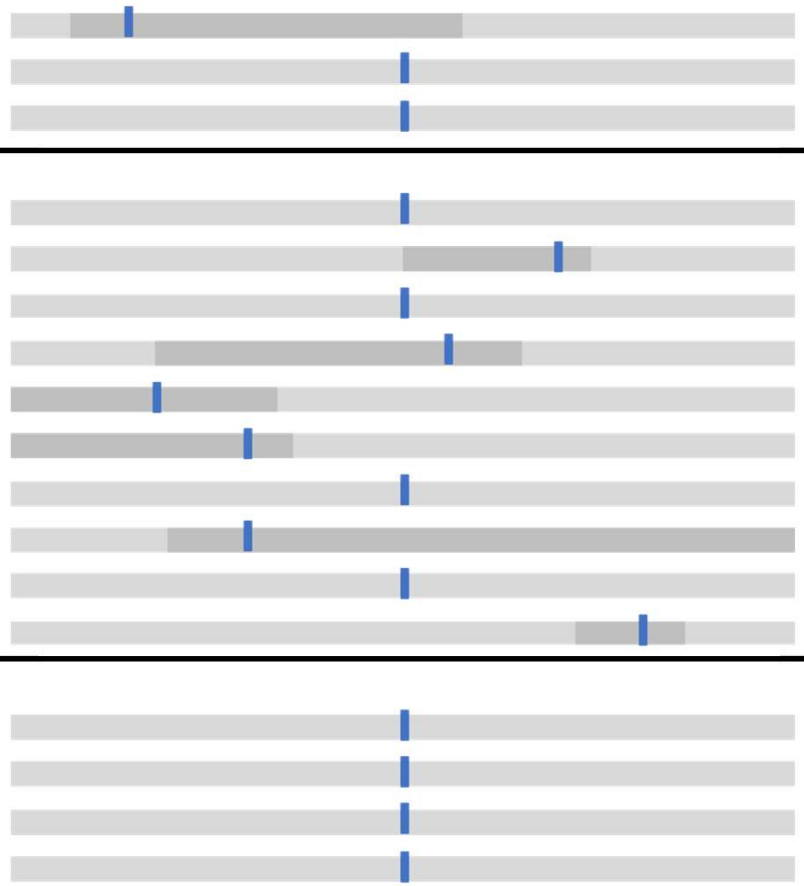

- Shared purchasers is significantly different from zero

- Mid-low preferences for income
- Mid-low preferences for the demand division rule
- Low good capacity (80% variance)

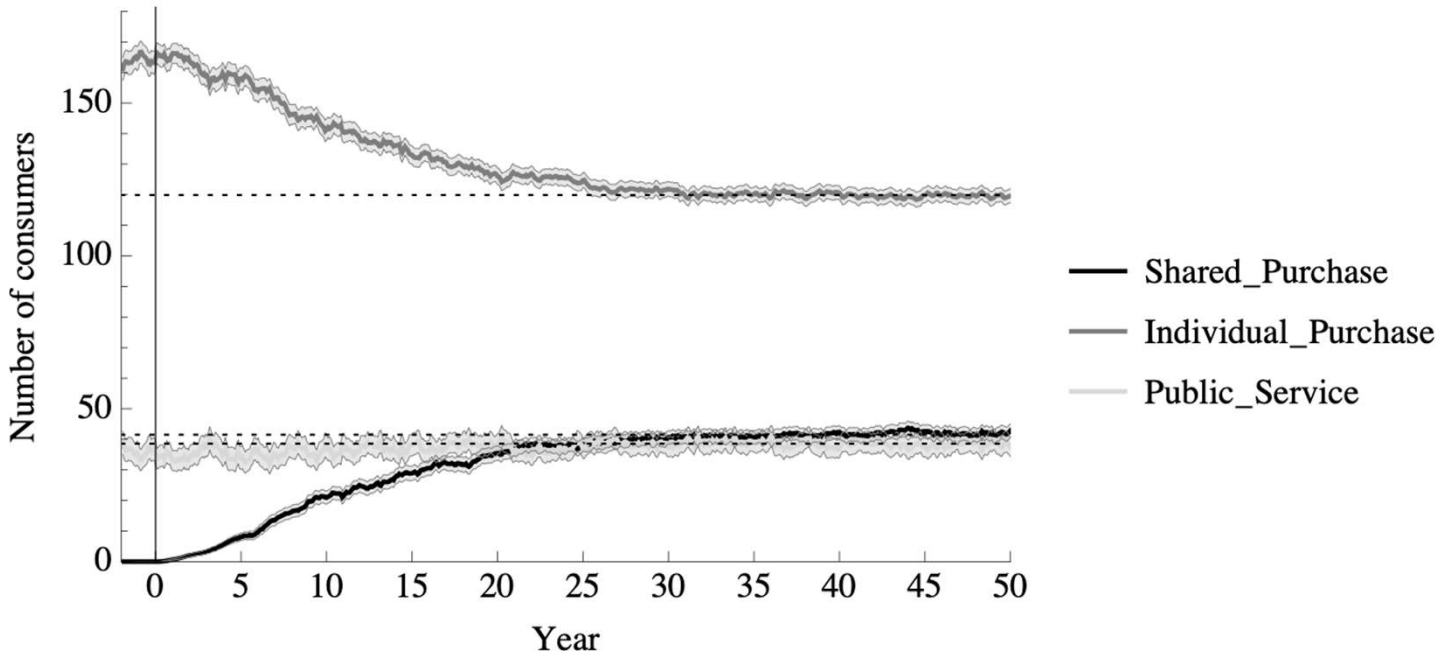
➢ Best simulation is the niche

# Model initialisation (4/4) - Niche

| Parameter | Symbol (a) | Initialisation (b) | Policy (c) |
|---|---|---|---|
| *Product features* | | | |
| Capacity | $S=S_2=S_3$ | 315.58 | ✓ |
| Investment | $I=I_2=I_3$ | 1300 | ✓ |
| Price | $p=p_1=p_2=p_3$ | 1.5 | ✓ |
| *Consumer features* | | | |
| Demand | $d_{delta}$ | 30 | |
| | $d_{mean}$ | 64.63 | |
| Income | $e_{delta}$ | 450 | |
| | $e_{mean}$ | 931.92 | |
| Preference for income | $\theta_{delta}$ | 0.13 | |
| | $\theta_{mean}$ | 0.40 | |
| Preference for demand division rule | $\alpha_{delta}$ | 0.25 | |
| | $\alpha_{mean}$ | 0.40 | |
| Preference for contribution division rule | $\beta_{delta}$ | 0.25 | |
| | $\beta_{mean}$ | 0.65 | |
| *Public service features* | | | |
| Lowest value of $K$ | $k$ | 0.5 | |
| Steepness | $r$ | 10 | |
| Sigmoid midpoint | $g$ | 0.5 | |
| General provider capacity | $Z$ | 0.75 | |

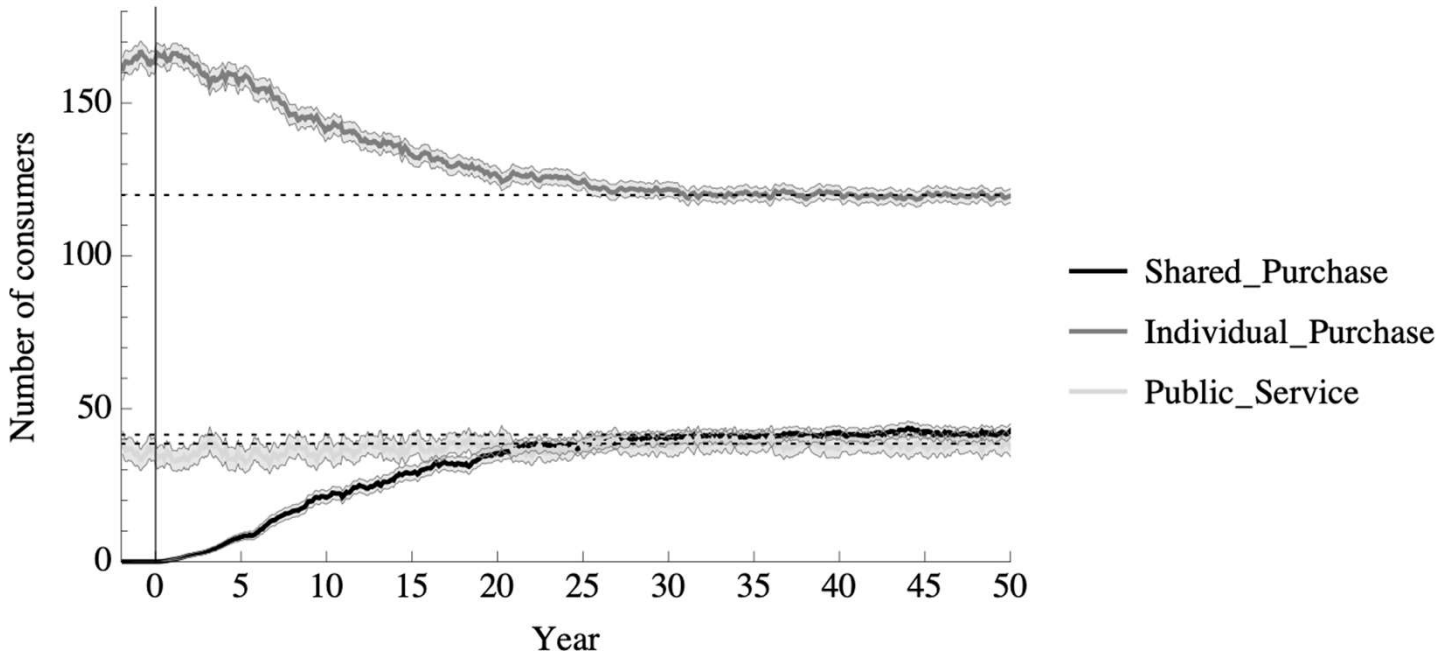


# Transition to Shared Purchase in the niche




From individual to shared purchase

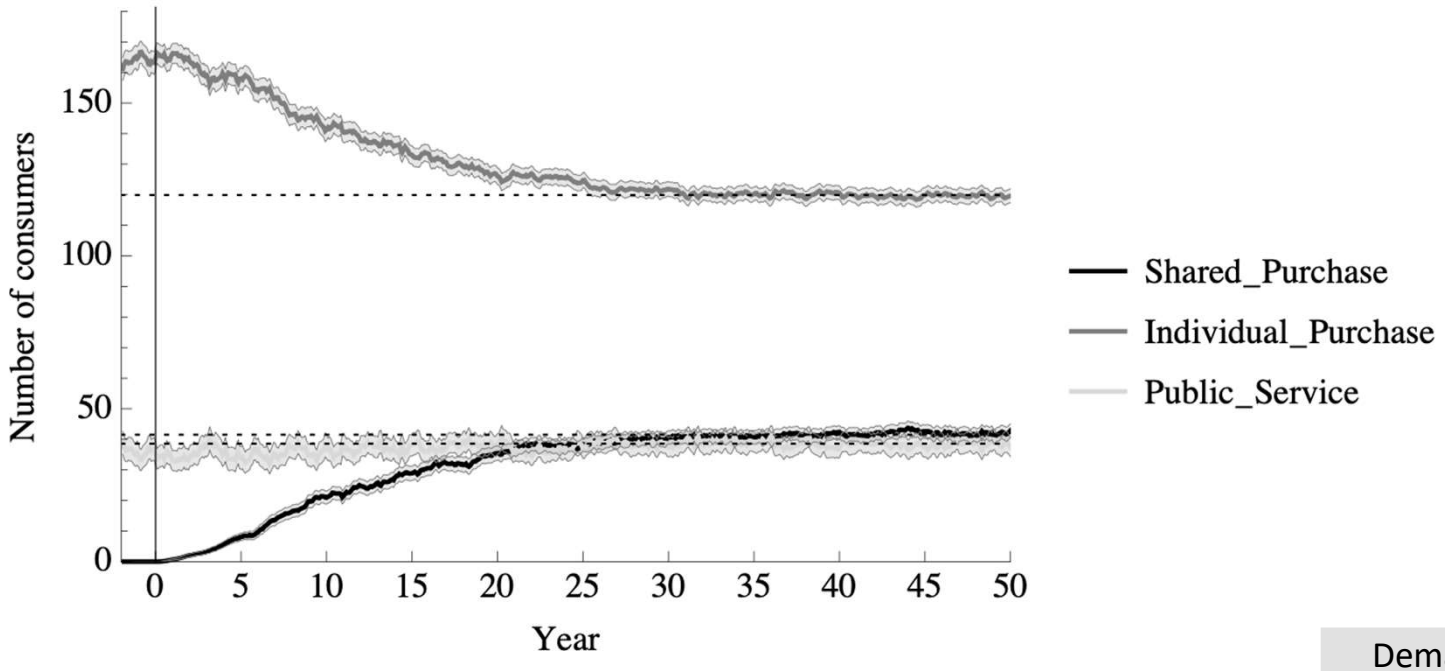
# Transition to Shared Purchase in the niche




From individual to shared purchase

-7.5% goods purchased yearly

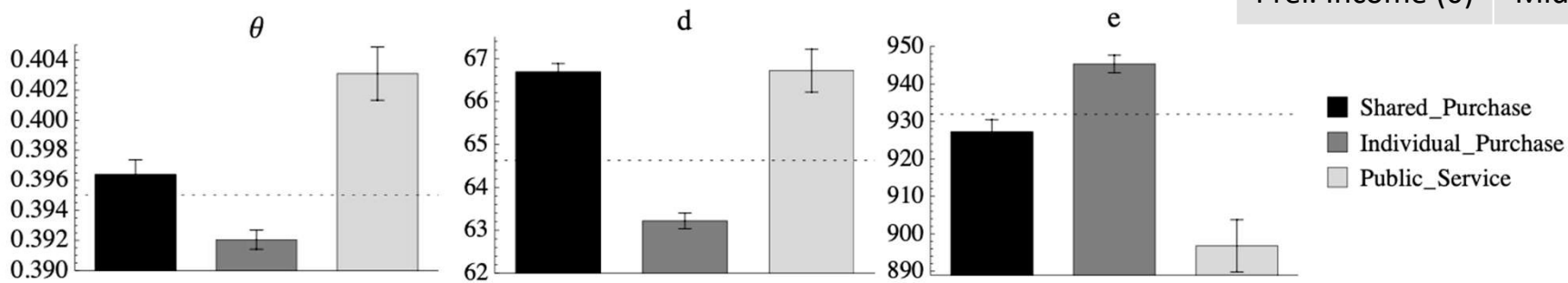
# Transition to Shared Purchase in the niche



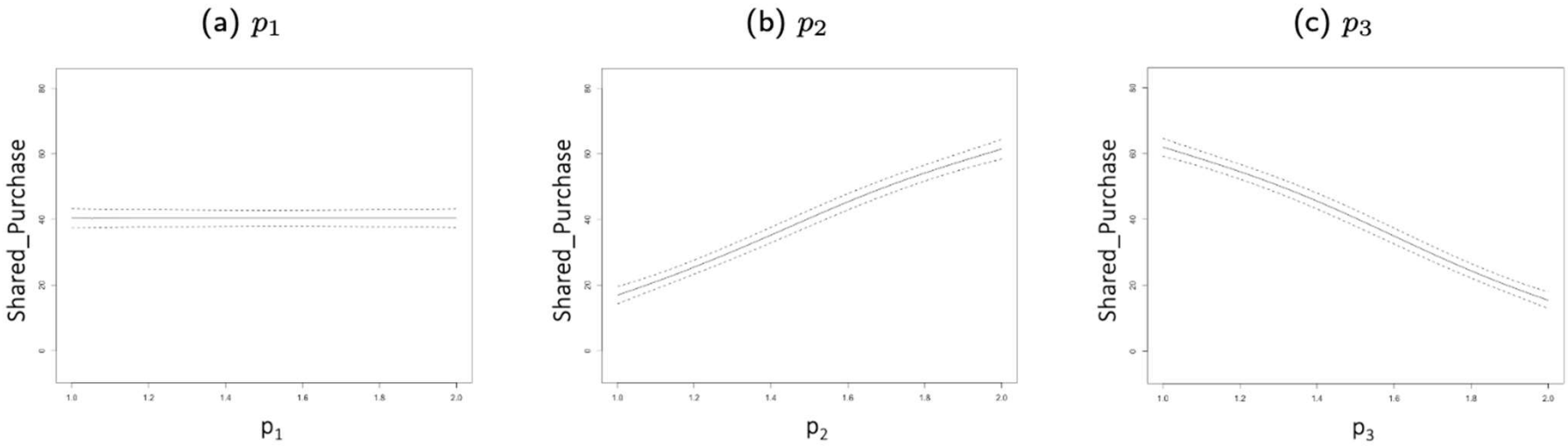

From individual to shared purchase

-7.5% goods purchased yearly

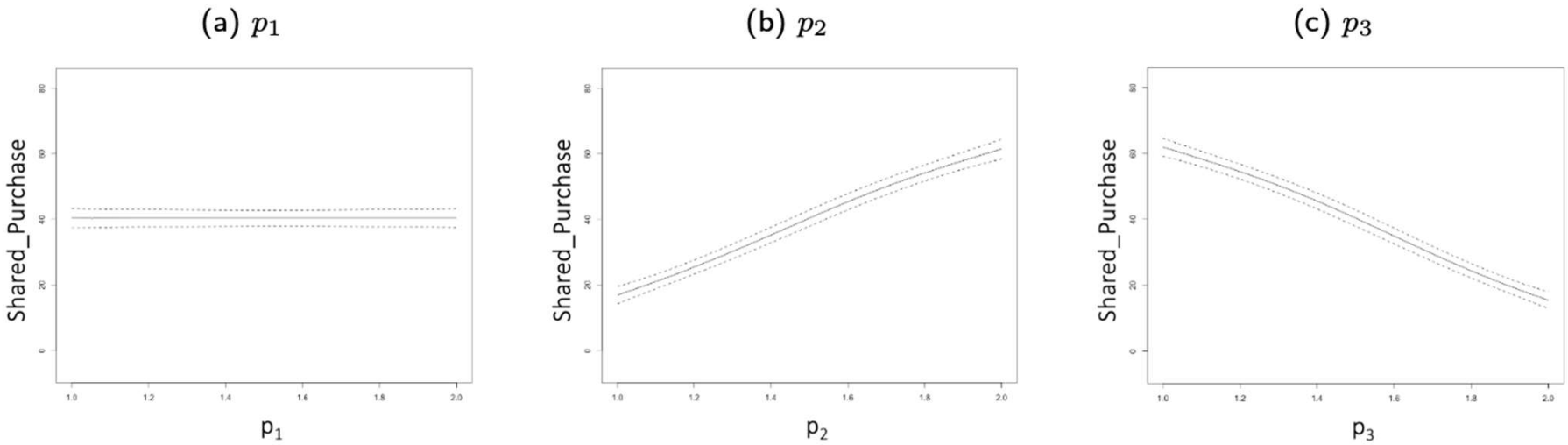
| | Shared purchase | Individual purchase | No purchase |
|---|---|---|---|
| Demand (d) | High | Low | High |
| Income (e) | Mid-low | High | Low |
| Pref. Income (θ) | Mid-high | Low | High |

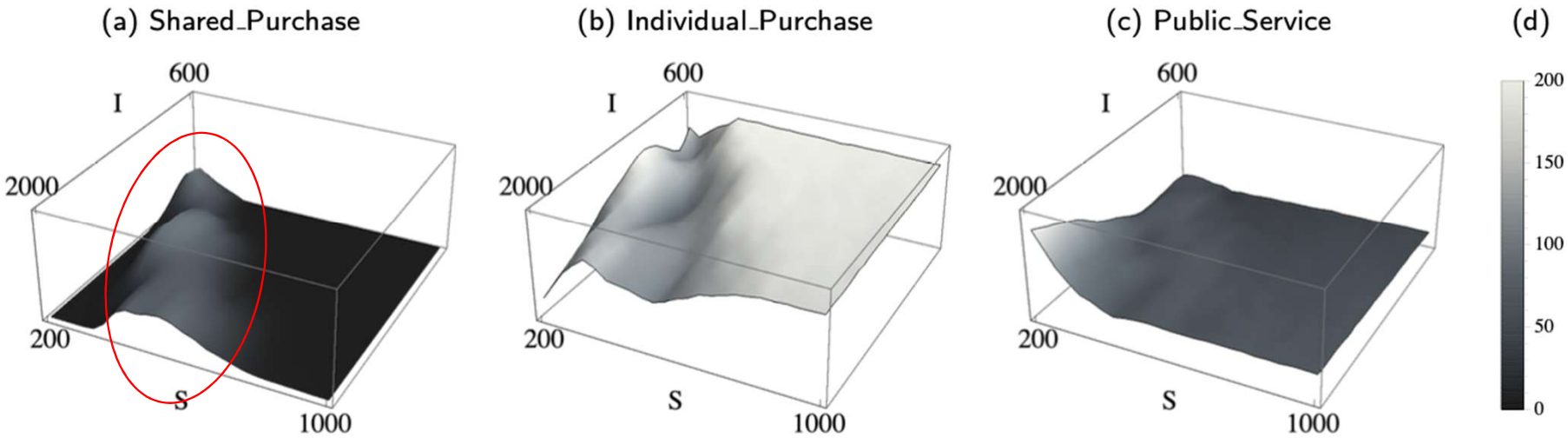


# Policy Intervention



# Policy Intervention



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**Policy interventions**

Incentives or lower tariffs to reduce unitary cost or increase prices for individual owners
Define right capacity and cost for policy (improve efficiency and effectiveness)

*Thank you!*

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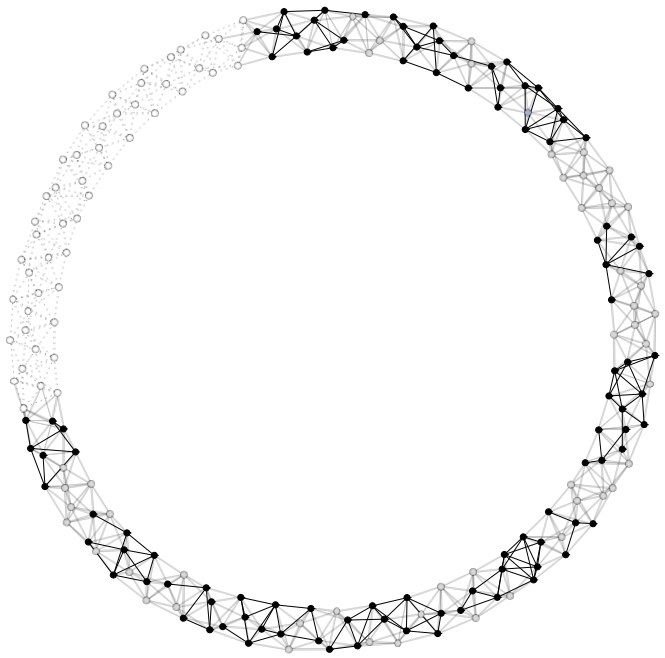
# Back-up

# The agent-based model (ABM)

- Extends previous model (Pasimeni and Ciarli, *2018*)

- Sequential games of coalition formation with the “best reply” type of adjustment dynamic
  - (Bloch 1995; Bloch 1996; Mutuswami and Winter 2002)
- Utility function in the evolutionary game theory of coalition formation
  - (Axtell 1999, 2002)
- Co-evolution of coalition formation and diffusion of shared goods



**Results**

- Bigger coalition are formed to invest in very expensive common goods
  → less individual contribution, despite higher negotiation
- Connections increase rapidity of information flow
  → determine higher diffusion
- There is not 100% diffusion
  → not all agents are better off in coalition

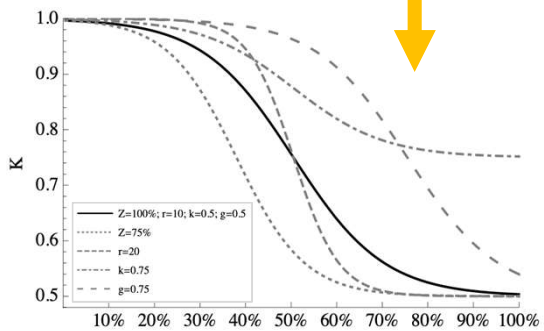
# ABM extension

| | **New ABM** | **Previous Model** |
|---|---|---|
| Network | Random | Regular |
| Shared good | Movable | Non-movable |
| Good's life cycle | Definite<br>(replacement/substitution) | Indefinite<br>(no replacement/substitution) |
| Consumption options | 1) No purchase<br>2) Individual purchase<br>3) Shared purchase | 1) No purchase<br>2) Purchase in coalition |
| Congestion to access service of general provider<br>(option No purchase) | Yes | No |

# The utility functions (Cobb-Douglas)

**1)** Public provider (no purchase)

$$U_{i1} = \underbrace{[e_i - d_i p_1]^{\theta_i}}_{\text{1) Preference for income}} \underbrace{(d_i * K)^{1-\theta_i}}_{\text{2) Preference for consumption}}$$




**2)** Individual purchase: $U_{i2} = [e_i - (d_i p_2 + \frac{I}{L_2})]^{\theta_i} (d)^{1-\theta_i}$

**3)** Shared purchase:

$$U_{i3} = \underbrace{[e_i - (d_i p_3 + x_i)]^{\theta_i}}_{\text{1) Preference for income}} \underbrace{\{(d_i + D_{-i})[\overset{\text{a.}}{\frac{\alpha_i d_i}{d_i + D_{-i}}} + (1-\alpha_i)(\overset{\text{b.}}{\frac{\beta_i x_i}{x_i + X_{-i}}} + \overset{\text{c.}}{\frac{1-\beta_i}{N}})]\}^{1-\theta_i}}_{\text{2) Preference for consumption (in group)}}$$

1) Preference for income

2) Preference for consumption (in group)

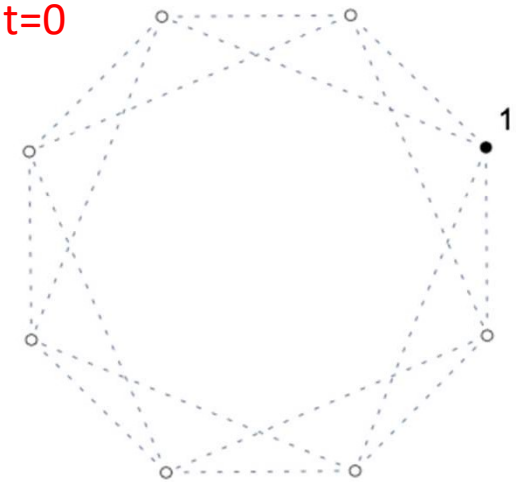
a. Proportional division rule based on agent's demand
b. Proportional division rule based on agent's monetary contribution
c. Equal shared division rule based on group size

$$\sum d_i \leq S \quad \text{and} \quad L_3 = \frac{S}{\sum d_i} \quad \text{and} \quad \frac{I}{L_3} \leq \sum x_i \leq \frac{I}{L_3} * 1.1$$

# Coalition Formation & Diffusion

(a) *Initiator* (in black) in regular network structure

t=0




<u>Initiators</u> (strong motivation)

1. Tie links with others
2. Starts the process of group formation

Knowledge diffusion & Network formation
Coordination & Coalition evaluation

$$W_t = MAX[W_{t-1}; min[1; Adv + (SharingAdopters_{t-1})^{\xi}]]$$

# Group Formation – Evaluation and decision

t=2


| | |
|---|---|
| S2=S3 | 175 |
| I2=I3 | 200 |
| p1 | 10.0 |
| p2 | 7.5 |
| p3 | 5.0 |
| K | 0.9 |

| Agent | d | e | θ1 | θ2 | θ3 | α | β |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 1000 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 2 | 55 | 1000 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 3 | 35 | 1000 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 4 | 45 | 1000 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

| 1) No_Purchase | |
|---|---|
| U1 | c1 |
| 137 | 300 |
| 149 | 550 |
| 143 | 350 |
| 149 | 450 |

| 2) Individual_Purchase | | | |
|---|---|---|---|
| L2 | I2/L2 | U2 | c2 |
| 6 | 33 | 149 | 258 |
| 3 | 67 | 169 | 479 |
| 5 | 40 | 156 | 303 |
| 4 | 50 | 166 | 388 |


| Agent | d | | L3 | I3/L3 | xi | | U3 | c3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | | | | 101 | | 169 | 251 |
| 2 | 55 | | | | 72 | | 175 | 347 |
| | 85 | YES | 2 | 100 | 173 | YES | | |


| Agent | d | | L3 | I3/L3 | xi | | U3 | c3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | | | | 95 | | 156 | 245 |
| 3 | 35 | | | | 88 | | 158 | 263 |
| | 65 | YES | 3 | 67 | 183 | NO | | |


| Agent | d | | L3 | I3/L3 | xi | | U3 | c3 |
|---|---|---|---|---|---|---|---|---|
| 2 | 55 | | | | 78 | | 182 | 353 |
| 4 | 45 | | | | 89 | | 181 | 314 |
| | 100 | YES | 2 | 100 | 167 | YES | | |

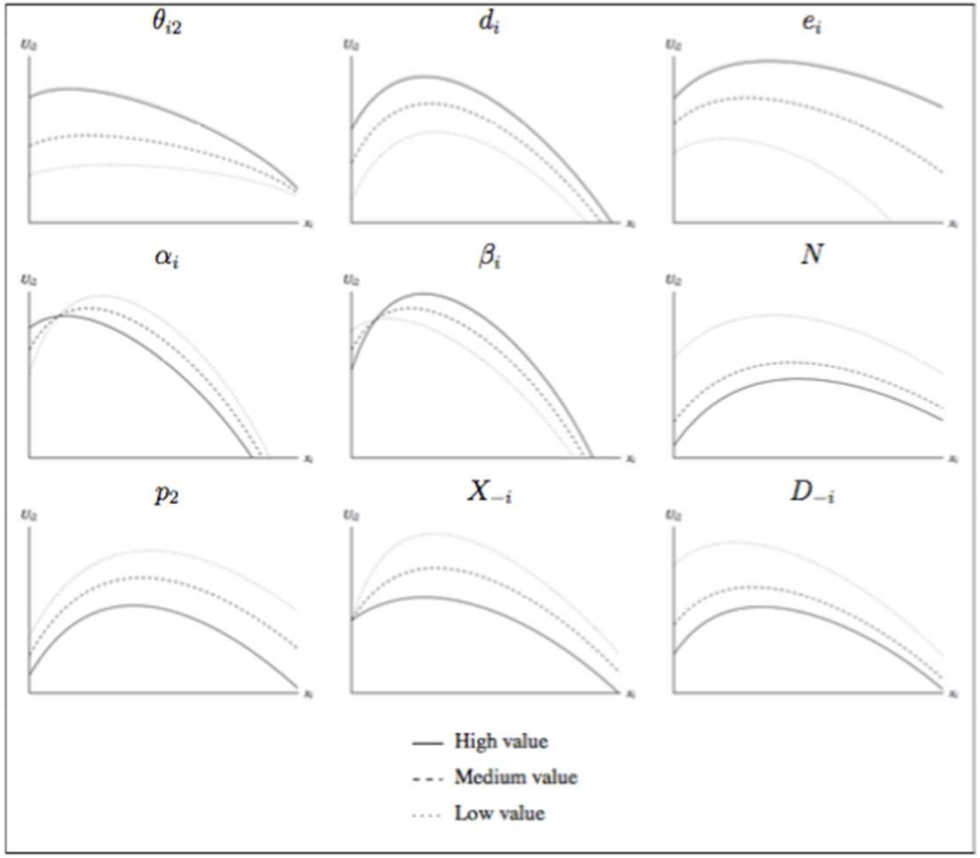

| Agent | d | | L3 | I3/L3 | xi | | U3 | c3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | | | | 138 | | 163 | 288 |
| 2 | 55 | | | | 76 | | 169 | 351 |
| 3 | 35 | | | | 127 | | 164 | 302 |
| | 120 | YES | 1 | 200 | 341 | YES | | |


| Agent | d | | L3 | I3/L3 | xi | | U3 | c3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | | | | 142 | | 167 | 292 |
| 2 | 55 | | | | 84 | | 173 | 359 |
| 4 | 45 | | | | 108 | | 171 | 333 |
| | 130 | YES | 1 | 200 | 334 | YES | | |


| Agent | d | | L3 | I3/L3 | xi | | U3 | c3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | | | | 161 | | 163 | 311 |
| 2 | 55 | | | | 81 | | 169 | 356 |
| 3 | 35 | | | | 145 | | 164 | 320 |
| 4 | 45 | | | | 113 | | 167 | 338 |
| | 165 | YES | 1 | 200 | 500 | NO | | |

| Agents' utility | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 1) No_Purchase | | 137 | 149 | 143 | 149 |
| 2) Individual_Purchase | | 149 | 169 | 156 | 166 |
| 3) Shared_Purchase | 1-2 | 169 | 175 | | |
| | 2-4 | | 182 | | 181 |
| | 1-2-3 | 163 | 169 | 164 | |
| | 1-2-4 | 167 | 173 | | 171 |

# Utility in sharing group




$$U_{i3} = [e_i - (d_i p_3 + x_i)]^{\theta_i} \{ (d_i + D_{-i}) [ \frac{\alpha_i d_i}{d_i + D_{-i}} + (1 - \alpha_i)( \frac{\beta_i x_i}{x_i + X_{-i}} + \frac{1 - \beta_i}{N} ) ] \}^{1-\theta_i}$$