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ASSOCIAZIONE ITALIANA DI ECONOMIA AGRARIA E APPLICATA

Collective targeting in rural policies:
review of proposed mechanisms and assessment of irrigation infrastructure measures in Emilia- Romagna

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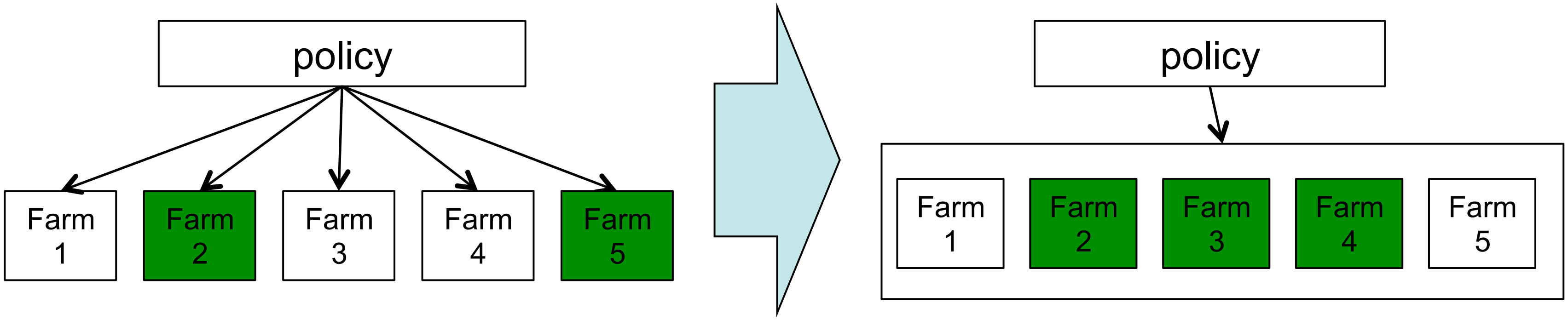
Introduction

- Topic:
  - Rural policies on natural resource management
  - Proper target: group of farmers (vs individual farmers)
    - Public good
  - Incentives for coordinated environmental efforts
    - Payment for environmental practices
    - Premium/bonus “if” coordination
  - Minimum participation rules
    - Minimum number of agents
    - Minimum extent of land contracted



Introduction

- Objective:
  1. Review of policy and literature
  2. Potential of Cooperative Game Theory (CGT):
     - Focus on minimum participation rules in rural policy (natural resource management)
     - Effect of threshold on benefits distribution
- Cooperative Game Theory
  - Communication - Binding agreement – superadditivity: pareto efficiency is no problem
  - Focus on the distribution of the benefits
  - Shapley Value (SV): attributes the value of a cooperative venture
- Application to Emilia-Romagna
  - Rural Development Plan measure 125

Background: policy

- EU (Biodiversity):
  - Collective implementation of the “greening” constraints
  - Group of farmers as recipients of agri-environment-climate payments
- Emilia-Romagna (water quantity) incentivizes collective reservoirs
  - Two sets of eligibility constrains for the potential projects: one on the minimum size of the reservoirs (greater than 50000 m^3), one on the minimum number of farmers participating (20)
- Emilia-Romagna (Biodiversity):
  - “environmental contracts”
- France (water quality):
  - Payments for buffer strips are increased by 20% if at least 60% or the river bank is is not cultivated (Dupraz et al., 2009)

Background: literature

- Biodiversity: agglomeration bonus/payment (Parkhurst et al. 2002)
  - Little on bargaining issues
  - Little on on the distribution of the benefits
  - Mostly based on Non Cooperative game theory
- Irrigation water (quantity) (Ostrom, 1990)
  - Little on relationship between policy / socio-ecological systems
  - Benefit distribution (Janssen et al., 2011)

Background: literature

- Biodiversity: agglomeration bonus/payment
  - Experiments:
    - Communication (Parkhurst et al. 2002)
    - Network size (Banerjee et al. 2012)
    - Information availability (Banerjee et al. 2014)
  - Mathematical programming model
    - Policy effectiveness (Albers et al., 2008; Dupraz et al., 2009)
    - Global optimization objective function (Bamière et al., 2013; Drechsler et al., 2010),
    - Side-payments (Wätzold and Drechsler, 2013)

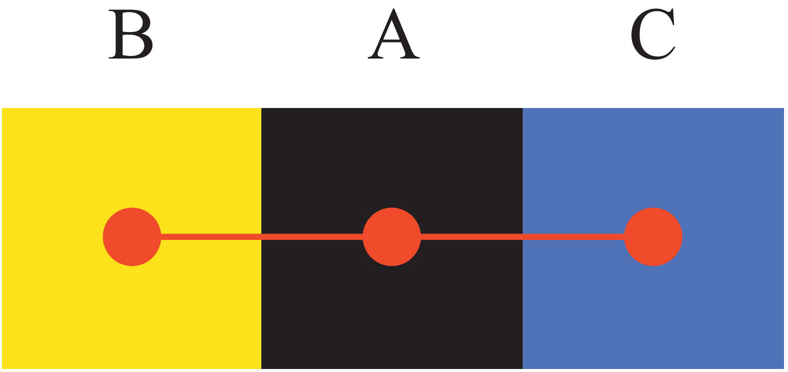
- Irrigation water (quantity)
    - Lack of a central coordination (Ostrom, 1990)

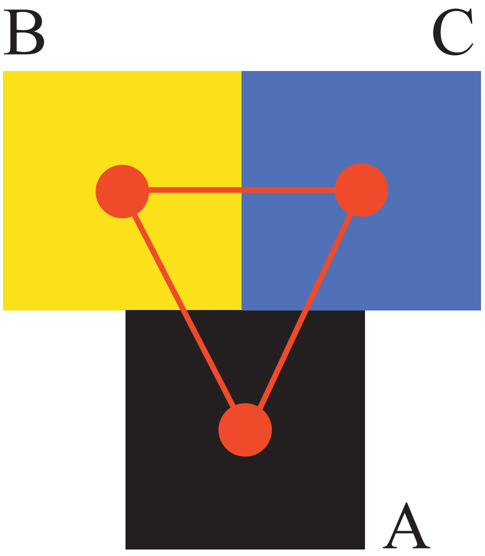
Cooperative Game Theory

- Coalitions
- Characteristic function
- Solutions

Cooperative Game Theory

- Coalitions: groupings of players
  - Modelling
    - Minimum participation rules
    - Spatial relations
    - Social relations





- **grand-coalition**: when all the players work together
- **coalitions**: possible sub-groups

Cooperative Game Theory

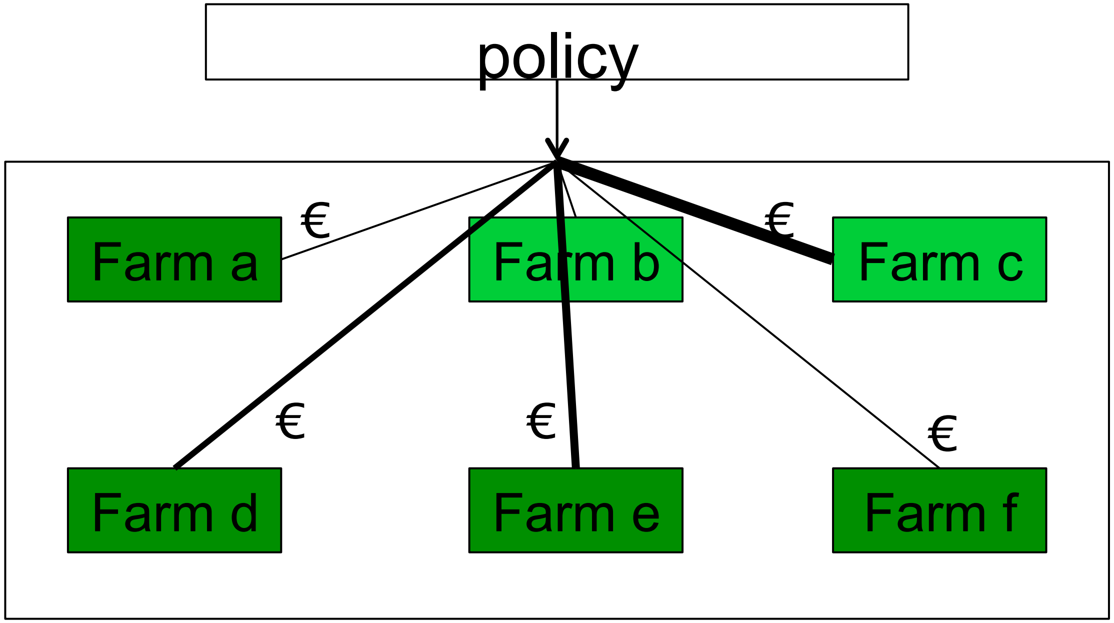
- Characteristic function
  - Attributes a value to the coalitions
    - Policy incentives
  - Super-additivity $v(N) \geq v(s) + v(t)$

	$q^t = 0$
v(A)	**5899**
v(B)	**13334**
v(C)	**38080**
v(A,B)	**19566**
v(A,C)	**44383**
v(B,C)	**52010**
v(A,B,C)	**58335**

	Super-additivity
v(A,B)+ v(C)	57646
v(A,C)+ v(B)	57718
v(B,C) + v(A)	57909
v(A)+ v(B)+ v(C)	57313

Cooperative Game Theory

- Solution: distribution of the worth
  - u_i^* : worth attributed to the i^{th} agent in the grand-coalition



Solution: core

The “core”: rationally acceptable grand-coalition worth allocation (Gillies, 1959):

Individual rationality $$u_i^* \geq v\left(\left\{i\right\}\right) \ \forall i \in N$$

Group rationality $$\sum_{i \in S} u_i^* \geq v\left(s\right) \ \forall s \in S$$

Efficiency: $$\sum_{i \in S} u_i^* = v\left(N\right)$$

Solution: Shapley Value

- The Shapley Value:
  - unique solution
  - surely in the core if convex game (Shapley, 1971, 1952):

$$u_i^* = u_i^{sv} = \sum_{\substack{s \subseteq N \\ i \in S}} \frac{\left(n - |s|\right)! \left(|s| - 1\right)!}{n!} \left[v(s) - v\left(s - \{i\}\right) \right]$$

The worth attributed to the *i*th player through the SV is given by its average marginal contribution for any possible grouping of the players.

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Characteristic function

Problem:

- N farms have to build a irrigation reservoir
- Pooling resources to build the reservoir
- Financial support of the RDP – minimum participation rules

Characteristic function

- The value for any possible coalition is given by:

$$\max\left[R-(1-\alpha P)k(Q_s)\right]$$

Revenues: $R=\sum_{i\in s} f^i(Q_i)$

Costs: $k(Q_s)$

Policy participation: $\begin{cases} P=1 \text{ if } Q_s \geq q^t \\ P=0 \text{ if } Q_s < q^t \end{cases}$

Assume $k(Q_s)$ exhibits economies of scale ($k'(Q_s) > 0$ and $k''(Q_s) < 0$) -> grand-coalition is the most efficient group arrangement

Theoretical analysis

- Solutions
  - With financial support

$$f^{i}_{Q_i} = f^{j}_{Q_j} = \alpha k_{Q_s}$$

  - Without financial support

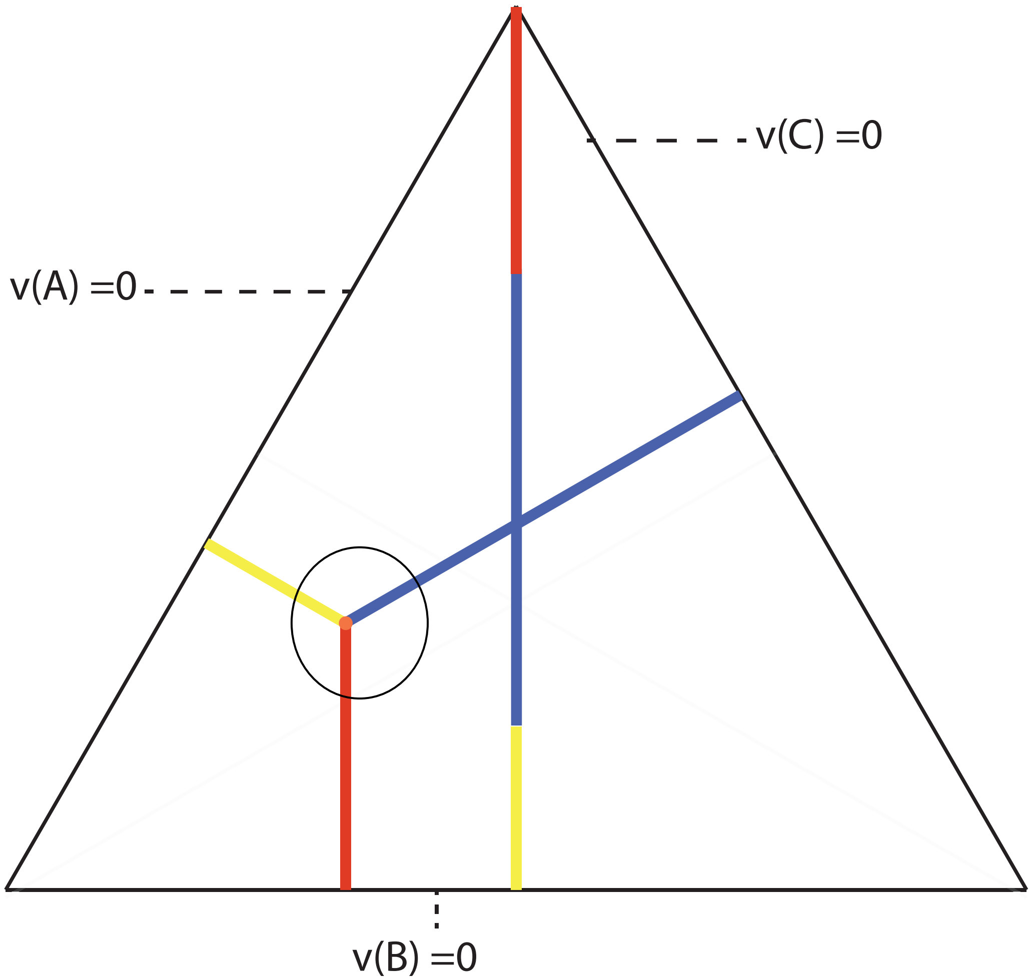
$$f^{i}_{Q_i} = f^{j}_{Q_j} = k_{Q_s}$$

- $Q_s^{*,P}$: water quantity of coalition financially supported by the policy if no threshold

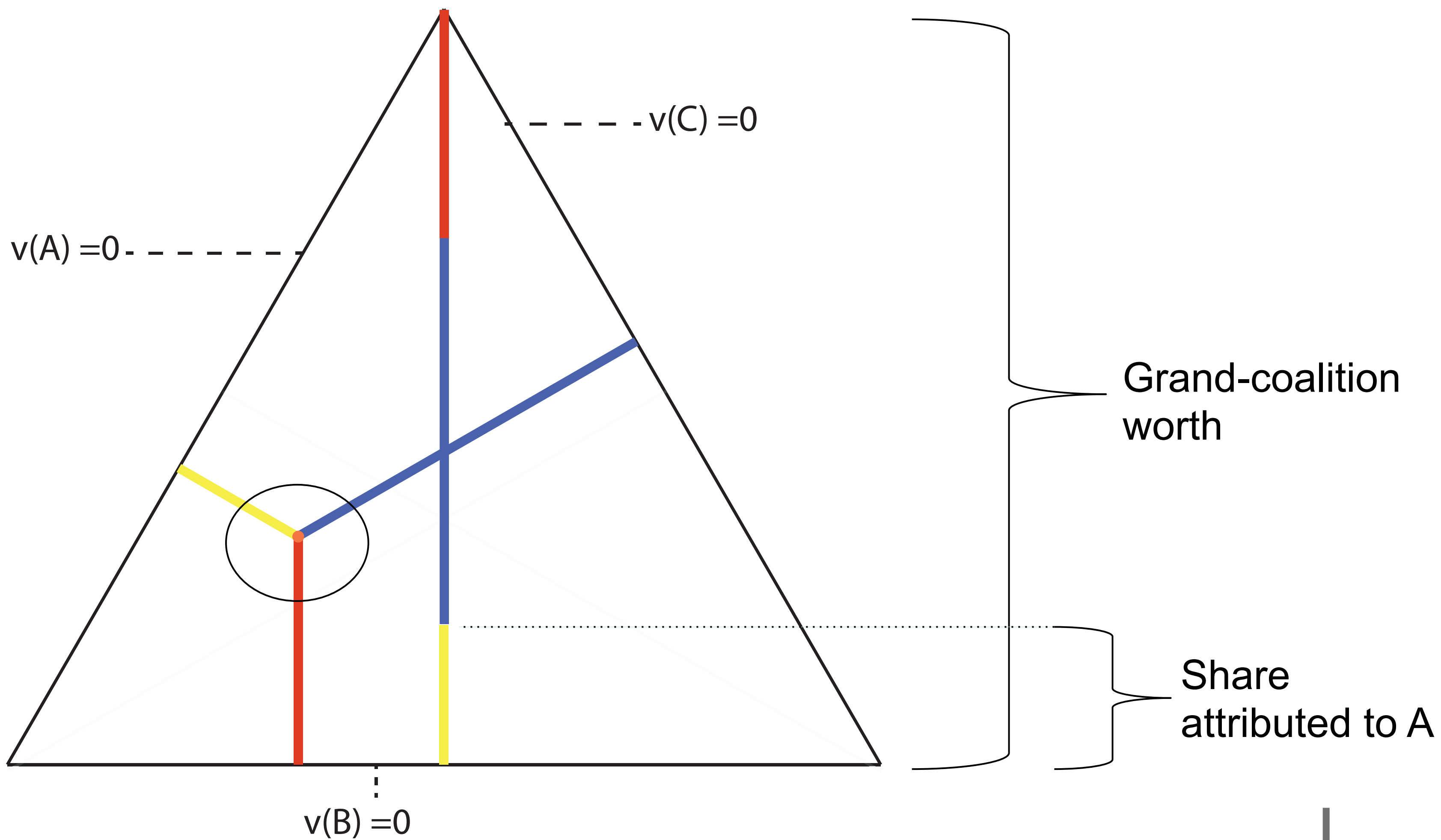
$$v(s) = \begin{cases} \Pi_s^{P} \text{ with } Q_s^{*} = Q_s^{*p} \text{ if } Q_s^{*p} \geq q^{t} \\ \Pi_s^{P,t} \text{ with } Q_s^{*} = q^{t} \text{ if } Q_s^{*p} < q^{t} \text{ and } \Pi_s^{P,t} \geq \Pi_s^{NP} \\ \Pi_s^{NP} \text{ with } Q_s^{*} = Q_s^{NP} \text{ if } Q_s^{*p} < q^{t} \text{ and } \Pi_s^{P,t} < \Pi_s^{NP} \end{cases}$$

- Increasing the threshold make the financial support more and more costly up to the point where the coalition withdraw from the policy

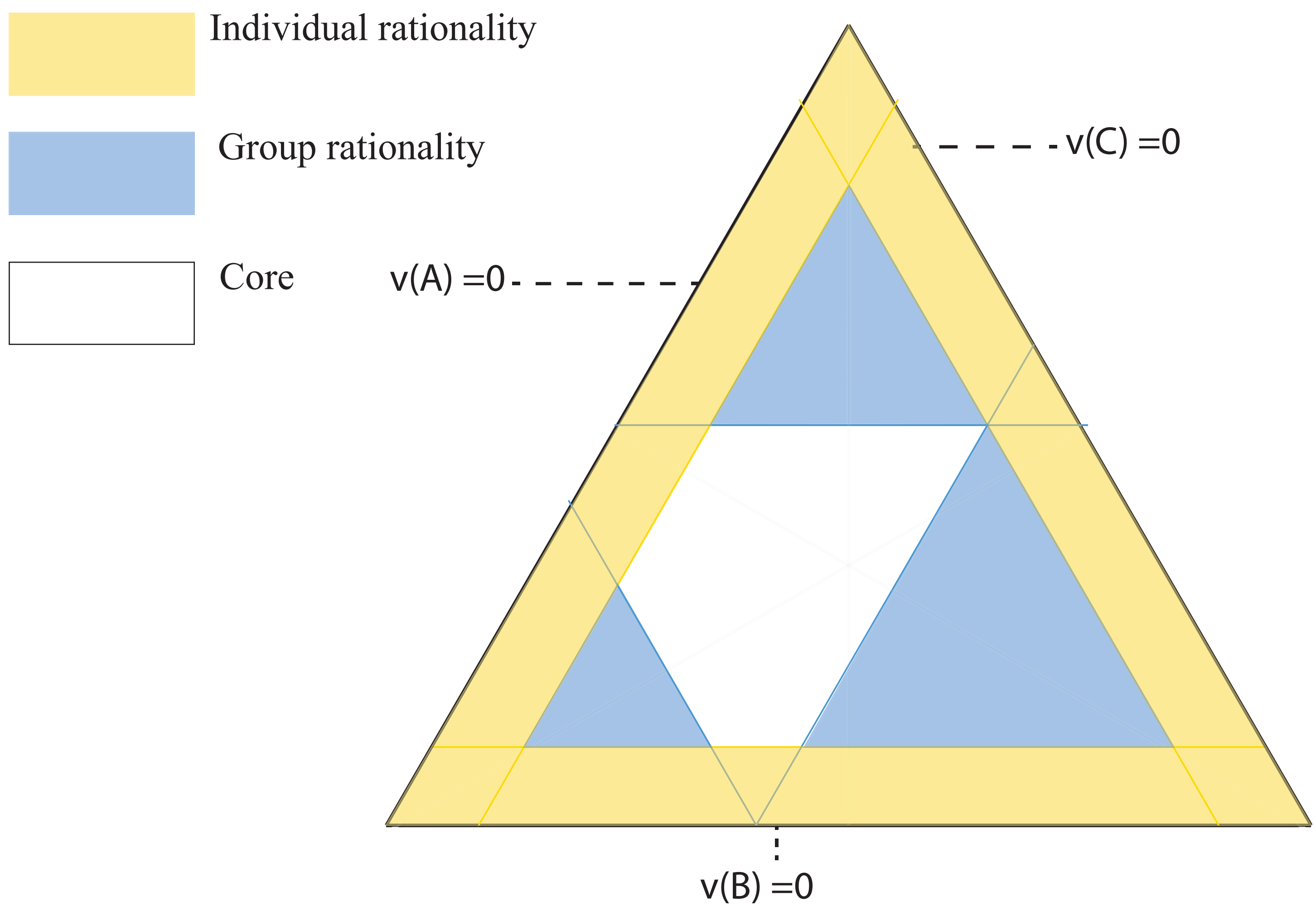
Theoretical analysis



Theoretical analysis



Theoretical analysis



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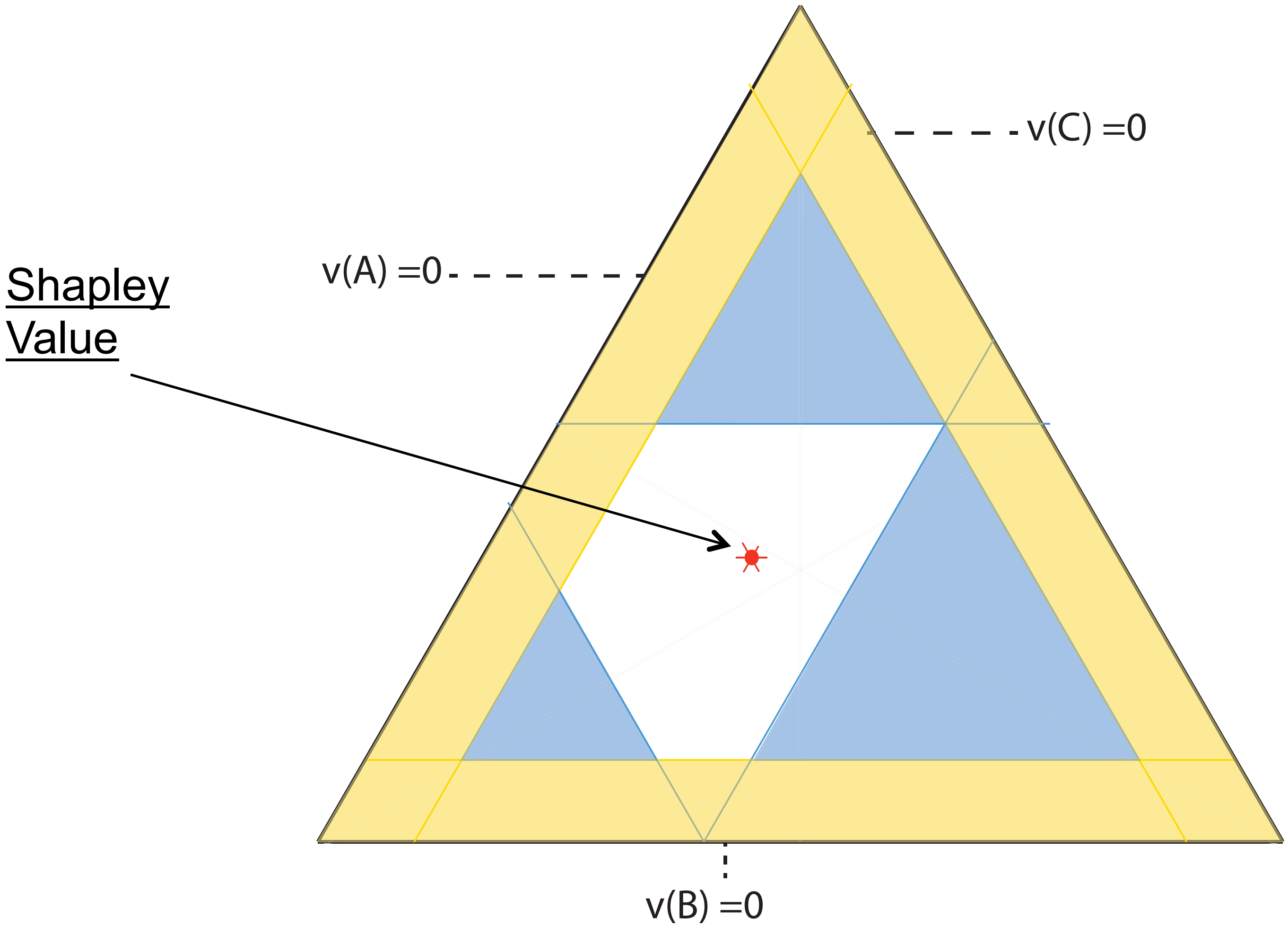
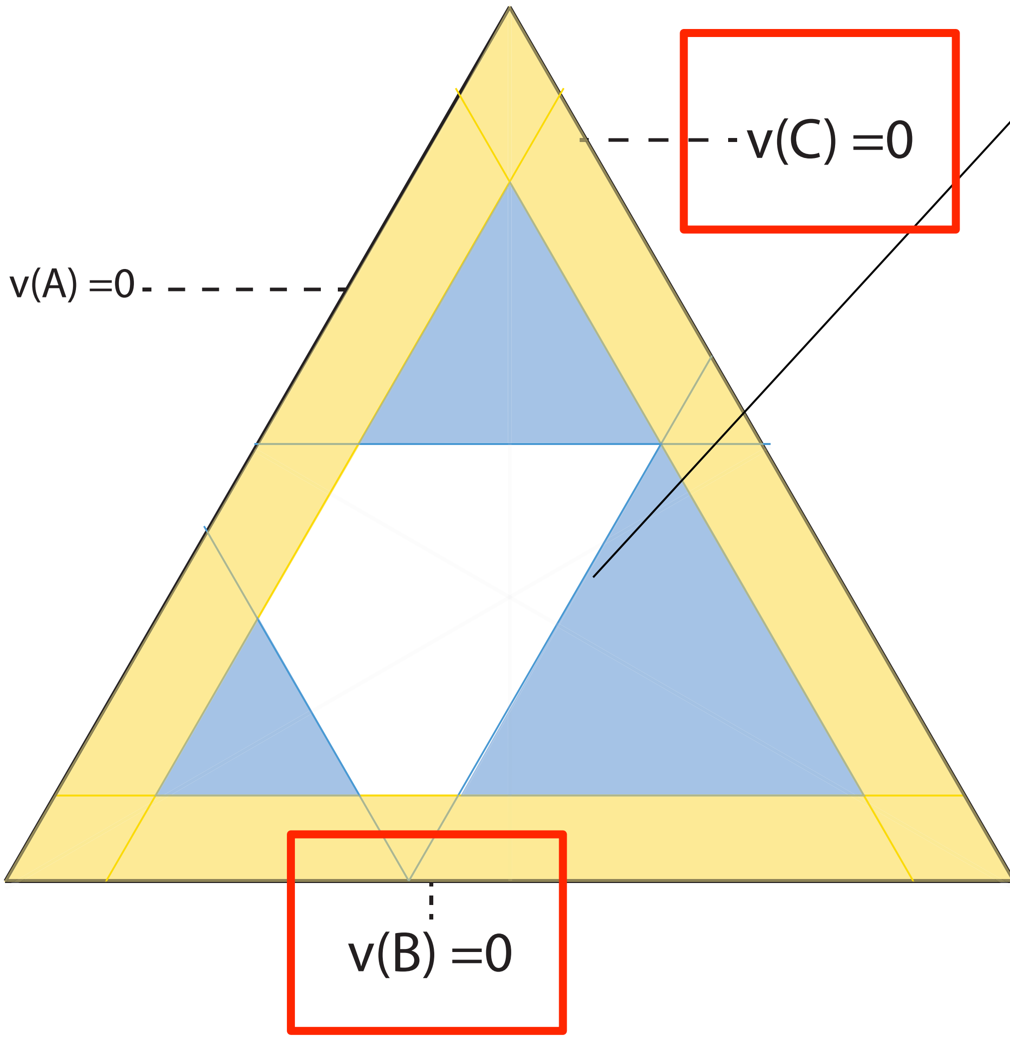


Theoretical analysis



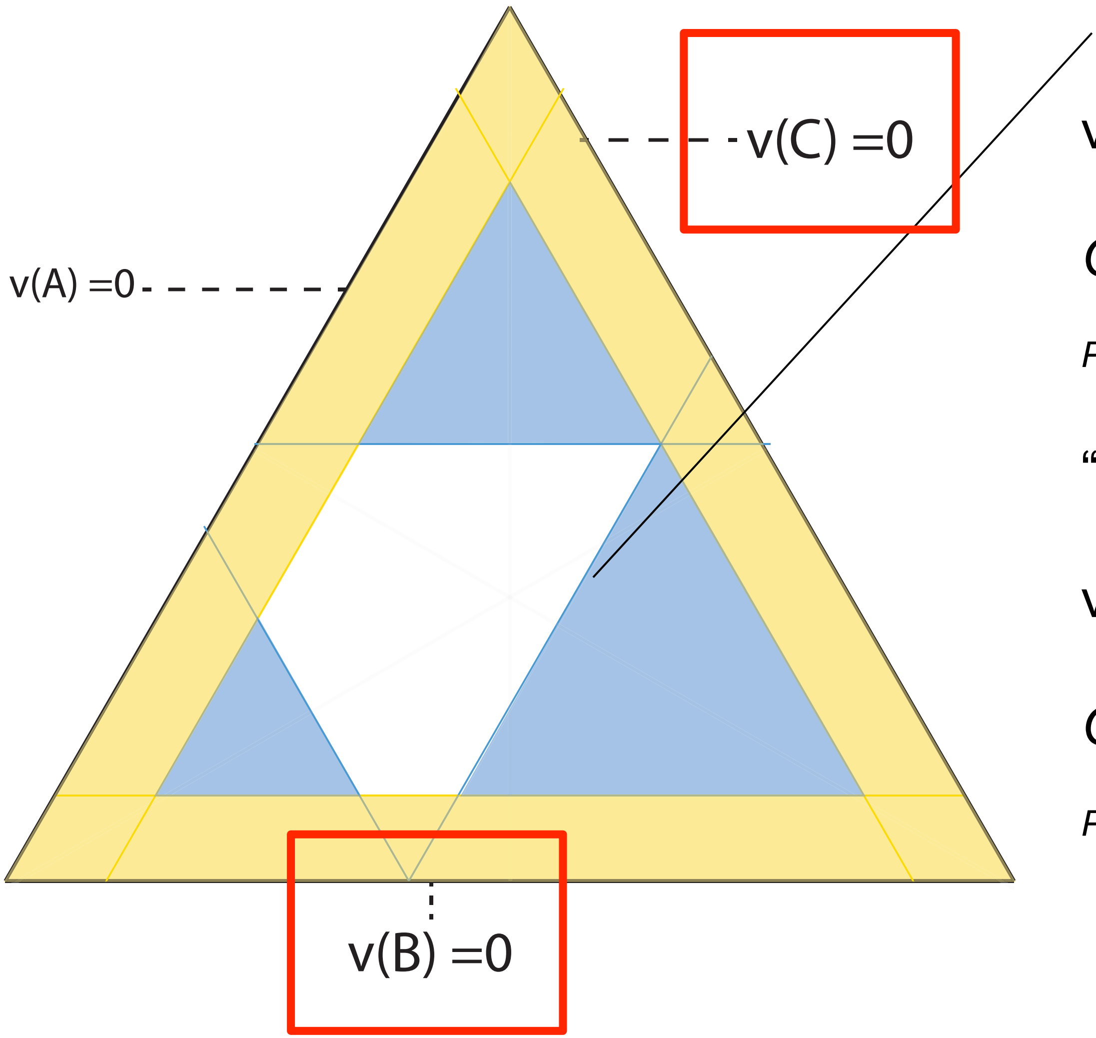
"Low" threshold:

$v(B,C)=\Pi_s^P$

$Q_s^{*,P} \geq q^{t,\,low}$

P=1

Theoretical analysis



"Low" threshold:

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P=1

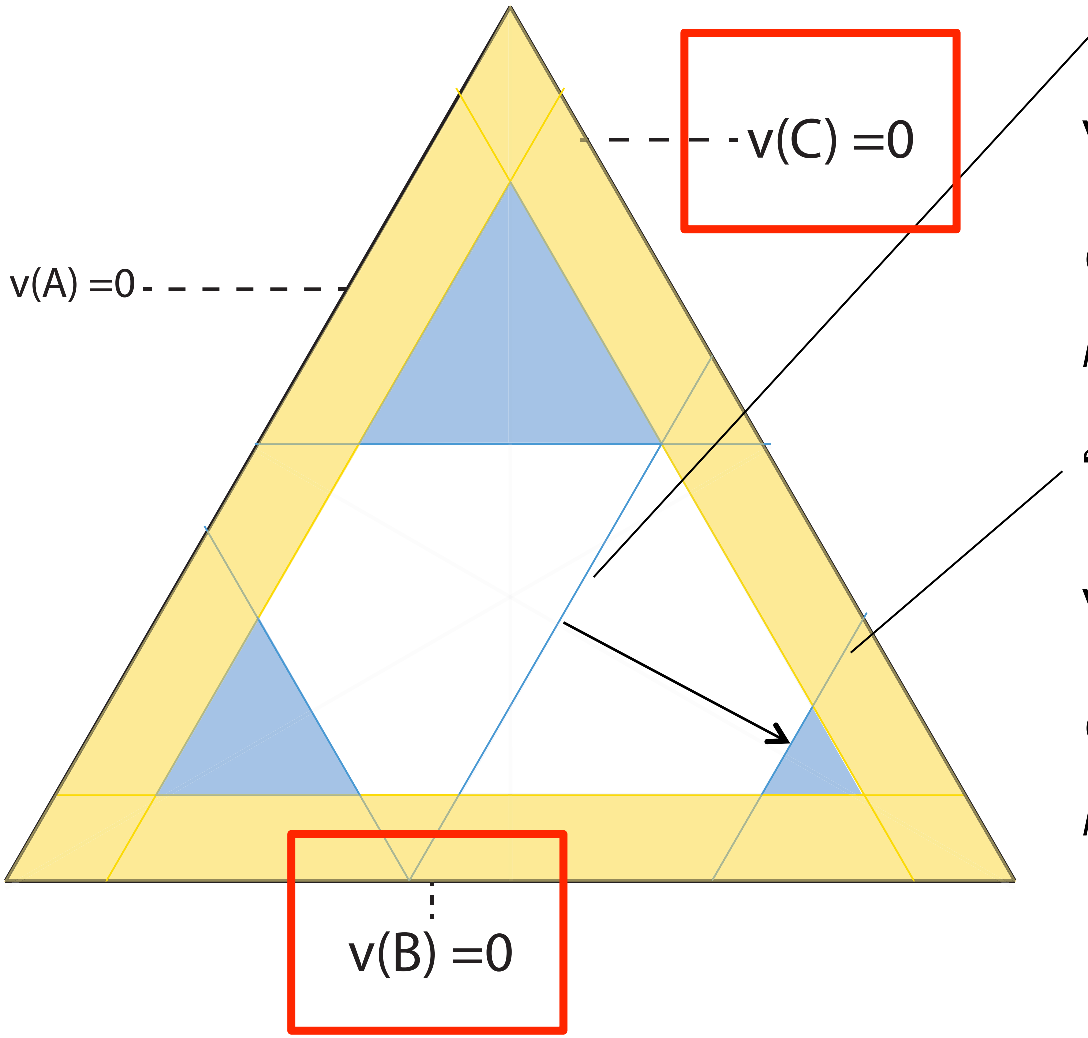
"High" threshold:

$v(B,C)=\Pi_s^{NP}$

$Q_s^{*,P} < q^{t,\, high}$

P=0

Theoretical analysis



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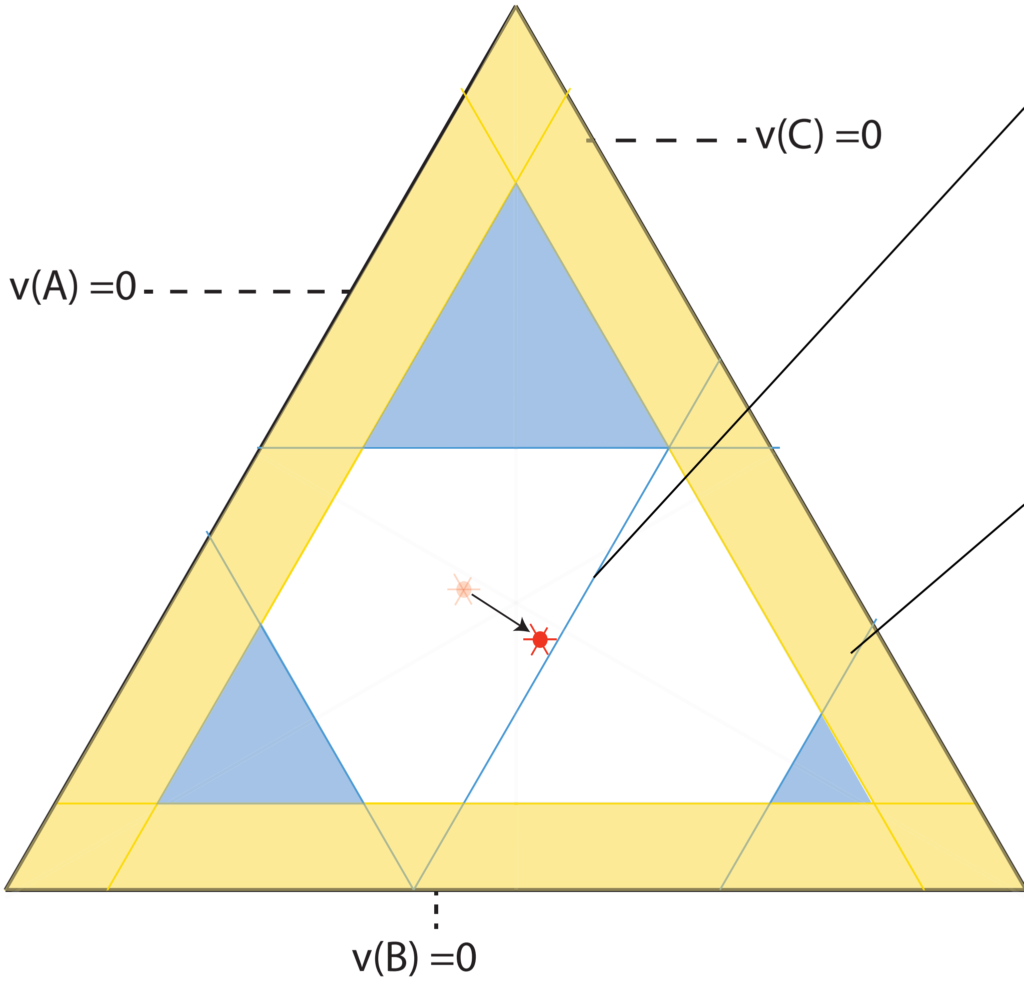
Theoretical analysis



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P=1

"High" threshold:

$v(B,C)=\Pi_s^{NP}$

$Q_s^{*,P} < q^{t,\ high}$

P=0

Data and Scenarios

- Application to the Emilia-Romagna RDP
- Secondary data for revenue functions (Zavalloni et al 2014)
  - 3 farms (different characteristics)
- Construction costs formulated with Consorzio Bonifica Romagna Occidentale
- Scenarios:
  - "Size-rule": a range of q^t
  - "n-rule": the minimum number of agents required to have access to the RDP ($n \geq 1$, $n \geq 2$, $n \geq 3$)
  - share of the cost covered by the RDP ($\alpha = 30\%$, $\alpha = 50\%$, $\alpha = 70\%$)

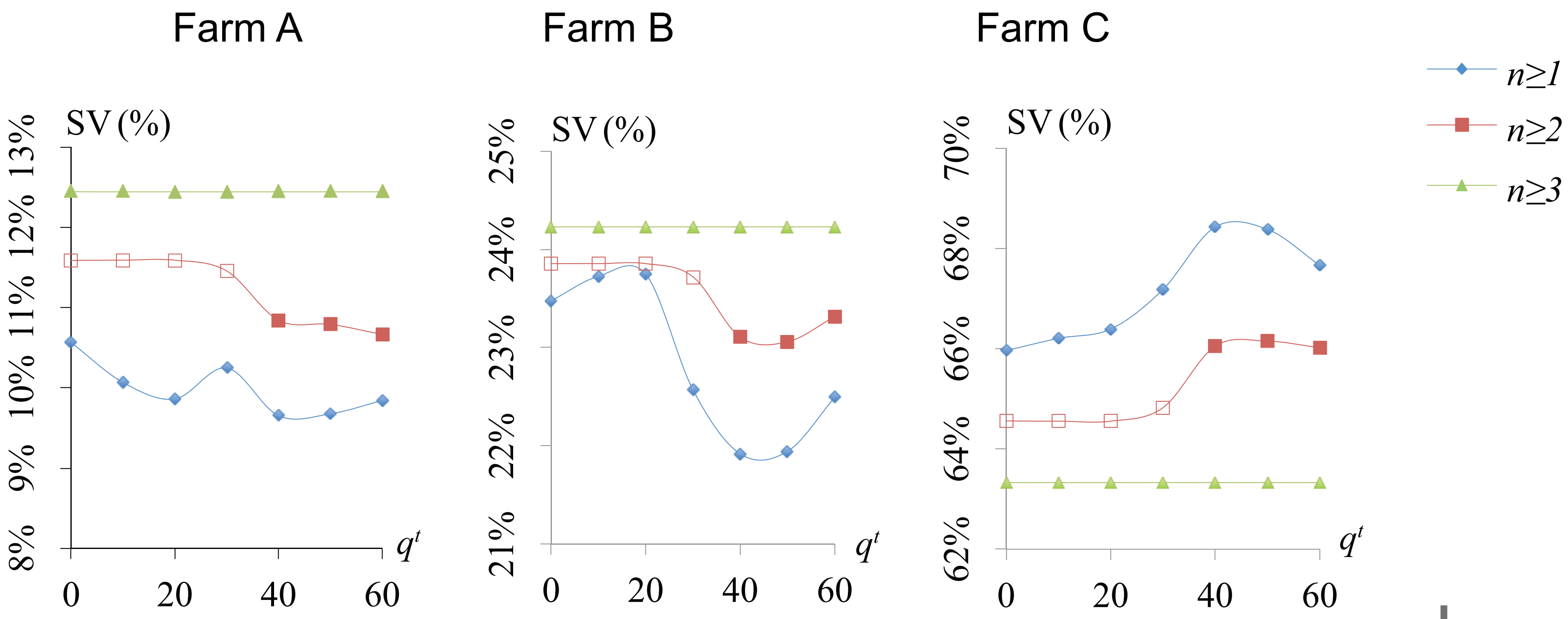
Results – Characteristic function

- Increasing the threshold makes more and more difficult to obtain the financial support (bold numbers)
- Grand-coalition is more and more attractive (brackets)

	$q^t = 0$	$q^t = 40000$	$q^t = 80000$
v(A)	**5899**	4572	4572
v(B)	**13334**	11254	11254
v(C)	**38080**	**38080**	33921
v(A,B)	**19566 (2%)**	**16946 (7%)**	16773 (7%)
v(A,C)	**44383 (1%)**	**44383 (4%)**	**40778 (6%)**
v(B,C)	**52010 (1%)**	**52010 (5%)**	**50735 (12%)**
v(A,B,C)	**58335 (1%)**	**58335 (6%)**	**57781 (11%)**

Results – n-Rule

- Shapley value (%)
  - 3 farms
  - Share of financial support: 70%

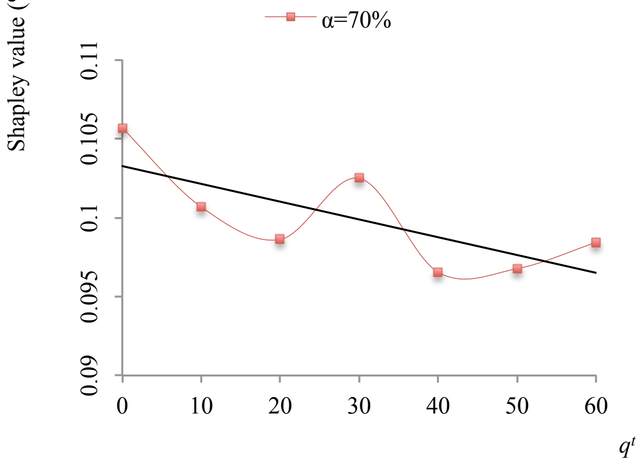


Results – size rule

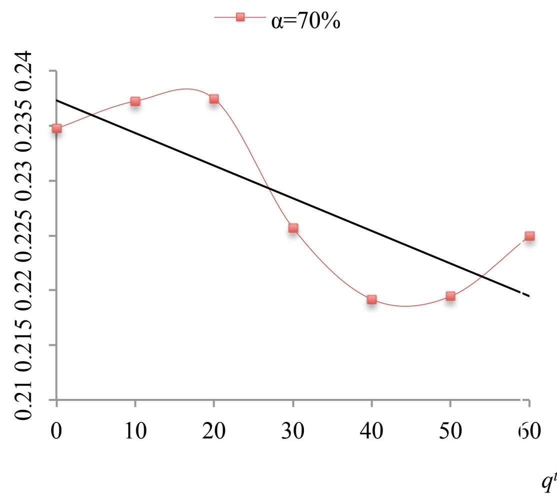
Shapley value (%)

- Different minimum participation threshold (size of reservoir)
- 3 farms
- Share of financial support: 70%

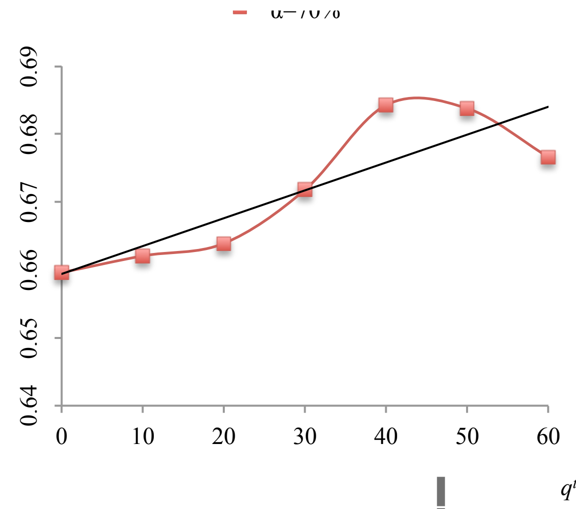
Farm A: ≅10%



Farm B: ≅22%



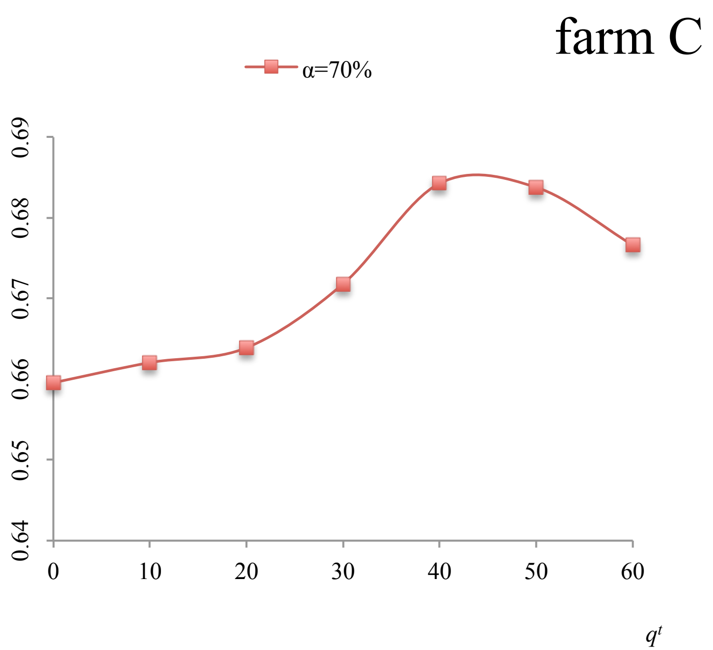
Farm C: ≅67%



Results – size rule

Shapley value (%)

- Farm C
- Different minimum participation threshold (size of reservoir)
- Share of financial support: 70%



Discussion

- Different solutions:
    - Shapley Value
    - Nash / Nash-Harsanyi
    - Nucleolus

- Limitations:
  - No public good:
    - SV assumes that the worth of a given coalition is not affected by the players outside the coalition
    - Further development to address this issue (Macho-Stadler et al., 2007)
  - Difficult to scale up

Conclusions

- Increasing interest from policy makers
- Literature not yet comprehensive
- Cooperative game theory worth further exploring
  - Conditionality rules are not neutral on benefit distributions – to take into account in policy formulation
    - Distribution matters in collective actions (Janssen et al 2011)
  - Coalition formation theory

Thanks!

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Results – Characteristic function

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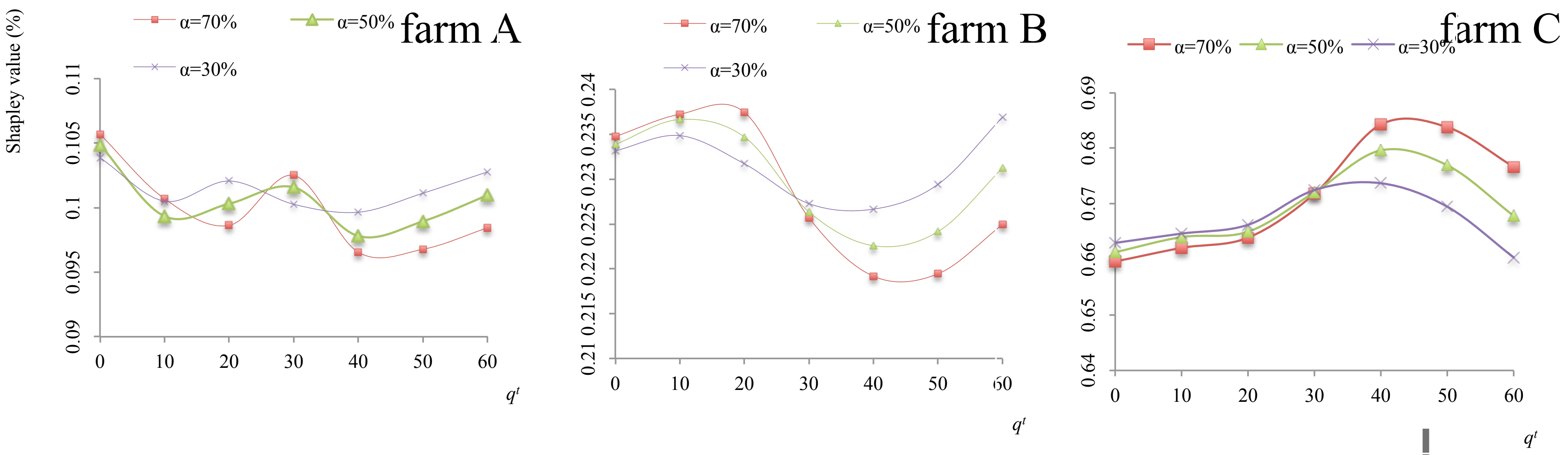
Check super-additivity:

v(A,B)+ v(C)	57646	55026	50695
v(A,C)+ v(B)	57718	55637	52032
v(B,C) + v(A)	57909	56583	55308
v(A)+ v(B)+ v(C)	57313	53906	49747

Results – size rule

Shapley Value (%)

- Different minimum participation threshold (size of reservoir)
- 3 farms
- 3 different share of financial support



Discussion

- Increasing minimum participation threshold:
  - Increase attractiveness of cooperation
  - Asymmetric effect
  - Threshold on reservoir size: tend to empower bigger farms (up to a given level)
  - Threshold on number of participants: tend to empower smaller farms
- Extension/application to agglomeration incentives
  - Agglomeration payments vs agglomeration bonus
  - Cooperative game theory can address:
    - Spatial element
    - Social interactions