Analyzing the Economy-wide Impact of the Supply Chains Activated by a new Biomass Power Plant
The case of cardoon in Sardinia

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Objectives (1)

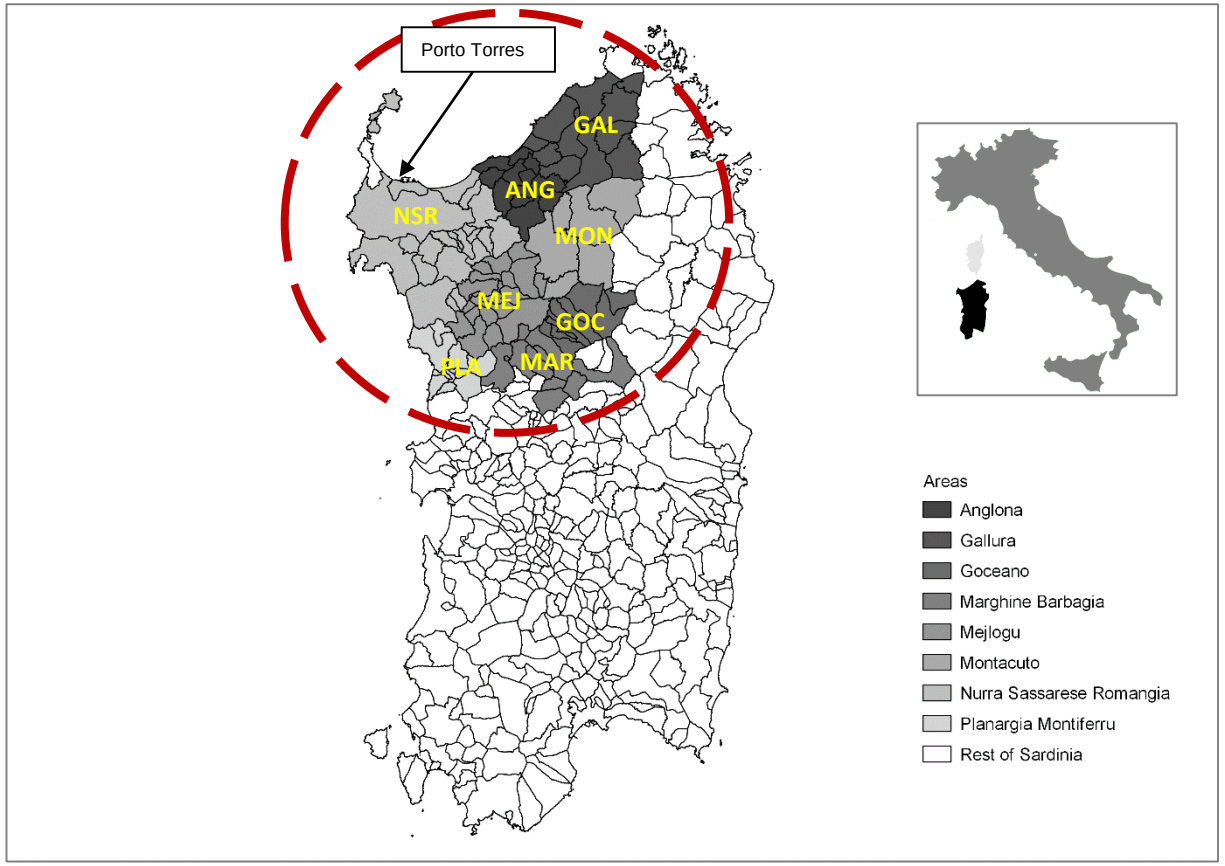
- Assessing local and supra-local economy-wide impacts from a project of implementation of a **biomass power plant** in Sardinia
- **Project aims**
  - Reconversion of an industrial site towards higher sustainability by reducing the used quantity of fossil fuels
  - Stimulating local development
- 135 MWt, 250 thousand ton/year of biomass (straw) from local cultivation of cardoon (***Cynara cardunculus***) for the production of electricity and thermal energy (needs of industrial site)

Objectives (2)

- Value added and employment **effects**
  - **Supply chains** activated by a new biomass power plant during its full operational phase
  - Neglected phases: construction of power plant, temporary provision of wood chips and relevant transport port operations
  - Supply chains:
    - **Local cultivation of cardoon**: for production of **biomass** (as an input for feeding the power plant) and **oilseeds** used for production of biopolymers in replacement with petroleum-based plastics
    - all the other chains activated by **purchases of inputs** necessary for the functioning of the power plant
  - **Possible substitution of existing agricultural activities with cardoon**
  - **Alternative scenarios** in relation to the degree of substitution

Area under study

- North-western portion of the Italian region of the Sardinia
- Industrial site of Porto Torres (production of bioenergy and biopolymers)
- 8 local districts
  - About 100 communes
  - Common historical, geographical and productive characteristics
  - Why? Reducing transport costs, strong socio-economic relationships with industrial site, negative dynamics of agro-food sectors



Socio-economic situation of local districts

Main socio-economic indicators of the local districts involved in the project, Sardinia, Italy (Source: ISTAT)

	Pop. (2011)		Employees (2008)			Var.% farms 2000-10	UAA per farm (2010)	Var. % UAA 2000-10
	per Km^2	Var. % 2001-11	% of Pop.	% in agr.	% In manif.			
Anglona	46,1	-0,2	28,1	8,0	7,2	-50,6	29,9	5,53
Gallura	29,5	-1,0	41,0	4,7	16,3	-50,5	26,5	-6,85
Goceano	24,5	-9,6	30,0	16,9	9,8	-47,6	30,3	-12,5
Marghine Barbagia	40,1	-7,2	38,4	7,5	26,5	-44,5	33,5	14,97
Mejlogu	24,9	-9,1	31,6	17,2	13,6	-52,1	39,3	5,39
Montacuto	23,7	-6,2	32,1	9,7	9,0	-31,2	41,5	21,3
Nurra Sassarese Romangia	138,8	4,0	33,5	4,3	8,2	-47,7	13,4	-1,53
Planargia Montiferru	39,8	-3,2	31,3	15,3	6,8	-49,0	27,5	11,15

- Some diversity between districts
- Few areas with relatively higher degree of urbanization (*Nurra Sassarese Romangia*) and presence of manufacturing industry (*Marghine Barbagia* and *Gallura*)
- The majority are characterized by a **high degree of rurality**: low population density, depopulation and high incidence of agricultural activity (*Mejlogu*, *Goceano*, *Planargia Montiferru*)
- A **common** aspect: **profound transformation of AGR** characterized by extensification and progressive abandon

Production of cardoon

Area and production of cardoon in the local districts involved in the project, Sardinia

Comprensorio	Area			Production				
				Biomass			Oilseeds	
	ha	%		tons	%		tons	%
Anglona	1,482	6.7		17,340	7.0		1,907	7.0
Gallura	750	3.4		7,163	2.9		788	2.9
Goceano	1,066	4.8		10,732	4.3		1,181	4.3
Marghine Barbagia	2,163	9.8		21,175	8.5		2,329	8.5
Mejlogu	4,742	21.5		54,762	22.1		6,024	22.1
Montacuto	3,544	16.1		35,786	14.4		3,936	14.4
Nurra Sassarese Romangia	6,792	30.8		86,163	34.7		9,478	34.7
Planargia Montiferru	1,530	6.9		15,129	6.1		1,664	6.1
TOTALE	22,070	100.0		248,250	100.0		27,308	100.0

- Study based on Land Suitability Classification (FAO, 1976)
  - Available area divided into five different classes of suitability with different levels of productivity and profitability
  - Potential suitable area: **72 thousand hectares** -> **825 thousand tons** (> 250)
  - Identification of quantity of biomass and oilseeds per each district
  - Corresponding area estimated as QUANTITY / productivity: **22 thousand hectares**
  - **Nurra Sassarese Romangia** and **Mejlogu** concentrate **over 50%** of area, biomass and oilseeds

Methodology

- **Multi-regional closed I-O model**
  - Effective tool to estimate **economic-wide effects** induced by shocks in final demand (output)
  - Commonly used to assess socio-economic benefits of **agricultural projects** or investments (Bonfiglio and Esposti, 2014)
  - Very useful for evaluating impacts generated by linkages along **supply chains**
  - Best **methodological compromise**: need to capture intersectoral and spatial relationships and data scarcity especially at sub-regional levels
- Different kinds of **effects**:
  - **Direct** effects
  - **Indirect** effects
  - **Induced** effects
  - **Spatial** effects (spillover and feedback effects)
- Two **versions**
  - **Demand-driven I-O model** (final demand variation)
  - **Mixed-variable I-O model** (output variation)
- **9 Regions** considered:
  - 8 Districts + the Rest of Sardinia

Data and regionalisation

- **2008 35-sector I-O table** for the Sardinia region (IRPET)
- Three-stage **regionalization procedure** (Bonfiglio, 2006)
- **A)** Application of **location quotients**
  - Augmented **FLQ** (Flegg and Webber, 2000)
  - **Regional input coefficients** and total regional imports of each region from the rest of Sardinia
- **B) Gravity model**
  - Probability of attraction = f[*distance* (-), *importance of regional sectors* (+)]
  - Allocation of total imports among exporting regions (**trade coefficients**)
- **C)** Insertion of **superior data** and **balancing**
- Introduction of two new cardoon-related sub-sectors: **biomass** and **oilseeds sectors**
- Result: **(37-sector) x (9-region) I-O model of the Sardinia region**

Alternative scenarios (1)

Available unused agricultural area and required cardoon area in the various districts, 2010 (Source: Istat)

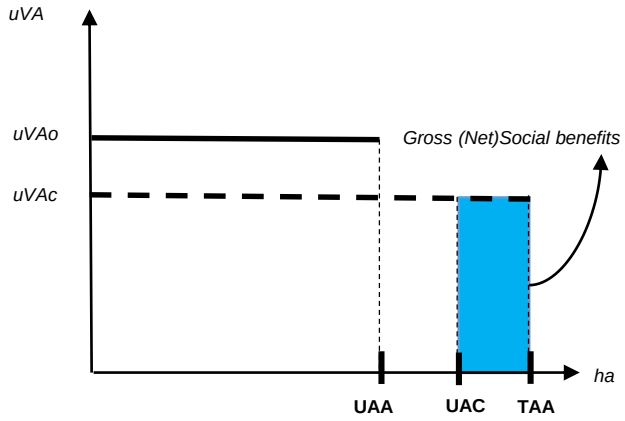
Area	Available Area (ha)				Utilized Agricultural Area to be replaced	
	Unused Agricultural Area	Set-aside	Total		ha	% of area for cardoon
Anglona	1,176.20	0	1,176.20		305.80	20.6
Gallura	2,230.50	757.5	2,988.00		0.00	0.0
Goceano	411.9	74.7	486.7		579.30	54.3
Marghine Barbagia	988.1	152.7	1,140.70		1,022.30	47.3
Mejlogu	2,479.10	0	2,479.10		2,262.90	47.7
Montacuto	1,083.80	587.5	1,671.20		1,872.80	52.8
Nurra Sassarese Romangia	4,866.40	1,603.50	6,469.90		322.10	4.7
Planargia Montiferru	561.3	80.3	641.6		888.40	58.1
TOTALE	13,797.30	3,256.20	17,053.50		5,015.50	22.7

- **Optimal scenario**: all the area necessary for the cardoon is available (or will be available owing to ongoing processes of abandon in agriculture)
- However, summing unused agricultural area and set-aside, **only in Gallura** and **mostly in NSR there is sufficient land for cardoon** (provided that it is suitable). Moreover, the process of abandon that should release land could not be complete when the power plant will be fully operational
- **Substitution processes are desirable (necessary)** for the aims of the project (especially in Mejlogu – over 2,000 hectares from UAA)
- **Economic reasons for substitution**: higher profitability, contracts (fixing quantities and prices and thus reducing risks of market volatility), simplicity (mechanization, agricultural contractors)

Alternative scenarios (2)

- A) **Full-additional**
  - the cardoon adds to existing agriculture by occupying unused and suitable area (optimal)
- B) **Partial-subtitution**
  - A part of the area for the cardoon will be taken from already used agricultural area (realistic) – **5,000 hectares (20% of necessary area)**
- C) **Full-substitution**
  - All the area for the cardoon will come from currently used agricultural area (pessimistic) - **22,000 hectares**
- *Break-event point analysis*
  - Level of substitution at which the benefits of the supply chains activated by the power plant are offset by the costs generated by the replacement of agricultural activities

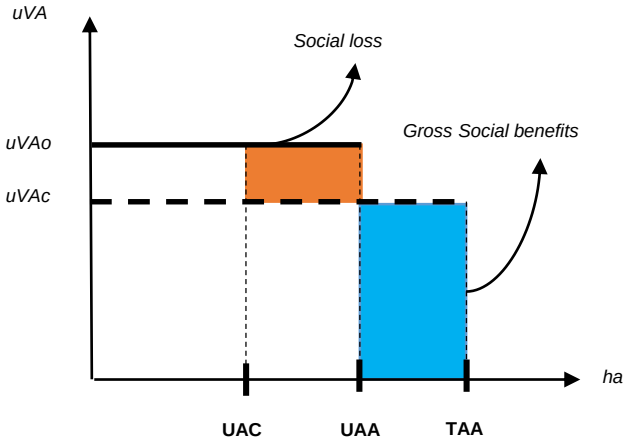
1. Full-additional scenario



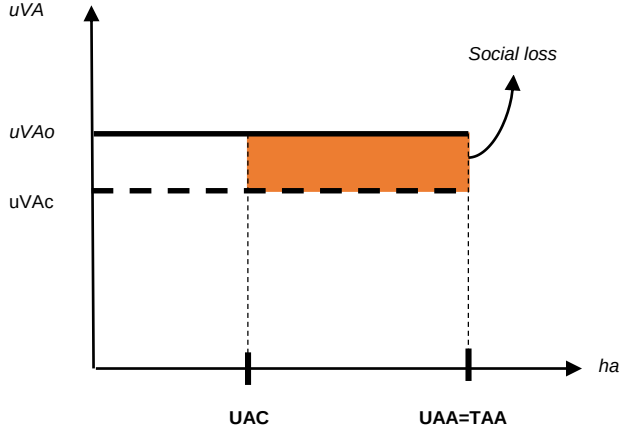
Legend:

uVAc = VA of cardoon per hectare
uVAo = VA of other agricultural activities per hectare
TAA = Total Agricultural Area (ha)
UAA = Utilized Agricultural Area (ha)
UAC = Utilized Area for Cardoon (the area in hectares is measured by the segment UAC-TAA)

2. Partial-substitution scenario



3. Full-substitution scenario



Assumption: uVAo > uVAc

Modelling scenarios

- The level of **substitution**: % reduction in agricultural output, corresponding to the average value of the UAA replaced by the cardoon
  - Output reduction in each district = hectares replaced X unitary output of the agricultural sector
    - Unitary output = total agricultural output (multiregional I-O table) / 2010 UAA
  - No assumptions about the type of activity that will be replaced (average output and I-O coefficients, which take account of different activities in terms of value and degree of economic integration)
- **Full-additional** scenario
  - Demand-driven version of multi-regional I-O model
    - Effects generated by activation of supply chains to guarantee the functioning of the biomass power plant (purchase of inputs such as biomass, machinery maintenance, water, transport, etc.)
  - Mixed-variable version
    - Effects generated by the production and sale of oilseeds modelled as positive change in output
- **Partial and full substitution** scenario
  - Mixed-variable version
    - Effects generated by a decrease in agricultural output corresponding to the level of substitution
    - Negative effects that compensate positive effects associated with full-additional scenario

Results: **value added impacts**

Impacts produced by the supply chain of the cardoon in terms of **value added**

Area	Benefits per scenario				Break-even point (% of hectares replaced)	Substitution elasticity of impact
	Full Additional (000 €)	% VA (2008)	Partial Substitution (% of full impact)	Full Substitution (% of full impact)		
Anglona	856.1	0.21	77.8	-7.5	93.0	1.075
Gallura	463.9	0.08	97.2	-34.5	74.4	1.345
Goceano	494.5	0.27	-26.9	-134.2	42.7	2.342
Marghine Barbagia	971.6	0.24	70.0	35.3	154.6	0.647
Mejlogu	2,508.7	0.64	15.7	-78.0	56.2	1.780
Montacuto	1,602.0	0.40	30.4	-32.8	75.3	1.328
Nurra Sassarese Romangia	9,166.0	0.22	93.9	4.0	104.1	0.960
Planargia Montiferru	653.4	0.28	6.6	-62.0	61.7	1.620
Rest of Sardinia	3,766.1	0.02	90.8	69.5	327.9	0.305
Sardinia	20,482.3	0.07	71.4	-2.2	97.8	1.022

% of reduction in benefits due to a replacement of 1% of used hectares (sensitivity to replacement of agricultural activity)

- **Full-Additional**: 20 million €/year (<1% of 2008 VA)
  - Most impact in NSR (most operations) but higher relative impacts in less developed economies (Mejlogu)
- **Partial-Substitution**: Loss of 30% of benefits
  - Goceano is the most penalised one (-27%)
  - Interestingly, also Gallura (where there is no substitution) and the rest of Sardinia (where there is no even cultivation of cardoon) experience losses (spatial relationships)
- **Full-Substitution**: Loss of all benefits + further loss of 2% of full-additional benefits
  - Most districts penalised (especially Goceano); only MB and NSR maintain a part of benefits
- **BEP** = **98% of used hectares** should be replaced to see benefits vanish (high importance of the project)
  - BEP is lower (higher) where the **sensitivity** of the economy to replacement of agricultural activities is higher (lower)

Results: **employment impacts**

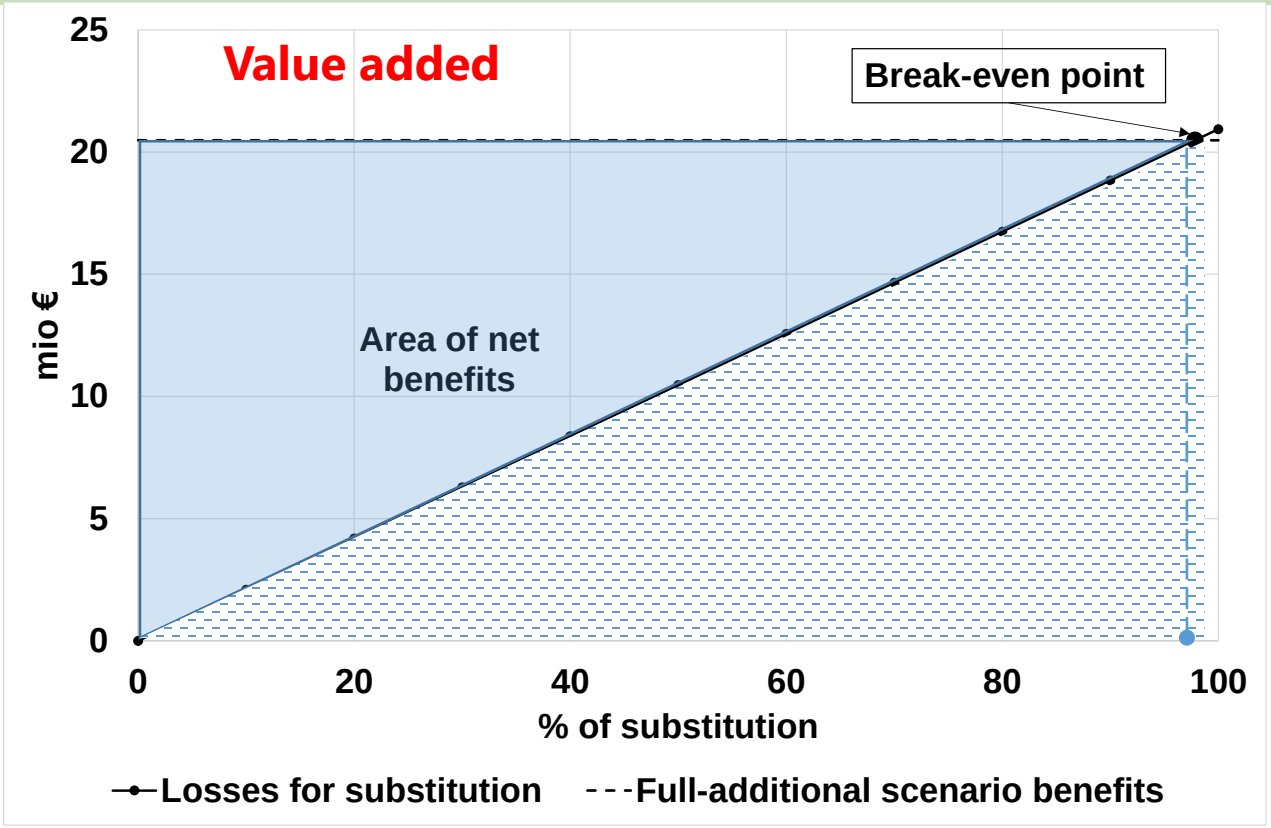
Impacts produced by the supply chain of the cardoon in terms of **employment**

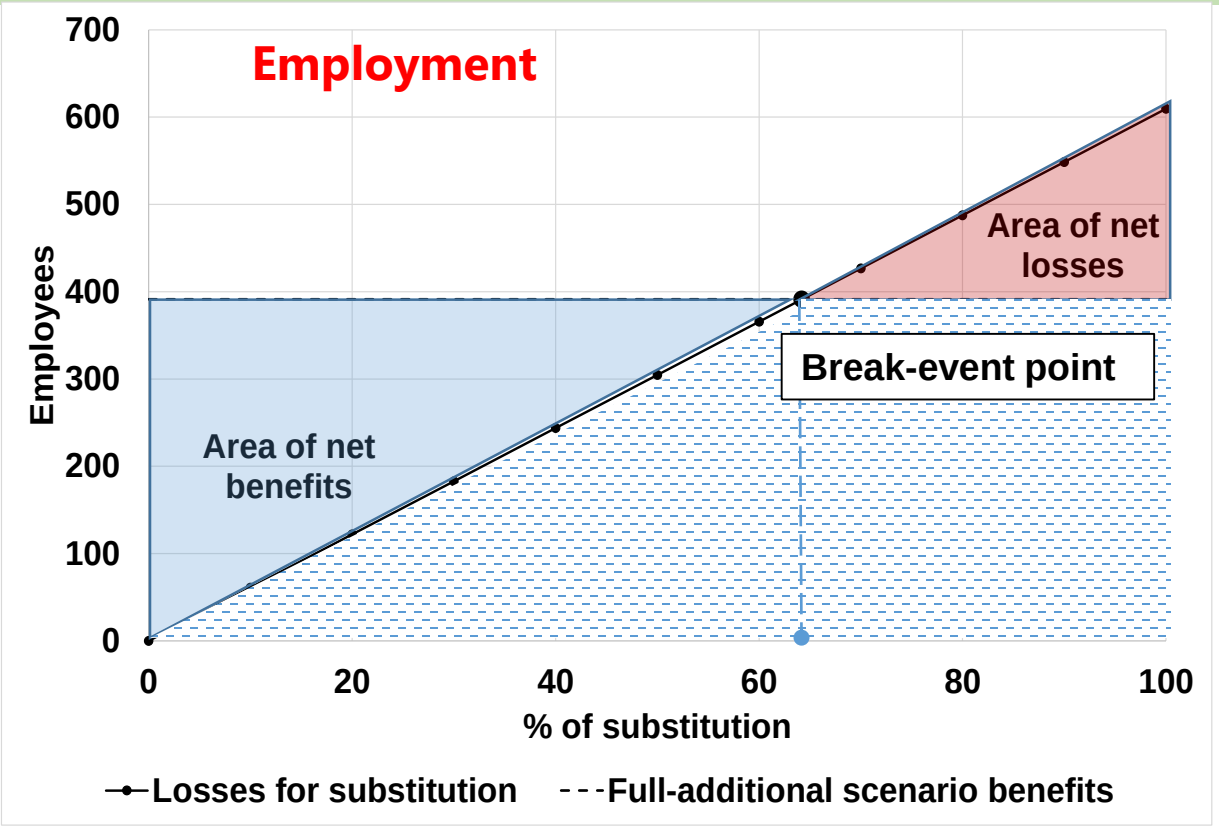
Area	Benefits per scenario				Break-even point (% of hectares replaced)	Substitution elasticity of impact
	Full Additional (employees)	% empl. (2008)	Partial Substitution (% of full impact)	Full Substitution (% of full impact)		
Anglona	11.4	0.17	51.5	-135.0	42.6	2.350
Gallura	8.5	0.06	93.8	-104.5	48.9	2.045
Goceano	5.4	0.15	-149.4	-361.0	21.7	4.610
Marghine Barbagia	20.8	0.21	18.3	-74.5	57.3	1.745
Mejlogu	24.6	0.38	-74.2	-267.2	27.2	3.672
Montacuto	20.1	0.27	-31.0	-150.2	40.0	2.502
Nurra Sassarese Romangia	212.8	0.25	92.3	-37.8	72.6	1.378
Planargia Montiferru	12.6	0.25	-113.6	-269.6	27.1	3.696
Rest of Sardinia	75.1	0.02	90.6	68.6	318.1	0.314
Sardinia	391.3	0.06	60.0	-55.8	64.2	1.558

% of reduction in benefits due to a replacement of 1% of used hectares (sensitivity to replacement of agricultural activity)

- **Full-Additional**: 400 employees (<1% of 2008 employment)
  - Most impact in NSR (most operations) but higher relative impacts in less developed economies (Mejlogu)
- **Partial-Substitution**: Loss of 40% of benefits (160 jobs are no more created)
  - Goceano and Planargia Montiferru are the most penalised ones
- **Full-Substitution**: Loss of all benefits + further loss of 56% of full-additional benefits
  - All districts penalised (especially Goceano); only the Rest of Sardinia maintains a part of benefits
- **BEP** = **64% of used hectares** should be replaced to see benefits vanish
- **Substitution impacts** are **more amplified**: relatively higher agricultural EMP multipliers especially in less developed economies where agriculture still plays an important role (employment contribution)

Results: break-event point analysis





- As the level of substitution increases, the area of **net benefits** (net losses) tends to shrink (enlarge) proportionally
- **Critical area** is substantially absent in the case of **value added**
- It is more evident in the case of **employment** (BEP identifies **two distinct areas**)

Concluding remarks (1)

- **Positive and locally significant impacts** in terms of value added and employment, though limited in comparison with the overall economy size
  - Direct, indirect and induced effects generated by intersectoral and interspatial linkages of the economy of the Sardinia
- There could be **processes of substitutions** of existing agricultural activities that compensate the gross positive effects
  - Available and suitable area could not be enough also following the foreseen process of progressive abandon of land: **substitution** becomes **desirable** for the aims of the project
  - Several **economic factors** could push farmers to replace current agricultural activities

Concluding remarks (2)

- In the case of **partial substitution** (the most realistic scenario), most effects in terms of value added will be maintained while, in terms of employment, there would be more negative effects
- A **full substitution** scenario would exacerbate the negative effects
- There are **areas** that are **more sensitive** to replacement of agricultural activities especially with reference to employment
- There are also **areas** that would be **indirectly affected** by the project and processes of substitution (even if not directly involved)
- Results of simulation do not diminish the **economic importance of the project**
  - Activation of supply chains, incentives to agricultural diversification, more economic opportunities for areas undergoing negative dynamics in the agro-food system
- They provide policy makers and all the stakeholders involved with a **more complete** (though approximated) **picture** of possible implications of introducing a new activity like the cardoon in the current Sardinian system, taking account of its intersectoral and spatial relationships