

Coupled mathematical programming and CGE modelling for drought policy assessment

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The challenge: scarcity and droughts

RCP4.5 2016-2035 April-September





Source: IPCC, 2013

> Water crises are perceived as the most relevant global risk in terms of impact

- > Irrigation represents 70% of total water withdrawals worldwide
- > CC will reduce supply. Demand for crop irrigation is expected to increase by more than 40% up to 2080
 - > Absolute scarcity is a reality already

> How can we adapt? What will be the repercussions?



A tale of engineering



> Success in harnessing environment for economic growth> In the face of CC, this model is unsustainable

- > Financial crisis increases opportunity costs
- > Environmental costs are overcoming financial benefits
- > CC demands ever-increasing investments

> Some of the solutions have backfired (e.g. irrigation modernization in Mediterranean areas)



Mathematical programming and CGE modelling

Managing demand

> The water crisis is mostly a **crisis of governance**

> Technical CC and disaster risk management developed to a very large extent...

> ...while social, political, institutional and economic aspects are still treated in an incipient form, with major problems persisting

> **Economic instruments**: *align individual decisions with collectively agreed goals*

- > Complementary to engineering
- > Not panaceas –case sensitive
- > Streamed into the policy mix to solve CC-related problems (not revenue raising –although this is a welcome byproduct)

> Tool: Coupled Revealed Preference and CGE models

> Examples: Adaptation to water scarcity in agriculture



Chapter 1: Coupling with droughts in the Regione Emilia Romagna (Italy)

The context: droughts in the Regione Emilia Romagna (Italy)



- > Water use in the RER has increased over the last decades
- > Drought spells are increasingly frequent
 - > State of Emergency declared three times (2003, 2006, 2007) for a total of 21 months



A highly engineered river – for millennia





- > Water is abundant in normal years
 - > (often too much!)
- > <u>WFD</u>: guarantee the good ecological status & cost recovery
- > Po RBD: voluntary agreements (effective? Costly?)



> Charges short run marginal cost

> on top of the long run marginal cost (partially) addressed by conventional charging arrangements

> Goal: recover the costs that arise during drought events, including:

- > Environmental costs
- > Resource costs

> Simulations are run in a modelling framework that couples a RPM and CGE models (Pérez-Blanco et al., 2015)



Simulation results



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Tradeoffs in water conservation





Coupled micro-macro level



Conclusions



- > Water use elastic in the range 0-54 Eurocents/m3
- > Macroeconomic impacts increase with charges
- > Goal of \downarrow 25 Mm3
 - > 14.4 M€ (.58 €/m3) *Micro*
 - > 15.9 M€ (.63 €/m3) Macro
- > Goal of \downarrow 100 Mm3
 - > 198.7 M€ (.96 €/m3) *Micro*
 - > 223.3 M€ (1.09 €/m3) Macro
- > Significant economic impacts
- > Effective? Compare against alternative instruments (regulation, insurance + reg)

> Efficient?



Chapter 2: The absolute water scarce Segura River Basin (Spain)

The context: Absolute water scarcity



> Semi-arid basin

> Rainfall is uneven and unequally distributed

> Non-perennial rivers

> 1950s irrigation expansion(个 productivity)

> Agriculture: 89% of total water use

> Supply: 760 M m3;
Demand: 1,900 M m3; WEI:
2.5 (1.15 including TSWT & desalination)

> Water is gold



Water in SE Spain: Giving gold for free



> Average water charge: 0.09 EUR/m3



WATER CHARGING

 Conventional water prices are progressively increased
 Water use, gross variable margin, employment generation and gross value added are assessed



Conclusions



- > EU belief: \uparrow water **P**rices => \downarrow **W**ater use (EC, 2000, 2012)
- > This is at best debatable (Cornish et al., 2004; Perry, 2005; Steenbergen et al., 2007...)
- > \uparrow P may \downarrow GVM, marginal impact on W

>What about the SRB?

- > \uparrow P improve low CR ratios (54-81%)
- > But are insufficient to \downarrow W
 - > Until unrealistic \uparrow P over 600%
- > What can be done?



> De iure, RBAs are entitled to limit/revoke water concessions that harm the environment, without compensation

> *De facto*, concessions are renewed automatically

- > Transaction costs
- > Negative economic impact on rural areas
- > Water buyback aims at:
 - > restoring environmental flows;
 - > compensating farmers (& overcome resistance); and
 - > compensating other possible negative feedbacks

> Since 2006 government agencies can use *exchange centers* to buy water concessions

> We estimate a <u>benchmark</u> to inform and assess water purchase tenders (compensating variation)



Simulation results: buyback scenarios

Marginal and average water purchase prices and investment costs for selected environmental targets (3.7% capitalization rate)

		-	Com	pensating variation	n	Foregone income					
]	Target	Balance	Marginal price	Average price	Investment	Marginal price	Average price	Investment			
	(hm ³)	(hm ³)	(EUR/m ³)	(EUR/m ³)	(M EUR)	(EUR/m ³)	(EUR/m ³)	(M EUR)			
	50	-194	1.14	0.58	28.9	2.94	1.33	66.5			
	100	-144	3.30	1.37	137.2	4.51	2.65	265.2			
	150	-94	4.42	2.22	332.9	6.91	3.67	550.9			
	200	-44	6.03	2.89	578.9	9.93	4.73	945.4			
	250	6	8.81	3.81	952.8] 13.90	6.22	1,554.20			
	300	56	11.63	4.91	1,474.10	16.56	7.78	2,333.20			
	400	156	21.19	7.87	3,146.50	32.72	11.02	4,408.10			
	500	256	38.39	11.56	5,781.50	52.77	18.08	9,041.40			

Source: Own elaboration



Simulation results Average prices

> Buyback programs typically define ad hoc environmental targets for strategic points of the basin

> Market segmentation
 > Average purchase price
 in every AWDU in the
 Segura River Basin for
 selected buyback targets



Target: 50 hm³ (2.7% of initial concession)



Target: 100 hm³ (5.5% of initial concession)



Target: 200 hm³ (10.9% of initial concession)







20

Euro/m3 20



Target: 150 hm³ (8.2% of initial concession)

Conclusions

> Water buyback can help restore the balance > Average price about 3.8 EUR/m3

> A few caveats:

> Informal abstractions: track and ban, do not empower (not again!)

> Use water bought for environmental purposes

> not to maintain allotments during droughts (define ecological flows)

> Define priority areas for buyback (downstream vs upstream)

> This is but a policy option –others may exist

> Charges

> Insurance

> etc.

> Explore complementarities, sequencing

> Transaction costs are the key



Chapter 3: No silver bullets...

uthopter.

Some remarks

> Economic instruments complement supply policies

- > Both are preconditions for a successful policy mix
- > Putting all together –be aware of:
 - > Institutional setup the peril of transaction costs
 - > Policy mix
 - > Sequencing and spillovers
- > And remember: there are **no silver bullets**
 - > You better learn from other experiences...
 - > ...but it is the context what ultimately determines the solution





Thanks for your attention



This research is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 660608.



http://wateragora.eu/



Calibration results: RER

Agricultural District a. a. a. e. e. e. e. e. e. Planura di Regio Emila 68.3% 6.2% 0.0% 2.4% 10.9% 12.6% 10.4% 5.1% 0.0% 5.4% 0.0% 1.2% 1.46% 5.2% 1.2% 1.46% 5.2% 1.0% 0.0% 0.0% 0.0% 1.3% 2.0% 1.46% 5.2% 1.0% 0.0% 0.0% 1.3% 0.0% 1.3% 2.0% 1.5% 2.0% 1.5% 0.0% 1.5% 0.0% 1.3% 1.4% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 0.0% 1.3% 1.4% 0.0% 1.3% 1.3% 2.0% 1.4% 1.3% 1.4% 1.3% 1.4% 1.3% <td< th=""><th></th><th></th><th>Alpł</th><th>na Values</th><th></th><th colspan="5">Errors</th></td<>			Alpł	na Values		Errors				
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bassa Reggiana 76.1% 0.7% 0.0% 24.2% 0.0% 3.4% 1.8% 4.7% 2.0% Bassa Reggiana 76.3% 1.4% 0.0% 24.2% 0.0% 7.6% 2.1% 7.0% 3.5% Bassa Reggiana 86.1% 1.3% 0.0% 14.6% 0.0% 2.6% 0.5% 2.7% 1.3% Planura di Parena 86.1% 1.3% 0.0% 10.6% 0.0% 2.2% 0.9% 0.0% 2.9% 4.3% 3.9% 2.1% Colline del Nortene edel Bidente 88.6% 0.7% 0.0% 10.7% 0.0% 1.3% 2.9% 6.6% 3.2% Colline del Silaro e del Lamone 89.9% 10.1% 0.0% 0.0% 1.3% 6.6% 2.9% 6.6% 3.2% Colline del Silaro e del Lamone 85.2% 1.3% 0.0% 0.0% 0.0% 8.4% 4.1% 8.5% 6.7% 4.5% 5.7% 4.5% 6.7% 2.9% 4.6% 4.9% 2.0% 6.6% 3.2% 2.0% 6.6% 3.2% 2.0% 6.6% 3.2	Bonifica Ferrarese Orientale	85.8%	3.6%	0.0%	10.6%	0.0%	13.7%	2.7%	14.0%	6.6%
Bassa Medgiana/6.3%1.4%0.0%22.3%0.0%7.6%2.1%7.0%3.57Pianura di Parma86.1%1.3%0.0%12.6%0.0%6.3%0.9%6.0%2.99Pianura di Pianeraz87.5%1.9%0.0%11.7%0.0%2.2%0.9%0.0%0.88Colline del Nure e dell'Arda84.5%3.7%0.0%11.7%0.0%2.9%4.3%3.9%2.1%Colline del Nure e dell'Arda84.5%3.7%0.0%10.7%0.0%1.9%2.1%1.4%1.1%Colline del Nurie e dell'Arda88.6%0.7%0.0%10.7%0.0%6.6%2.0%6.6%3.2%Colline del Salorio e del Lamone88.2%1.3%0.0%13.5%0.0%8.4%4.1%8.5%4.2%Colline del Salorio e del Santerno99.7%0.3%0.0%0.0%0.0%4.5%5.7%4.5%2.8%Colline di Balsomaggiore75.4%8.7%0.0%0.0%0.0%7.2%0.3%0.1%2.4%Colline del Salornagoire75.4%8.9%1.1%0.0%0.0%0.0%8.3%3.7%8.3%4.1%Colline del Conca97.3%1.1%0.0%0.0%0.0%0.0%0.0%0.0%0.4%0.4%0.33%Colline del Conca99.0%1.1%0.0%0.0%0.0%0.0%0.0%0.0%0.0%0.0%0.0%0.0%0.0%0.0%0.0%	Basso Arda	75.1%	0.7%	0.0%	24.2%	0.0%	3.4%	1.8%	4.7%	2.0%
Bassa Modenese 80,7% 4.8% 0.0% 14.5% 0.0% 2.6% 0.5% 2.7% 1.3% Pianura di Parana 85,7% 1.3% 0.0% 12.6% 0.0% 2.2% 0.9% 0.0% 0.2% Colline del Nure a dell'Arda 84,5% 3.7% 0.0% 11.7% 0.0% 2.9% 4.3% 3.9% 2.1% Colline del Montone e del Bidente 88,6% 0.7% 0.0% 0.0% 0.0% 2.9% 4.3% 3.9% 2.1% 1.4% 1.1% Colline di Montone e del Bidente 88,6% 0.7% 0.0% 0.0% 0.0% 6.6% 2.0% 6.6% 3.2% 6.6% 3.2% 6.6% 3.2% 6.6% 4.2% 9.2% 6.6% 3.2% 6.6% 4.2% 9.2% 6.6% 3.2% 6.6% 2.0% 6.6% 4.2% 9.2% 6.6% 3.2% 6.6% 3.2% 6.6% 4.2% 9.2% 6.0% 0.0% 0.0% 0.0% 0.0% 0.3%	Bassa Reggiana	76.3%	1.4%	0.0%	22.3%	0.0%	7.6%	2.1%	7.0%	3.5%
Pianura di Parma 86.1% 1.3% 0.0% 12.6% 0.0% 6.3% 0.9% 6.0% 2.9% Colline del Nure e dell'Arda 84.5% 3.7% 0.0% 11.7% 0.0% 2.2% 0.9% 0.0% 2.1% Colline del Murte e dell'Arda 84.5% 3.7% 0.0% 10.7% 0.0% 1.9% 2.1% 1.4% 1.1% Colline del Murte e del Bidente 88.6% 0.7% 0.0% 10.7% 0.0% 1.9% 2.1% 1.4% 1.1% Colline del Silaro 90.2% 0.7% 0.0% 9.1% 0.0% 6.6% 3.2% 1.3% 0.0% 13.5% 0.0% 8.4% 4.1% 8.5% 4.28 Colline del Silaro e del Lamone 90.7% 0.3% 0.0% 0.0% 0.0% 0.0% 4.4% 9.9% 4.2% 9.9% 4.2% 9.9% 4.2% 9.9% 4.2% 0.9% 4.2% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0%	Bassa Modenese	80.7%	4.8%	0.0%	14.5%	0.0%	2.6%	0.5%	2.7%	1.3%
Planutz di Placenza 87.5% 1.9% 0.0% 10.5% 0.0% 2.2% 0.9% 0.0% 0.2% Colline del Montone e del Bidente 88.6% 0.7% 0.0% 11.7% 0.0% 1.9% 2.1% 1.4% 1.1% Colline del Montone e del Bidente 88.6% 0.7% 0.0% 10.7% 0.0% 1.9% 2.1% 1.4% 1.1% Colline del Nontone e del Bidente 88.6% 0.7% 0.0% 0.0% 0.0% 6.6% 2.0% 6.6% 3.2% Colline di Sonio 90.2% 0.7% 0.0% 0.0% 0.0% 8.4% 4.1% 8.5% 4.2% Colline di Salzon aggiore 99.7% 0.3% 0.0% 0.0% 0.0% 4.5% 5.7% 4.5% 2.9% 4.9% Colline di Golgan 98.9% 1.1% 0.0% 0.0% 0.0% 3.7% 8.3% 4.9% Colline del Gonca 75.4% 8.7% 0.0% 0.0% 0.0% 0.0% 3.7% 2.2% 0.1% 2.9% 0.1% 2.9% 0.1% 2.9% 0.1%	Pianura di Parma	86.1%	1.3%	0.0%	12.6%	0.0%	6.3%	0.9%	6.0%	2.9%
Colline del Nure e dell'Arda 84.5% 3.7% 0.0% 11.7% 0.0% 2.9% 4.3% 3.9% 2.1% Colline del Montone e del Bidente 88.6% 0.7% 0.0% 0.0% 0.0% 1.9% 2.1% 1.4% 1.1% Colline del Montone e del Bidente 88.9% 10.1% 0.0% 0.0% 13.5% 6.6% 2.0% 6.6% 3.2% Colline del Salto o del Lamone 85.2% 1.3% 0.0% 13.5% 0.0% 8.4% 4.1% 8.5% 4.2% Colline del Saltor del Lamone 99.7% 0.3% 0.0% 0.0% 9.9% 4.2% 9.9% 4.9% Colline di Bologna 0.98,9% 1.1% 0.0% 0.0% 0.0% 8.3% 3.7% 8.3% 4.1% Colline del Salsomaggiore 75.4% 8.7% 0.0% 0.0% 0.0% 3.7% 0.2% 0.1% 1.2% Colline del Conca 97.3% 1.1% 0.0% 0.0% 0.0% 0.7% 0.4% 0	Planura di Placenza	87.5%	1.9%	0.0%	10.6%	0.0%	2.2%	0.9%	0.0%	0.8%
Colline del Montone e del Bidente 88.6% 0.7% 0.0% 10.7% 0.0% 1.9% 2.1% 1.4% 1.1% Colline int Rubicone 89.9% 10.1% 0.0% 0.0% 0.0% 13.7% 5.2% 13.7% 6.7% Colline del Senice del Lamone 85.2% 1.3% 0.0% 0.0% 8.4% 4.1% 8.5% 6.7% Colline del Santerno 99.7% 0.3% 0.0% 0.0% 0.0% 8.4% 4.1% 8.5% 4.2% Colline di Salsortaggiore 98.9% 1.1% 0.0% 0.0% 0.0% 3.8% 3.7% 8.3% 4.4% Colline di Goldenesi 88.9% 11.1% 0.0% 0.0% 0.0% 3.7% 0.3% 0.1% 1.29 Colline del Conca 97.3% 0.5% 0.0% 0.0% 0.7% 0.4% 0.4% 2.9% Colline del Conca 97.3% 1.1% 0.0% 0.0% 0.7% 0.4% 0.4% 1.9% Colline del Conca 97.3% 1.9% 0.0% 0.0% 0.0% 0.5% 0.0% <td>Colline del Nure e dell'Arda</td> <td>84.5%</td> <td>3.7%</td> <td>0.0%</td> <td>11.7%</td> <td>0.0%</td> <td>2.9%</td> <td>4.3%</td> <td>3.9%</td> <td>2.1%</td>	Colline del Nure e dell'Arda	84.5%	3.7%	0.0%	11.7%	0.0%	2.9%	4.3%	3.9%	2.1%
Colline Int. Rubicone 89.9% 10.1% 0.0% 0.0% 0.0% 2.0% 6.6% 2.0% 6.6% 3.7% 5.2% 13.7% 5.2% 13.7% 6.7% Colline del Savio 99.7% 0.3% 0.0% 13.5% 0.0% 8.4% 4.1% 8.5% 4.2% Colline del Santemo 99.7% 0.3% 0.0% 0.0% 0.0% 4.5% 5.7% 4.5% 2.8% Colline del Salsomaggiore 75.4% 8.7% 0.0% 0.0% 0.0% 7.2% 0.3% 0.1% 2.4% Colline di Salsomaggiore 75.4% 8.7% 0.0% 0.0% 0.0% 7.2% 0.3% 0.1% 2.4% Colline del Canca 99.5% 0.5% 0.0% 0.0% 0.0% 8.3% 3.7% 8.3% 4.19 Colline del Canca 99.5% 0.5% 0.0% 0.0% 0.0% 4.0% 0.1% 1.2% Colline del Canca 99.5% 0.5% 0.0% 1.6% 0.0% 0.0% 1.7% 0.4% 0.4% 0.5% 0.1% 0.0%<	Colline del Montone e del Bidente	88.6%	0.7%	0.0%	10.7%	0.0%	1.9%	2.1%	1.4%	1.1%
Colline Salvo 90.2% 0.7% 0.0% 9.1% 0.0% 13.7% 5.2% 13.7% 6.7% Collina del Senio e del Lamone 99.7% 0.3% 0.0% 0.0% 0.0% 4.5% 5.7% 4.5% 2.8% Colline del Sillaro e del Santerno 99.7% 0.3% 0.0% 0.0% 0.0% 4.5% 5.7% 4.5% 2.8% Colline di Bologna 98.9% 1.1% 0.0% 0.0% 0.0% 9.9% 4.2% 9.9% 4.9% Colline di Salsomaggiore 75.4% 8.7% 0.0% 0.0% 0.0% 8.3% 3.7% 8.3% 4.19 Colline ta Enza e Secchia 99.5% 0.5% 0.0% 0.0% 0.0% 4.1% 2.9% 4.0% 2.12 Colline del Conca 97.3% 1.1% 0.0% 0.0% 0.0% 0.4% 0.4% 0.3% Colline del Trebbia e del Tidone 81.3% 4.9% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 2.3	Colline Int. Rubicone	89.9%	10.1%	0.0%	0.0%	0.0%	6.6%	2.0%	6.6%	3.2%
Collina del Sento e del Lamone 35.2% 1.3% 0.0% 13.3% 0.0% 8.4% 4.1% 8.5% 4.2% Colline del Bologna 99.7% 0.3% 0.0% 0.0% 0.0% 0.0% 4.5% 4.7% 4.5% 4.2% Colline di Bologna 98.9% 1.1% 0.0% 0.0% 0.0% 0.0% 4.2% 9.9% 4.9% Colline di Salsomaggiore 75.4% 8.7% 0.0% 0.0% 0.0% 0.0% 3.7% 0.2% 0.1% 2.4% Colline Modenesi 88.9% 11.1% 0.0% 0.0% 0.0% 3.7% 0.2% 0.1% 1.2% Colline del Conca 99.5% 0.5% 0.0% 0.0% 0.0% 3.7% 0.2% 0.1% 1.2% Colline del Trebia e del Tidone 81.3% 1.1% 0.0% 0.0% 0.0% 0.7% 0.4% 0.4% 0.4% 0.3% 0.4% 0.3% 0.4% 0.3% 0.4% 0.3% 0.6% 0.3% 0.1% 0.3% 0.6% 0.3% 0.1% 0.3% 0.6% 0.3%<	Colline Savio	90.2%	0.7%	0.0%	9.1%	0.0%	13.7%	5.2%	13.7%	0.7%
Colline del Silial de Uter Santenito 99,7% 0.5% 0.0% 0.0% 1.0% 4.3% 3.7% 4.2% 9.9% 4.2% 9.9% 4.9% 2.0% Colline di Salsomaggiore 75,4% 8.7% 0.0% 15.9% 0.0% 7.2% 0.3% 0.1% 2.4% Colline di Salsomaggiore 75,4% 8.7% 0.0% 0.0% 0.0% 8.3% 3.7% 8.3% 4.19 Colline di Salsomaggiore 88,9% 11.1% 0.0% 0.0% 0.0% 8.3% 3.7% 8.3% 4.19 Colline de Texa e Secchia 99,5% 0.5% 0.0% 0.0% 0.0% 4.1% 2.9% 4.0% 2.19 Colline del Conca 97,3% 1.1% 0.0% 1.6% 0.0% 0.4% 0.4% 0.3% Colline del Conca 97,3% 1.1% 0.0% 0.0% 0.7% 0.4% 0.4% 0.4% 0.3% Colline del Conca 99,0% 1.0% 0.0% 0.0% 0.0% 0.4% 0.4% 0.4% 0.4% 0.3% 0.1% 0.4%	Collina del Senio e del Lamone	00.2% 00.7%	1.3%	0.0%	13.5%	0.0%	0.4%	4.1% 5.7%	0.0%	4.27
Colline di Salsomaggiore 99.7% 1.1% 0.0% 0.0% 9.9% 4.2% 9.9% 4.2% Colline di Salsomaggiore 75.4% 8.7% 0.0% 15.9% 0.0% 7.2% 0.3% 0.1% 2.4% Colline ta Enza e Secchia 99.5% 0.5% 0.0% 0.0% 3.7% 0.2% 0.1% 1.2% Medio Parma 98.9% 1.1% 0.0% 0.0% 0.0% 4.1% 2.9% 4.0% 0.3% Colline del Conca 97.3% 1.1% 0.0% 1.6% 0.0% 0.8% 4.5% 2.0% 1.7% Colline del Conca 97.3% 1.1% 0.0% 1.6% 0.8% 4.5% 2.0% 1.7% Colline del Conca 99.0% 1.0% 0.0% 0.0% 0.8% 4.5% 2.0% 1.7% Colline del Rono 99.0% 1.0% 0.0% 0.0% 0.0% 0.8% 2.0% 1.5% Alto Taro 97.6% 2.4% 0.0% 0.0% 0.0% 2.2% 3.6% 0.1% 1.5% Alto Panar		99.7%	0.3%	0.0%	0.0%	0.0%	4.5%	J.7%	4.5%	2.07
Colline di Gabriaggiole 73,4% 0.7% 0.0% 13,9% 0.0% 17,2% 0.3% 0.1% 1.2% 0.3% 0.1% 1.2% 0.1% 1.2% 0.1% 1.1% 0.0% 0.0% 0.0% 0.0% 0.0% 0.0% 0.1% 1.1% 0.0% 0.0% 0.0% 0.0% 0.0% 0.1% 1.1% 0.0% 0.0% 0.0% 0.0% 0.0% 0.1% 1.1% 0.0%	Colline di Bologna	96.9%	1.1% 0.70/	0.0%	0.0%	0.0%	9.9%	4.2%	9.9%	4.97
Colline indications 00.5% 11.1% 0.0% 0.0% 0.0% 0.0% 0.0% 0.1% <t< td=""><td>Colline Modenesi</td><td>75.4%</td><td>0.770</td><td>0.0%</td><td>15.9%</td><td>0.0%</td><td>7.2% 9.2%</td><td>0.3%</td><td>0.1%</td><td>Z.47 1 10</td></t<>	Colline Modenesi	75.4%	0.770	0.0%	15.9%	0.0%	7.2% 9.2%	0.3%	0.1%	Z.47 1 10
Medio Parma 98.5% 0.5% 0.0% 0.0% 0.0% 0.0% 0.0% 0.1% 0.1% 1.2% 0.1% 1.1% Colline del Conca 97.3% 1.1% 0.0%	Colline tra Enza e Secchia	00.970	0.5%	0.0%	0.0%	0.0%	2 7%	0.2%	0.3%	4.17
Colline del Conca 97.3% 1.1% 0.0% 0.0% 0.0% 1.7% 2.5% 4.0% 2.1% Colline del Conca 97.3% 1.1% 0.0% 1.6% 0.0% 0.7% 0.4% 1.5% 0.0% 0.0% 0.0% 0.4% 0.4% 1.5% 0.1% 1.5% 0.0% 0.0% 0.0% 0.4% 0.4% <td>Medio Parma</td> <td>99.5%</td> <td>0.5%</td> <td>0.0%</td> <td>0.0%</td> <td>0.0%</td> <td>J.1 %</td> <td>2.0%</td> <td>4.0%</td> <td>2.10</td>	Medio Parma	99.5%	0.5%	0.0%	0.0%	0.0%	J.1 %	2.0%	4.0%	2.10
Colline del Collda 57.5% 1.17% 0.0% 1.0% 0.0% 0.7% 0.4% 0.4% 0.0% Colline del Trebbia e del Tidone 81.3% 4.9% 0.0% 13.8% 0.0% 0.8% 4.5% 2.0% 1.7% Colline del Reno 99.0% 1.0% 0.0% 0.0% 0.0% 7.0% 5.7% 7.0% 3.8% Colline del Montefeltro 98.1% 1.9% 0.0% 0.0% 0.0% 2.2% 3.6% 2.0% 1.5% Valli del Dragone e del Rossenna 79.6% 0.5% 0.0% 0.0% 0.0% 2.2% 3.6% 2.0% 1.5% Alto Taro 97.6% 2.4% 0.0% 0.0% 0.0% 2.2% 3.6% 2.0% 1.5% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 2.0% 2.3% 0.1% 8.4% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 3.3% 9.6% 4.7% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 3.3%	Colline del Conca	90.978 07.3%	1.170	0.0%	1.6%	0.0%	4.1%	2.570	4.078	0.30
Colline del Andrie 91.3 % 4.3 % 0.0 % 10.0 % 0.0 % 4.3 % 2.0 % 1.1 % Colline del Reno 99.0 % 1.0 % 0.0 % 0.0 % 0.0 % 7.0 % 5.7 % 7.0 % 3.8 % Colline del Montefeltro 98.1 % 1.9 % 0.0 % 0.0 % 0.0 % 2.3 % 1.2 % 2.1 % 1.1 % Valli del Dragone e del Rossenna 79.6 % 0.5 % 0.0 % 0.0 % 0.0 % 2.2 % 3.6 % 2.0 % 1.5 % Alto Taro 97.6 % 2.4 % 0.0 % 0.0 % 0.0 % 4.6 % 0.5 % 0.1 % 1.5 % Alto Reno 83.5 % 16.5 % 0.0 % 0.0 % 0.0 % 4.6 % 0.5 % 0.1 % 1.6 % Alto Parma 98.8 % 0.7 % 0.0 % 0.0 % 0.0 % 4.7 % 0.6 % 0.1 % 1.6 % Alto Pararo 86.3 % 13.7 % 0.0 % 0.0 % 0.0 % 3.3 % 9.6 % 4.7 % Montagna del Medio Trebbia 99.9 % 0.1 % 0.0 % 0.0 % <td< td=""><td>Colline del Trebbia e del Tidone</td><td>97.370 81.3%</td><td>1.178</td><td>0.0%</td><td>13.8%</td><td>0.0%</td><td>0.7 %</td><td>0.470 4.5%</td><td>2.0%</td><td>1 70</td></td<>	Colline del Trebbia e del Tidone	97.370 81.3%	1.178	0.0%	13.8%	0.0%	0.7 %	0.470 4.5%	2.0%	1 70
Colline del Montefeltro 98.1% 1.9% 0.0% 0.0% 0.0% 1.0% 1.1% 1.1% 1.1% Colline del Montefeltro 98.1% 1.9% 0.0% 0.0% 0.0% 2.3% 1.2% 2.1% 1.1% Valli del Dragone e del Rossenna 79.6% 0.5% 0.0% 19.9% 0.0% 2.3% 1.2% 2.1% 1.5% Alto Taro 97.6% 2.4% 0.0% 0.0% 0.0% 4.6% 0.5% 0.1% 1.5% Alto Reno 83.5% 16.5% 0.0% 0.0% 0.0% 2.0% 1.4% 8.4% Alto Parma 98.8% 0.7% 0.0% 0.0% 4.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 3.3% 9.6% 4.7% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 3.3% 9.6% 4.7% Montagna tra l'Al	Colline del Reno	99.0%	4.9%	0.0%	0.0%	0.0%	7.0%	4.3 <i>%</i>	2.0%	3.80
Valli del Dragone e del Rossenna 79.6% 0.5% 0.0% 19.9% 0.0% 2.2% 3.6% 2.0% 1.5% Alto Taro 97.6% 2.4% 0.0% 0.0% 0.0% 4.6% 0.5% 0.1% 1.5% Alto Reno 83.5% 16.5% 0.0% 0.0% 0.0% 2.3% 0.1% 8.4% Alto Parma 98.8% 0.7% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 9.6% 3.3% 9.6% 4.7% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 3.5% 0.1% 7.0% Montagna del Medio Reno 97.2% 2.8% 0.0% 0.0% 8.5% 3.3% 9.0% 4.3% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 0.0% 1.0% 1.4% 7.0% 4.4% <td>Colline del Montefeltro</td> <td>98.1%</td> <td>1.0%</td> <td>0.0%</td> <td>0.0%</td> <td>0.0%</td> <td>2.3%</td> <td>1.2%</td> <td>2.1%</td> <td>1 10</td>	Colline del Montefeltro	98.1%	1.0%	0.0%	0.0%	0.0%	2.3%	1.2%	2.1%	1 10
Alto Taro 97.6% 2.4% 0.0% 0.0% 0.0% 4.6% 0.5% 0.1% 1.5% Alto Taro 97.6% 2.4% 0.0% 0.0% 0.0% 4.6% 0.5% 0.1% 1.5% Alto Reno 83.5% 16.5% 0.0% 0.0% 0.0% 2.3% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.5% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Panaro 86.3% 13.7% 0.0% 0.0% 0.0% 3.3% 9.6% 4.7% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 3.3% 9.0% 4.3% Montagna del Montefeltro 99.0% 1.0% 0.0% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Montagna tr	Valli del Dragone e del Rossenna	79.6%	0.5%	0.0%	19.9%	0.0%	2.3%	3.6%	2.1%	1.17
Alto Reno 83.5% 16.5% 0.0% 0.0% 0.0% 25.0% 2.3% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.5% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 3.5% 0.1% 7.0% Montagna del Medio Reno 97.2% 2.8% 0.0% 0.0% 0.0% 8.5% 3.3% 9.0% 4.3% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 1.0% 1.4% 7.0% 4.4%<	Alto Taro	97.6%	2.4%	0.0%	0.0%	0.0%	4.6%	0.5%	0.1%	1.5%
Alto Parma 98.8% 0.7% 0.0% 0.5% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.5% 0.0% 4.7% 0.6% 0.1% 1.6% Alto Parma 98.8% 0.7% 0.0% 0.0% 0.0% 4.7% 0.6% 0.1% 1.6% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 20.6% 3.5% 0.1% 7.0% Montagna del Medio Reno 97.2% 2.8% 0.0% 0.0% 0.0% 8.5% 3.3% 9.0% 4.3% Montagna del Montefeltro 99.0% 1.0% 0.0% 0.0% 0.0% 1.2% 0.1% 0.3% 0.8% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 10.1% 1.4% 7.0% 4.1%	Alto Reno	83.5%	16.5%	0.0%	0.0%	0.0%	25.0%	2.3%	0.1%	8.49
Alto Panaro 86.3% 13.7% 0.0% 0.0% 0.0% 9.6% 3.3% 9.6% 4.7% Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 20.6% 3.5% 0.1% 7.0% Montagna del Medio Reno 97.2% 2.8% 0.0% 0.0% 0.0% 8.5% 3.3% 9.0% 4.3% Montagna del Montefeitro 99.0% 1.0% 0.0% 0.0% 0.0% 2.4% 0.1% 0.3% 0.8% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 10.1% 1.4% 7.0% 4.1%	Alto Parma	98.8%	0.7%	0.0%	0.5%	0.0%	4 7%	0.6%	0.1%	1.69
Montagna del Medio Trebbia 99.9% 0.1% 0.0% 0.0% 0.0% 20.6% 3.5% 0.1% 7.0% Montagna del Medio Reno 97.2% 2.8% 0.0% 0.0% 0.0% 8.5% 3.3% 9.0% 4.3% Montagna del Medio Reno 99.0% 1.0% 0.0% 0.0% 0.0% 2.4% 0.1% 0.3% 0.8% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 10.1% 1.4% 7.0% 4.1%	Alto Panaro	86.3%	13.7%	0.0%	0.0%	0.0%	9.6%	3.3%	9.6%	4.79
Montagna del Medio Reno 97.2% 2.8% 0.0% 0.0% 0.0% 8.5% 3.3% 9.0% 4.3% Montagna del Montefeltro 99.0% 1.0% 0.0% 0.0% 0.0% 2.4% 0.1% 0.3% 0.8% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 10.1% 1.4% 7.0% 4.1%	Montagna del Medio Trebbia	99.9%	0.1%	0.0%	0.0%	0.0%	20.6%	3.5%	0.1%	7.09
Montagna del Montefeltro 99.0% 1.0% 0.0% 0.0% 2.4% 0.1% 0.3% 0.8% Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 1.2% 0.1% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 10.1% 1.4% 7.0% 4.1%	Montagna del Medio Reno	97.2%	2.8%	0.0%	0.0%	0.0%	8.5%	3.3%	9.0%	4.39
Montagna tra l'Alto Enza e Alto Dolo 99.2% 0.8% 0.0% 0.0% 1.2% 0.1% 0.4% Alto Nure 94.0% 1.0% 0.0% 4.7% 0.0% 10.1% 1.4% 7.0% 4.1%	Montagna del Montefeltro	99.0%	1.0%	0.0%	0.0%	0.0%	2.4%	0.1%	0.3%	0.8%
Alto Nure 94.0% 1.0% 0.0% 0.0% 0.0% 10.1% 0.1% 0.1%	Montagna tra l'Alto Enza e Alto Dolo	00.2%	0.80/	0.0%	0.0%	0.00/	1 20/	0.10/	0.1%	0.40
	Alto Nure	99.2% 94.0%	1.0%	0.0%	0.0 <i>%</i> 4.7%	0.0%	10.1%	0.1% 1.4%	7.0%	4.19

Calibration results: SRB

AWDU	a1	a2	a3	a4	a5	e_x	e_t	e_av	AWDU	a1	a2	a3	a4	a5	e_x	e_t	e_av
1	0.99	0.01	0.00	0.00	0.00	8.06%	1.83%	4.94%	39	0.95	0.02	0.00	0.03	0.00	1.42%	2.42%	1.92%
2	0.88	0.12	0.00	0.00	0.00	2.26%	8.35%	5.30%	40	0.88	0.12	0.00	0.00	0.00	0.89%	3.77%	2.33%
3	0.86	0.05	0.03	0.00	0.06	0.70%	2.76%	1.73%	41	0.81	0.19	0.00	0.00	0.00	3.24%	1.68%	2.46%
4	0.95	0.02	0.01	0.01	0.00	0.39%	1.75%	1.07%	42	0.91	0.09	0.00	0.00	0.00	1.83%	3.31%	2.57%
5	0.92	0.08	0.00	0.00	0.00	1.84%	1.76%	1.80%	43	0.90	0.08	0.00	0.00	0.02	1.29%	1.95%	1.62%
6	0.95	0.03	0.02	0.00	0.00	0.24%	0.72%	0.48%	44	0.92	0.02	0.04	0.00	0.01	1.34%	3.50%	2.42%
7	0.78	0.22	0.00	0.00	0.00	5.27%	5.91%	5.59%	45	0.74	0.07	0.00	0.18	0.00	1.52%	5.08%	3.30%
8	0.50	0.48	0.00	0.02	0.00	7.78%	5.62%	6.70%	46	0.98	0.02	0.00	0.01	0.00	1.03%	3.17%	2.10%
9	0.85	0.04	0.00	0.11	0.00	1.38%	6.22%	3.80%	48	0.38	0.12	0.00	0.36	0.14	4.27%	11.63%	7.95%
10	0.92	0.08	0.00	0.00	0.00	3.69%	3.49%	3.59%	51	0.92	0.01	0.00	0.00	0.08	0.13%	0.39%	0.26%
12	0.80	0.20	0.00	0.00	0.00	4.07%	9.07%	6.57%	52	0.97	0.02	0.00	0.00	0.00	1.36%	4.10%	2.73%
13	0.88	0.01	0.00	0.00	0.11	2.25%	5.39%	3.82%	53	0.44	0.23	0.00	0.34	0.00	6.12%	13.98%	10.05%
14	0.63	0.37	0.00	0.00	0.00	3.02%	2.26%	2.64%	54	0.59	0.41	0.00	0.00	0.00	10.44%	13.30%	11.87%
15	0.72	0.28	0.00	0.00	0.00	1.53%	3.81%	2.67%	55	0.95	0.05	0.00	0.00	0.00	0.20%	0.32%	0.26%
16	0.60	0.40	0.00	0.00	0.00	0.89%	7.69%	4.29%	56	0.73	0.27	0.00	0.00	0.00	1.63%	7.13%	4.38%
17	0.85	0.15	0.00	0.00	0.00	8.59%	3.81%	6.20%	57	0.10	0.90	0.00	0.00	0.00	9.50%	14.32%	11.91%
18	0.89	0.11	0.00	0.00	0.00	0.43%	1.67%	1.05%	58	0.48	0.52	0.00	0.00	0.00	10.58%	11.74%	11.16%
20	0.83	0.17	0.00	0.00	0.00	4.30%	2.96%	3.63%	59	0.52	0.48	0.00	0.00	0.00	9.88%	13.88%	11.88%
21	0.88	0.12	0.00	0.00	0.00	1.45%	9.21%	5.33%	60	0.83	0.16	0.00	0.00	0.01	3.22%	13.64%	8.43%
22	0.83	0.17	0.00	0.00	0.00	2.26%	2.12%	2.19%	61	0.28	0.72	0.00	0.00	0.00	8.61%	15.21%	11.91%
25	0.93	0.07	0.00	0.00	0.00	0.27%	1.17%	0.72%	63	0.43	0.40	0.17	0.00	0.00	1.94%	8.74%	5.34%
26	0.90	0.04	0.00	0.02	0.03	0.64%	3.38%	2.01%	64	0.53	0.47	0.00	0.00	0.00	0.82%	4.40%	2.61%
27	0.99	0.01	0.00	0.00	0.00	4.47%	9.33%	6.90%	65	0.43	0.55	0.00	0.00	0.02	2.03%	3.75%	2.89%
28	0.94	0.06	0.00	0.00	0.00	1.83%	6.91%	4.37%	66	0.87	0.07	0.00	0.00	0.06	1.37%	3.29%	2.33%
29	0.79	0.13	0.09	0.00	0.00	1.49%	3.83%	2.66%	67	0.29	0.49	0.00	0.00	0.22	0.62%	9.90%	5.26%
30	0.49	0.51	0.00	0.00	0.00	3.16%	7.22%	5.19%	68	0.79	0.21	0.00	0.00	0.00	0.50%	3.38%	1.94%
31	0.83	0.17	0.00	0.00	0.00	6.74%	4.96%	5.85%	69	0.34	0.66	0.00	0.00	0.00	1.22%	6.44%	3.83%
32	0.51	0.49	0.00	0.00	0.00	4.48%	13.04%	8.76%	70	0.67	0.26	0.00	0.00	0.07	1.40%	9.22%	5.31%
34	0.95	0.01	0.00	0.03	0.00	0.80%	1.44%	1.12%	71	0.98	0.02	0.00	0.01	0.00	1.34%	3.94%	2.64%
36	0.97	0.01	0.00	0.02	0.00	0.39%	0.61%	0.50%	72	0.40	0.21	0.00	0.00	0.39	2.51%	9.83%	6.17%
37	0.89	0.09	0.01	0.00	0.01	0.65%	2.17%	1.41%	73	0.99	0.01	0.00	0.00	0.00	2.03%	2.87%	2.45%



Mathematical programming and CGE modelling

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Error terms

The first metric for performance evaluation is based on the distance between the observed and calibrated portfolios:

$$e_x = \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{x_i^o - x_i^*}{x_i^o} \right)^2}$$

The second metric for performance evaluation assesses the distance between the observed attributes and the calibrated ones:

$$e_{\tau} = \sqrt{\frac{1}{m} \sum_{r=1}^{m} \left(\frac{z_r^0 - z_r^*}{z_r^0}\right)^2}$$

An average error is estimated as the ordinary arithmetic mean of the two metrics above:

$$e = \frac{e_x + e_\tau}{2}$$

