water

MDPI

Supplementary Information

Main equations of technological change:

Water and capital-land aggregate (Irrigated agriculture sectors, $ireg$)

$$KTW_{i,t,sw} = CES\left(KT_{i,t,sw}; W_{i,t,sw} \cdot \varphi; \sigma^{KTW}\right) = \beta_i \left(a_{iKLW} \cdot KT_{i,t,sw}{}^{\frac{\sigma^{KTW}-1}{\sigma^{KTW}}} + (1 - a_{iKTW}) \cdot (\varphi_t \cdot W_{i,t,sw})^{\frac{\sigma^{KTW}-1}{\sigma^{KTW}}}\right)^{\frac{\sigma^{KTW}}{\sigma^{KTW}-1}}, \forall (i = ireg, t) \quad \text{(S1)}$$

where KT= capital and land composite; W= water factor; σ^{KTW}= Elasticity of substitution; β_i= scale and productivity gains parameter in the production function; a_i= share in the functions; φ = water efficiency parameter; and sw = set of alternatives that involve another set of probabilities.

Level of irrigation water efficiency (Gompertz function)

$$\varphi_t = a \cdot e^{(-e^{b-c \cdot t})} \ , \ \forall (t) \quad \text{(S2)}$$

According to CGRAA data, see [33] and [44],

$$a = 0.90 \ (upper\ asymptotic);\ b = \ln\left(-\ln\left(\frac{0.55}{0.90}\right)\right);\ c = \frac{\ln\left(-\ln\left(\frac{0.64}{0.90}\right)\right) - b}{-8}$$

Note: Each sw has a different probability "pi(sw)" that multiplies to all prices of the model.

Calibration and Data:

A base scenario is a prerequisite for the application of any CGE model. The 2002 SAM (Social Accounting Matrix) for the province of Huesca, obtained from [45,43], is used as a base scenario for the period 2002 to 2040. This SAM incudes water as a factor of production. The elasticity parameters are selected on the basis of a review of the literature of CGE models, based on similar peculiarities of the region and simulations (Table S1).

The values of the main dynamic model parameters are obtained from actual average data for the region in the period 2002–2010 [46]. Specifically, the annual interest rate is 4.31% and the growth rate is 2.01%. The relationship between capital and investment in the steady state is obtained from the calibration of the model using SAM data. The model is formulated as a mixed complementarity problem (MCP) using GAMS/MPSGE [41] and is solved with the PATH algorithm.

Table S1. Elasticity parameters used in the model. Source: Philip et al. (2014).

Substitution elasticity between:	
Intermediate inputs and value-added	σ^{Y} = 0
Intermediate inputs	σ^{I} = 0
Irrigated and Rainfed agricultural production [a]	σ^{RS} = 1
Labor and KTW bundle	[b] σ^{KTWL} = 0.7 (Farm sectors) [c] σ^{KTWL}= 0.8
Capital and water (KTW bundle) [d]	σ^{KTW}= 0.3 σ^{KTW}= 0.2 (Fruit and vegetables) σ^{KTW}= 0.1 (Olives and vineyards)
Capital and land[e]	σ^{KT}= 0.3
Domestic and import goods[f]	σ^{A}= 1.9 - 3
Demand elasticity coefficients[g]	σ^{C}= 0.51-1.45
Transformation elasticity between:	
Exports and domestic goods[h]	σ^{T}= 0.7 - 3.9
Land [i]	σ^{TT} = 0.1 and 0.3

[a] Land and climate characteristics and differences in farming techniques mean that final goods produced by irrigated and rainfed agriculture are considered imperfect substitutes, following [18]. [b] The substitution between aggregate KTW and labor is lower in the Farm sector due to the importance of aggregate KTW [47]. [c] [48]. [d] [18]. We assume 0.3 in all sectors and cereals and industrial crops because they use sprinkler irrigation. However, the substitution elasticity is 0.2 in fruit and vegetables and 0.1 in olives and vineyards, because they use drip systems. [e] [18]. [f] [49]. [g] All sector demand elasticity coefficients are taken from [50]. [h] [51]. [i] [52].

Supplementary Tables:

Table S2. Results of irrigated agriculture prices in Scenarios 1, 2 and 3 as an average value of each period (Source: Own work.).

Without modernization		**With modernization**																		
Period	*% difference Compared to the Base Period*	*Percentage-Points Difference between Non-Modernization and Modernization*																		
	Impact of Declining Water Supply	**Scenario 1**						**Scenario 2**						**Scenario 3**						
		Year in which the 80% Level of Efficiency Is Reached and Expected Values																		
		‘2020’	‘2025’	‘2030’	‘2035’	‘2040’	*Expected Values*	‘2020’	‘2025’	‘2030’	‘2035’	‘2040’	*Expected Values*	‘2020’	‘2025’	‘2030’	‘2035’	‘2040’	‘2100’	*Expected Values*
2002–2010	4.34	−3.01	−2.48	−2.01	−1.70	−1.54	**−2.15**	−3.01	−2.48	−2.01	−1.70	−1.54	**−2.05**	−3.01	−2.48	−2.02	−1.71	−1.55	−0.49	**−0.66**
2011–2019	9.51	−6.45	−5.68	−4.92	−4.38	−3.97	**−5.08**	−6.45	−5.67	−4.92	−4.38	−3.97	**−4.97**	−6.45	−5.68	−4.92	−4.38	−3.98	−1.22	**−1.60**
2020–2028	15.09	−8.32	−7.62	−6.86	−6.27	−5.78	**−6.97**	−8.32	−7.62	−6.86	−6.27	−5.78	**−6.90**	−8.30	−7.60	−6.84	−6.24	−5.76	−2.08	**−2.57**
2029–2037	20.20	−8.89	−8.37	−7.74	−7.21	−6.73	**−7.78**	−8.88	−8.36	−7.74	−7.20	−6.73	**−7.76**	−8.84	−8.32	−7.69	−7.16	−6.68	−2.35	**−2.89**

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