Waters run deep: A coupled Revealed Preference and CGE model to assess the economy-wide impacts of agricultural water buyback

C.D. Pérez Blanco;

Euro-Mediterranean Center on Climate Change, Risk Assessment and Adaptation Strategies Division, Italy

Corresponding author email: dionisio.perez@cmcc.it

Abstract:

Little is known about the economy-wide repercussions of water buyback, which may include relevant feedbacks on the output of economic sectors at a regional and supra-regional scale. Limited applied studies available rely on stand-alone Computable General Equilibrium (CGE) models that represent competition for water explicitly, but this approach presents significant data and methodological challenges in areas where mature water markets are not in place –the case of most regions worldwide. To bridge this gap, this paper couples a bottom-up Revealed Preference Model that elicits the value and price share to water with a top-down, regionally-calibrated CGE model for Spain. Methods are illustrated with a case study in the Murcia Region in southeastern Spain. Economy-wide feedbacks amplify income losses in Murcia's agriculture from -20.5% in the bottom-up model up to -33% in the coupled model. Compensations paid to irrigators enhance demand in the region, but supply contraction in agriculture and related sectors lead to a GDP loss (up to -2.1%) in most scenarios. The supply gap is partially filled in by other Spanish regions, which experience a GDP gain through a substitution effect (up to +.034%). In all scenarios, aggregate GDP for Spain decreases (up to -.023%).

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Keywords: Mathematical programming, CGE, water buyback, Spain.

1. Introduction

Water institutions are increasingly reliant on the reacquisition or *buyback* of water rights to restore the balance in overexploited basins. Buyback programmes are operated through purchase tenders that compensate farmers who choose to relinquish their rights to withdraw water, complemented with flanking measures to address negative feedbacks on agriculture and related economic sectors at a regional and supra-regional scale (DSEWPAC, 2016; GRBA, 2008; Hanak and Stryjewski, 2012). An expanding research analyzes the interaction between user-level choices and tender design to limit information rents and prevent overcompensation (Iftekhar et al., 2013; Qureshi et al., 2009; Wheeler et al., 2013; Zuo et al., 2015). Less is known, however, about the economy-wide impacts of buyback –despite the large amount of resources committed to mitigate them. For example, the buyback programme of the Upper Guadiana River Basin in Spain projected an investment of EUR 3 billion along a 20-year transition period, of which only 33% addressed purchase tenders directly; the remaining 77% envisaged flanking measures to compensate for negative feedbacks, including subsidies for economic diversification and new transportation, communication and energy infrastructures (GRBA, 2008). In Australia's Murray-Darling Basin, an investment of AUD 3.1 billion for the reacquisition of 1,500 million m^3 from irrigators was complemented with an irrigation modernization programme worth AUD 7.36 billion aiming to i) compensate for negative feedbacks through enhanced productivity and ii) limit water use by another 1,900 million m^3 (Department of the Environment, 2015; DSEWPAC, 2016), although the achievement of the latter target has been questioned (Adamson and Loch, 2014; Perry and Steduto, 2017).

Research available on the topic is limited and relies on theoretical models (Marchiori et al., 2012) or Computable General Equilibrium (CGE) models applied to the Australian case (Dixon et al., 2011; Dixon et al., 2012a). Dixon et al. (2012a, 2011) use a dynamic CGE model containing water accounts to analyze the effects of an illustrative buyback scheme in the Southern Murray-Darling Basin. Simulation results show that, contrary to what could be expected, buyback has a positive impact on the regional economy, and a negative albeit marginal one at a national level. This is explained by supply-demand interaction in water markets, which lead to higher prices that i) increase net exports of water and consumption and ii) cause a reallocation of farm production factors that partially compensates for the negative impact on agricultural output. Notably, the adjustment dynamics of the model relies on the existence of full-fledged water markets, a prerequisite that holds only in Australia, Chile and the semi-arid states of Western US. In most regions and countries today, allocation rules are still conditioned by historical rights and queuing, and prices represent administrative charges to (partially) recover the cost of conveying water to users (OECD, 2015). In this context, attempts to model competition for water explicitly in a CGE environment must rely on estimations that assign a price and value share to water (see e.g. Darwin et al., 1995), which is challenging due to limited information available. More importantly, recent research rightly claims that the shadow price of water must correspond to the gap between irrigated and rainfed production to pay for the returns to water, which is often not reflected in value and price estimations (Hertel and Liu, 2016). Addressing this methodological challenge in a CGE environment calls for an alternative approach that models water competition implicitly, e.g. through irrigated land (Berrittella et al., 2007; Calzadilla et al., 2011; Hassan et al., 2008; Taheripour et al., 2013) or virtual water (Cazcarro et al., 2014), which however is inadequate to model and inform water purchase tenders and thus the economy-wide impact of buyback programmes.

In the absence of water markets or data sources with equivalent information, an economy-wide assessment of buyback programmes may require the macroeconomic model to be simulated in concert with a complementary bottom-up model that supplies the missing information (Hertel and Liu, 2016). A wide range of applications coupling top-down with bottom-up models can be found in the literature, and not only related to water issues. Bottom-up models can be bio-physical (Carrera et al., 2015; Ciscar et al., 2011; Eboli and Standardi, 2015; Koks et al., 2015), agent-based (Husby, 2016, chap. 7), or rely on mathematical programming methods such as Linear Programming or Revealed Preference Models (RPM) (Baghersad and Zobel, 2015; Koks and Thissen, 2016; Pérez-Blanco et al., 2017; Rose et al., 1997); while top-down approaches typically include CGE or Input-Output (IO) models. The combination between bottom-up and top-down approaches vary depending on the research focus, data availability and policy experiment. CGE models are preferred over IO where price dynamics are expected to be relevant, as happens with policies involving large reallocations of physical and financial resources such as buyback (Dudu and Chumi, 2008), and to examine the medium and long run effects. On the other hand, mathematical programming methods such as RPM are the approach typically used to model behavioral responses in agriculture (Graveline, 2016).

This paper couples a bottom-up RPM with a top-down CGE model to assess the economy-wide impacts of agricultural water buyback. Methods are illustrated with an application to the Region of Murcia in southeastern Spain. The RPM is calibrated at an Agricultural Water Demand Unit (AWDU) scale, a basic agricultural unit in Spain that encompasses irrigation communities with a common source of water and similar administrative and hydrological characteristics (SRBA, 2015a). On the other hand, top-down CGE models typically work at a national or supranational scale, although some examples considering the sub-national regions within a country or a group of countries can be found in Australia (Wittwer and Horridge, 2010), Europe (Brandsma et al., 2015), Spain (Cazcarro et al., 2014), US (Dixon et al., 2012b), Russia (Bohringer et al., 2014) and China (Horridge and Wittwer, 2008). This work relies on the Intertemporal Computable Equilibrium System (ICES), a global CGE model that has been used extensively to assess the macro-economic impacts of climate change and to evaluate different environmental and climate policies (Bosello et al., 2012, 2013; Parrado and De Cian, 2014). For the purpose of this research, the model has been calibrated for 17 sub-national units at a NUTS2[1] level in Spain. This bridges the scale gap and makes feasible the coupling between both models, which is resolved in two steps. In the *first step*, the water constraint is progressively strengthened in the RPM to assess agents' responses to buyback and reveal: i) the foregone income; and ii) the compensating variation that addresses foregone utility, or *shadow price* of water. This step relies on previous work by Pérez-Blanco and Gutiérrez-Martín (2017). In *the second step*, the foregone income and compensating variation obtained for every agent are aggregated at a regional level and reproduced in a macroeconomic context through two shocks: i) a shock on production based on the foregone income; and ii) a shock on the income of the representative agent in the CGE model resulting from the water sales – a function of the compensating variation. The economy-wide repercussions of water buyback are estimated as the difference between the economic output of the economic sectors and regions under a given water reacquisition target and that of the baseline without water buyback.

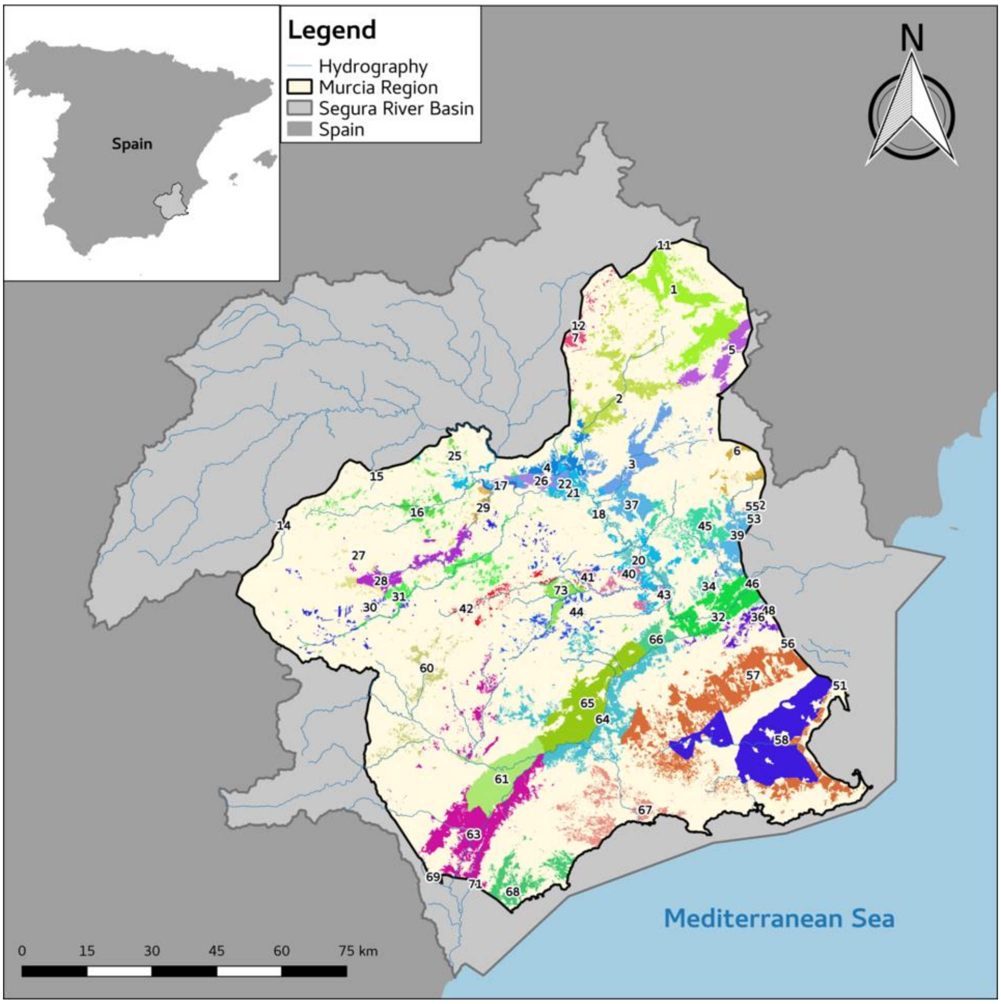
Results show income or GVA losses in Murcia's agriculture can be as high as -33%, as compared to -20% in the microeconomic simulation. Compensations paid to irrigators enhance demand in the region, but supply contraction in agriculture and related sectors lead to a GDP loss (up to -2.1%) in Murcia in most scenarios. Also the welfare effects are negative in Murcia in most scenarios. This last outcome can only be reversed at the expense of higher compensations and transfers from the rest of Spain. The supply gap in Murcia is partially filled in by other Spanish regions, which experience a GDP gain through a substitution effect (up to +.034%). These asymmetric impacts are underpinned by capital and labor reallocation dynamics among Spanish regions following the shocks. In all scenarios, aggregate GDP for Spain decreases (up to -.023%).

[1] The *Nomenclature of Units for Territorial Statistics* (NUTS) is a EU standard that refers to the subdivisions of countries. In Spain, NUTS 1 refers to groups of autonomous communities; NUTS 2 to Autonomous communities and cities; and NUTS 3 to provinces (Eurostat, 2016).

2. Case study area: the Region of Murcia in Spain

The Region of Murcia is located in southeastern Spain, within the boundaries of the absolute water scarce Segura River Basin. Murcia has a surface of 11,313 km^2, a population of 1.5 million inhabitants and a GDP per capita of EUR 19,089 (Eurostat, 2016). Historically located along the middle stretches of the Segura River (*Huerta Murciana*), Murcia's irrigated agriculture sprawled towards coastal areas from the 50s. This resulted in an increasing number of AWDUs (the *agent* in the RPM model), which now total 55, and water use (SRBA, 2015a). Figure 1 displays the AWDUs in the Murcia region.

Figure 1. Location of the Murcia Region and detail of the AWDUs



1. Yecla-Corral Rubio; 2. Jumilla; 3. Regadíos sobre Ascoy-Sopalmo; 4. Regadíos del Ascoy Sopalmo sobre el Sinclinal de Calasparra; 5. Acuífero de Serral-Salinas; 6. Acuífero de Quibas; 7. Subterráneas Hellín-Tobarra; 12. Superficiales Tobarra-Albatana-Agramón; 14. Regadíos aguas arriba de Taibilla; 15. Regadíos aguas arriba de Cenajo; 16. Moratalla; 17. Tradicional Vega Alta, Calasparra; 18. Tradicional Vega Alta, Abarán-Blanca; 20. Tradicional Vega Alta, Ojós-Contraparada; 21. Tradicional Vega Alta, Cieza; 22. Vega Alta, posteriores al 33 y ampliación del 53; 25. Regadíos de acuíferos en la Vega Alta; 26. Nuevos regadíos Zona I Vega Alta-Media; 27. Cabecera del Argos, pozos; 28. Cabecera del Argos, mixto; 29. Embalse del Argos; 30. Cabecera del Quípar, pozos; 31. Cabecera del Quípar, mixto; 32. Tradicional Vega Media; 34. Vega Media, posterior al 33 y ampliación del 53; 36. Regadíos de acuíferos en la Vega Media; 37. Nuevos regadíos Zona II Vega Alta-Media; 39. Nuevos regadíos Zona IV Vega Alta-Media; 40. Nuevos regadíos

Zona V Vega Alta-Media; 41. Nuevos Regadíos Yéchar; 42. Tradicionales de Mula; 43. Mula, manantial de los Baños; 44. Pliego; 45. Regadíos del Ascoy-Sopalmo, Fortuna-Abanilla-Molina; 46. Tradicional Vega Baja; 48. Vega Baja, posteriores al 33 y ampliación del 53; 51. Regadíos de acuíferos en la Vega Baja; 53. Riegos de Levante Margen izquierda-Levante; 55. Acuífero de Crevillente; 56. Nuevos regadíos La Pedrera; 57. Acuíferos del Campo de Cartagena; 58. Campo de Cartagena redotado con trasvase; 59. Nuevos regadíos Campo de Cartagena; 60. Regadíos aguas arriba de Puentes; 61. Regadíos de Lorca; 63. Acuífero del Alto Guadalentín; 64. Mixtos del Bajo Guadalentín; 65. Subterráneas zona del Bajo Guadalentín; 66. Nuevos Regadíos Lorca y Valle del Guadalentín; 67. Mazarrón; 68. Águilas; 69. Almería-Segura; 70. Nuevos regadíos Almería-Sur; 72. Nuevos regadíos Riegos de Levante Margen Izquierda-Poniente; 73. Nuevos regadíos Mula y Pliego. The 55 numbers are not consecutive because they indicate the numbering within the Segura River Basin, which also includes AWDUs outside the Murcia region.

Source: Own elaboration from SRBA (2015a).

Irrigation expansion was propelled by a series of publicly-led water works, including subsidies to localize groundwater sources and drill wells in the 50s and 60s, the construction of an inter-basin water transfer from the Tagus River Basin in the 70s, desalination and wastewater treatment plants in the 2000s, and continued investments on reservoirs, canals and irrigation infrastructures. Water works enlarged the supply base and harnessed the potential of water resources for economic growth, but failed to acknowledge the limits of nature and created unfulfilled expectations on the capacity of the system to meet further demand. As a consequence, while agricultural water use has steadily increased from the 1950s and now represents 86% of the 1829 million cubic meters annually withdrawn in the Segura River Basin, recent water works have only increased marginally the supply base. Coupled with inelastic supply, demand expansion has resulted in a ratio of water withdrawals to renewable resources[2] of 1.15 (SRBA, 2015a). Along watercourses, the gap is addressed at the expense of environmental flows and through the reuse of return flows, resulting in a dry Segura River in its lower stretches (Avellá and García-Mollá, 2009). In areas served with groundwater, which include many of the new AWDUs, the gap is attended with non-renewable resources (Martínez-Granados and Calatrava, 2014). Overexploitation, as well as the degradation of water and related ecosystems, aggravates during the increasingly frequent and intense drought events (SRBA, 2015a).

Following EU guidelines (EC, 2009, 2015a, 2015b), Spain is in the process of designing transformative changes of the water allocation regime. However, reform has been sluggish. Despite being the highest in Spain, the average water charge of EUR 0.09/m^3 is insufficient to recover investments on water works, let alone environmental and resource costs (Pérez-Blanco et al., 2015a). Irrigation restrictions are enforced during shortages through the Segura River Basin Drought Management Plan (SRBA, 2008), which nonetheless does not address the structural overallocation problem and may be diverting overexploitation towards uncontrolled groundwater sources (Gómez and Pérez-Blanco, 2012). The worsening water crisis and difficulties to deploy more restrictive caps and charging arrangements led the Segura River Basin to pioneer water purchase tenders in the EU. Two buyback tenders for the temporary reacquisition (1 year) of water rights from rice farms upstream were implemented during the 2007-2008 drought. Tenders had a budget of EUR 700,000 and envisaged a maximum purchase price of EUR 0.18/m^3. In 2007, the first tender consumed EUR 495,000 to purchase 2.93 million m^3 at an average price of EUR 0.17/m^3.

[2] Including water resources made available through desalination, wastewater treatment plants and inter-basin transfers.

Similar results were obtained in the 2008 tender. Both water reacquisitions were fully used to enhance environmental flows (Garrido et al., 2013).

Recent research in AWDUs of the Region of Murcia has estimated the annuity payment of alternative buyback targets to inform the design of purchase tenders in the area (Martínez-Granados and Calatrava, 2014; Pérez-Blanco and Gutiérrez-Martín, 2017). Yet, a major and persisting concern relates to the economy-wide repercussions of water buyback. The Region of Murcia is highly dependent on agriculture, which represents around 4.4% of regional GDP and 10.4% of regional employment, as compared to 2.3% and 4% at a national level (INE, 2017). Food industry and tourism, closely connected to the agricultural sector, account for 4.5% and 5.6% of the GDP, respectively (INE, 2017) Relevant feedbacks on the output of economic sectors in the region can be anticipated from this sectoral GDP distribution, which are yet to be estimated.

3. The multiattribute Revealed Preference Model

The RPM builds on the seminal work by Gutiérrez-Martín and Gómez (2011), who combine the revealed preference theory and mathematical programming methods in order to elicit the parameters of a non-linear multiattribute objective function. RPM offer a series of advantages as compared to alternative single-attribute mathematical programming methods such as Linear Programming, Expected Utility and Positive Mathematical Programming (see e.g. Graveline, 2016 for a review). Most relevant advantages of RPM include: i) metrics for performance evaluation (Varian, 2012); ii) avoidance of corner solutions or abrupt discontinuities in agents' responses through the introduction of non-linear terms in the utility function, while ensuring a sound economic and technological rationale in the model (the latter being a major shortcoming in Positive Mathematical Programming models) (Heckelei et al., 2012); and iii) compliance with the Theory of Planned Behavior, which states that attitudes towards behavior are a function of the strength of beliefs concerning a number of *attributes*, thus calling for multiattribute utility functions (Gómez-Limón et al., 2016).

RPM have been increasingly used for the *ex-ante* assessment of agricultural policies and shocks such as water charges, crop insurance, price volatility and irrigation modernization programmes (Gómez-Limón et al., 2016; Gutiérrez-Martín et al., 2014; Gutiérrez-Martín and Gómez, 2011; Pérez-Blanco et al., 2015b, 2016). In a recent application, Pérez-Blanco and Gutiérrez-Martín (2017) run a series of simulations in which the water allocation constraint in the model is progressively strengthened to estimate: i) the foregone income; and ii) the compensating variation that addresses foregone utility, or *shadow price* of water. The price and value share to water thus revealed are consistent with those observed in previous reacquisitions, and are used to feed simulations to assess the economy-wide repercussions of agricultural water buyback in a CGE environment.

In what follows we outline the major components of the RPM. A full description of the model is available in Gutiérrez-Martín and Gómez (2011), while a full description of the underlying assumptions and dataset used in the buyback simulations is available in Pérez-Blanco and Gutiérrez-Martín (2017).

3.1. Objective function

Agents maximize the multiattribute objective function in [1], subject to a set of constraints that define the domain of the optimization problem:

$$\max_{x} U(x) = U(z_1(x);\ z_2(x); z_3(x) \ldots\ z_m(x)) \qquad [1]$$

$$\text{s.t.:}\quad 0 \le x_i \le 1 \qquad [2]$$

$$\sum_{i=1}^{n} x_i = 1 \qquad [3]$$

$$x \in F(x) \qquad [4]$$

Farmers' decide on the crop portfolio $x \in R^n$, which is a vector containing the area devoted to every crop x_i $(i = 1, \ldots, n)$, measured as its corresponding share of available surface. The number of crops in the portfolio is determined by the number of species and possible management techniques, e.g. rainfed and irrigated vineyard are treated as independent crops. Agents' choices aim to maximize utility, which in turn is determined by the unique combination of dimensionless attributes of the crop portfolio $z(x) \in R^m$. Assuming crop attributes can be quantified, alternative crop portfolios can be ranked in accordance to the utility they yield. Rationality implies that agents will cultivate the crop portfolio that maximizes the objective function within the domain $F(x)$. The domain is defined by a set of quantifiable restrictions, notably agronomic features, land constraints (including ligneous crops surface threshold[3]), know-how, policy restrictions (notably the Common Agricultural Policy) and water allocation. The latter can be represented as:

$$\sum_{i=1}^{n} w_i\, x_i \le W \qquad [5]$$

Where water availability per hectare is denoted by W, and w_i is the water required by crop x_i, per hectare.

3.2. Model calibration

Following standard microeconomic theory, the parameters of a utility function can be elicited for a given set of attributes equalizing the Marginal Rate of Transformation (MRT_{kp}), which represents the opportunity cost between two attributes z_p, z_k; and the Marginal Rate of Substitution (MRS_{kp}), which represents the willingness to sacrifice one unit of attribute z_p for one unit of attribute z_k.

[3] In order to prevent disinvestments with negative impacts on ecosystem services not accounted for in the model (e.g. carbon sequestration), ligneous crops have to remain above 90% of the original surface.

The graphical representation of the $\mathrm{MRT_{kp}}$ is known as the efficient frontier, while the graphical representation of the $\mathrm{MRS_{kp}}$ is known as the utility function's indifference curve.

$$\mathrm{MRT_{kp}} = \mathrm{MRS_{kp}} = -\frac{\partial U/\partial z_p}{\partial U/\partial z_k}; \quad \forall p \neq k \qquad [6]$$

The utility function is parameterized in three steps:

i) *Efficient frontiers* are elicited for each pair of attributes using numerical methods, and the tangency point that serves as a landing point for the utility function's indifference curve is obtained.

ii) Given a tangency point and a functional specification, the *utility function* parameters are calibrated for every possible combination of attributes equalizing the $\mathrm{MRT_{kp}}$ and the $\mathrm{MRS_{kp}}$.

iii) Error terms are obtained as the distance between the observed decisions and the simulated decisions obtained using calibrated utility functions. The utility function with the lowest error contains the *relevant attributes* and is the one used in the simulations.

3.2.1. Efficient frontier

The efficient frontier represents the opportunity cost between two attributes z_p, z_k, or Marginal Rate of Transformation ($\mathrm{MRT_{kp}}$). Efficient frontiers are convex –otherwise there is no tradeoff and the choice between the two attributes becomes irrelevant. Real life efficient frontiers cannot be obtained through a closed mathematical function and are revealed using numerical methods, maximizing the value of attribute z_p for a given value of attribute z_k within the domain $F(x)$:

$$\underset{x}{\mathrm{Max}}\, z_p(x) \qquad [7]$$

$$\text{s.t.: } z_k(x) = c \quad \forall k \neq p \quad c = (0, \ldots, 1) \qquad [8]$$

$$0 \leq x_i \leq 1 \qquad [9]$$

$$\textstyle\sum_{i=1}^{n} x_i = 1 \qquad [10]$$

$$x \in F(x) \qquad [11]$$

For each pair of attributes, the tangency point that serves as a landing point for the utility function's indifference curve is obtained using a projection method (Pérez-Blanco and Gutiérrez-Martín, 2017). This method solves the optimization problem above equalizing the value of attribute z_k to its observed value z_k^o in Equation [7], thus *projecting* the value of z_p to the frontier. Following this procedure for each of the two attributes in the efficient frontier results in two (vertically and horizontally) projected points $\tau_{z_p,z_k^o}(x^f)$ and $\tau_{z_p^o,z_k}(x^f)$. The slope between them approaches the tangency point.

3.2.2. Utility function

The MRT_{kp} at the tangency point is equalized to the MRS_{kp} to parameterize the objective function for alternative attribute sets. Following the work by Gómez-Limón et al. (2016) and Gutiérrez-Martín et al. (2014), the RPM in this paper relies on a homothetic Cobb-Douglas objective function, which offers a flexible specification and guarantees the existence of a global optimum:

$$U(x) = \prod_{p=1}^{m} z_p(x)^{\alpha_p}; \quad \sum_{p=1}^{m} \alpha_p = 1 \qquad [12]$$

The objective function can be parameterized solving the following system of equations:

$$-\frac{\partial U / \partial z_p}{\partial U / \partial z_k} = -\frac{\alpha_p}{\alpha_k}\frac{z_k}{z_p} = MRT_{kp}; \quad \forall p \neq k \qquad [13]$$

$$\sum_{p=1}^{m} \alpha_p = 1 \qquad [14]$$

The values of the parameters obtained resolving the system of equations above for alternative combinations of attributes can be used in equations [1]-[5] to simulate the crop portfolio (x^{RPM}) and obtain the corresponding attributes values (z_p^{RPM}; $p = 1, \ldots, m$) and utility (U^{RPM}).

3.2.3. Relevant attributes

Rational agents cultivate the portfolio of crops that maximizes the utility obtained from the attributes they value. Therefore, the relevant attributes are those that minimize the distance between observed and calibrated behavior, which is measured through a calibration residual obtained as the ordinary arithmetic mean of two errors. The first error captures the distance between the observed (x^o) and simulated (x^{RPM}) crop portfolio:

$$e_x = \frac{1}{n}\sqrt{\sum_{i=1}^{n}\left(\frac{x_i^o - x_i^{RPM}}{x_i^o}\right)^2} \qquad [15]$$

The second error captures the distance between observed (z^o) and calibrated (z^{RPM}) attributes:

$$e_\tau = \frac{1}{m}\sqrt{\sum_{p=1}^{m}\left(\frac{z_p^o - z_p^{RPM}}{z_p^o}\right)^2} \qquad [16]$$

The relevant set of attributes minimizes the average calibration residual, which is obtained as follows:

$$e = \frac{e_x + e_\tau}{2} \qquad [17]$$

The set of attributes and corresponding parameters that minimize the average calibration residual are used in the simulations.

3.3. Data

Agents in the multiattribute RPM model are the AWDUs of the Segura River Basin located within the boundaries of the Region of Murcia. The calibration year (observed crop portfolio) is 2013. Five attributes are explored, namely: profit (z_1, gross variable margin), risk avoidance (z_2, obtained as the difference between the standard deviation of the crop portfolio that maximizes profit and that of an alternative portfolio x), direct costs avoidance (z_3, the difference between the per unit of revenue direct costs incurred in the management of the crop portfolio that maximizes profit and those of an alternative portfolio x), hired labor avoidance (z_4, the difference between the hired labor necessary to implement the crop portfolio that maximizes profit and that of an alternative portfolio x) and family labor avoidance (z_5, the difference between the hired labor necessary to implement the crop portfolio that maximizes profit and that of an alternative portfolio x). All attributes are non-dimensional with values between 0 and 1 and increasing their provision has a positive impact on the objective function (*more-is-better*). A full description of the attributes is available in Pérez-Blanco and Gutiérrez-Martín (2017).

Land use data per crop is obtained at a municipal level for the calibration year from Región de Murcia (2015), and disaggregated at an AWDU level crossing this information with the land use data per crop category[4] available for AWDUs (SRBA, 2014), using georeferenced data (SRBA, 2015b). Data on water sources, withdrawals and distribution and irrigation efficiency in 2013 are obtained for every AWDU from SRBA (2014). Crop yields and prices are available for every Spanish province (NUTS3) in MAGRAMA (2015b) for the period 2003-2013. Information on other revenues such as subsidies, family labor and variable costs including hired labor, contracts, fertilizers, phytosanitaries, water, fuel, replacement parts, repairs, lubricant, seeds plants and other supplies, are obtained at a provincial level for the period 2003-2013 from MAGRAMA (2015c). Monetary values are expressed in constant prices of 2007, which is also the CGE's reference year.

4. The Computable General Equilibrium model

4.1. Theoretical structure

From a general point of view a CGE model is a market-based tool which captures the economic interactions taking place between sectors, regions and factors. Prices are flexible and adjust to the different impacts and policies to clear the markets and achieve a new equilibrium in which supply equals demand. The regionalized ICES is a neoclassical model: perfect competition is assumed in all sectors of the economy, factors are fully employed and investments are saving-driven. In this

[4] Including: forage, winter cereal, summer cereal, spring cereal, industrial crop, legume, horticulture –bulb, horticulture –root, horticulture –flower, horticulture –leaf, horticulture –fruit, horticulture –greenhouse, horticulture –tuber, citrus tree, stone fruit, seed fruit, almond tree, vineyard (grape), vineyard (wine), olive grove.

experiment we use a regionalized version of the model that includes the 17 NUTS2 regions of Spain, the rest of Europe and the rest of the world; and seven economic sectors, namely agriculture, extraction, food industry, other industry, utilities sector, construction and services. The main characteristics of demand and supply are described in the following sub-sections.

4.1.1. Supply

A representative firm in every region and sector minimizes costs subject to a Leontief technology production function for output (y) considering GVA (va) and intermediate inputs (in):

$$\underset{va_{j,s},\, in_{j,s}}{\text{Min}} \left(pva_{j,s} va_{j,s} + pin_{j,s} in_{j,s} \right) \qquad [18]$$

$$\text{s.t.:} \quad y_{j,s} = \min\left\{ va_{j,s}, in_{j,s} \right\} \qquad [19]$$

where $pva_{j,s}$ and $pin_{j,s}$ are respectively the price of the value added composite and the price of intermediate inputs in sector j of region s. GVA in sector j is produced with a Constant Elasticity of Substitution (CES) function that depends on v_f primary factors (f = capital, land, labor, and natural resources), with sector-specific elasticity of substitution σ_j. Input augmenting or biased technical change is represented with the parameter $\gamma_{f,j,s}$ for each primary factor f in sector j and region s.

$$va_{j,s} = F\left(\gamma_{f,j,s}, v_{f,j,s}, \sigma_j\right) \quad ; \quad \sigma_j > 0 \qquad [20]$$

The regionally-calibrated CGE model assumes endogenous labor and capital supply at the regional level, allowing to some extent the spatial mobility of workers and capital within the national territory. Production factors are immobile with respect to the rest of Europe and the rest of the world. Within each Spanish region, labor and capital can move across sectors, while land is used in the agricultural sector only and natural resources in mining, forestry and fishing sectors. A Constant Elasticity of Transformation (CET) function is implemented for the purpose of modelling regional labor and capital supply given the national constraint. The First Order Conditions are obtained from the following maximization program.

$$\underset{w_{f,s}}{\text{Max}} \sum\nolimits_{s}^{Spain} w_{f,s} q_{f,s} \quad ; \quad f = \text{labor, capital}; \;\; s \in \text{Spain} \qquad [21]$$

$$q_{f,Spain} = \left(\sum q_{f,d}^{\frac{\eta_f - 1}{\eta_f}} \right)^{\frac{\eta_f}{\eta_f - 1}} \quad ; \quad \eta_f \leq 0 \qquad [22]$$

Where q_f represents the supply in the sub-country region s and in Spain, and w_f their corresponding prices. The elasticity of substitution η_f falls within the interval [0, -∞]. A higher absolute value indicates a higher interregional mobility, while a null value denotes perfect immobility at the regional level. Consistently with previous studies (Carrera et al., 2015; Koks et al., 2015) we set an intermediate value of minus two.

4.1.2. Demand

Final and intermediate goods can be traded in the domestic, national and international market. The *demand* side includes an upper and a lower bundle. Both thresholds postulate imperfect substitution between products coming from different spatial units (countries and/or regions) according to the standard Armington assumption (Armington, 1969). In the upper level, this is done by breaking agents' demand for any commodity in two parts using a CES function, $dd_{j,s}$ and $dm_{j,s}$, which are the domestic demand and the aggregate demand for imported products in regions s and sector j, respectively. The representative agent in each region includes the household and the government. For each economic sector, the representative agent minimizes the total expenditure under the CES constraint on domestic and imported goods.

$$\underset{dd_{j,s},\,dm_{j,s}}{\text{Min}} \left(pdd_{j,s}dd_{j,s} + pdm_{j,s}dm_{j,s} \right) \quad [23]$$

$$\text{s.t.:} \quad dtot_{j,s} = G_1\left(dd_{j,s}, dm_{j,s}, \sigma_j^{Up}\right) \; ; \qquad \sigma_j^{Up} > 0 \quad [24]$$

Where $dtot_{j,s}$ is the total demand and $pdd_{j,s}$ and $pdm_{j,s}$ are the prices associated with domestic and aggregate demand for imported goods, respectively. The Armington elasticity in the upper level (σ_j^{Up}) captures the imperfect substitution between domestic and imported commodities.

In the lower level the aggregate amount of imports ($dm_{j,s}$) are sourced from the country or the sub-country region of origin. The representative agent in each region and sector minimizes the expenditure for imports under a Constant Ratios of Elasticities of Substitution and Homothetic (CRESH) constraint (Cai and Arora, 2015; Hanoch, 1971; Pant, 2007).

$$\underset{imp_{j,s',s}}{\text{Min}} \sum_{s'} pimp_{j,s',s}imp_{j,s',s} \quad [25]$$

$$\text{s.t.:} \quad dm_{j,s}=G_2\left(imp_{j,s}, \sigma_{j,s}^{Lo}\right) \quad ; \; imp_{j,s} \in R^S \; , \; \sigma_{j,s}^{Lo} \in R^S \quad [26]$$

Where $imp_{j,s',s}$ is the bi-lateral trade flow from region/country s' to region/country s in sector j and $pimp_{j,s',s}$ is the associated price; $imp_{j,s}$ and $\sigma_{j,s,}^{Lo}$ are two S-dimensional vectors (S being the number of country/regions in the CGE) representing respectively all the bi-lateral imports and elasticities of substitution of region/country s in sector j. The advantage to use the CRESH function in the lower level consists in having a three dimensional elasticity ($\sigma_{j,s',s}^{Lo} > 0$), which allows for more flexibility than CES to model the product substitutability for each couple of spatial units. Since theoretical and empirical evidence shows that trade is larger within national borders than across them, given the same distance (Anderson and Wincoop, 2003; McCallum, 1995), intra-regional trade flows should be more fluid than international trade ones, and this is guaranteed by setting a higher value of the CRESH elasticity involving two Spanish regions.

The income (Inc_s) of the representative agent in each sub-national region or country is allocated in fixed proportions to private final consumption ($Cons_s$), government consumption (Gov_s) and saving ($Save_s$).

$$Inc_s = Cons_s + Gov_s + Save_s \quad [27]$$

The macro-economic closure assumes that the investments are mobile at the international level; global investments are equal to global savings; and trade balance in each country/region is given by the difference between regional/country savings and investments.

4.2. Data

The model uses information from the GTAP 8 database (Narayanan et al., 2012). The 8.1 version consists in a collection of Social Accounting Matrices (SAMs) for 57 economic sectors and 134 countries (or groups of countries) in the world. The reference year is 2007. We split the national SAM of Spain in the GTAP database[5] into 17 regions using information from Spanish Regional Accounting (INE, 2017) and Economic Accounts for Agriculture and Structural Business Statistics (Eurostat, 2016). To do this, first we match the sectors of the GTAP database with those of our data sources. Then, for each sector, the regional shares of value added, and accordingly of labor, capital, land and natural resources are computed using the sub-national data. Finally, these shares are used to distribute original country-level data across sub-national units. A detailed description of the methodology is available in Bosello and Standardi (2015).

INE (2016) provides information on both capital and labor at the sectoral level. For some manufacturing activities we referred to Structural Business Statistics (Eurostat, 2016) because they have a more detailed description of these sectors. To regionalize the agricultural economic components of value added we mainly rely on the Economic Accounts for Agriculture (Eurostat, 2016) because of the rich and already standardized information across EU regions.

One of the most challenging tasks to achieve in the database construction is the derivation of the sub-national domestic demand and trade with other regions within the country. This is because these data are often missing and need to be computed using different techniques. In our case we rely on the so-called Simple Locations Quotients (SLQs) (Bonfiglio, 2008; Bonfiglio and Chelli, 2008; Miller and Blair, 2009). SLQs give a measure of the regional specialization in the economic activity compared to the national average and allow us to determine the domestic demand and aggregate demand for imports. Then we follow the gravitational approach to obtain the bilateral trade flows across sub-national regions in line with Dixon et al. (2012b) and Wittwer and Horridge, (2010).

[5] Specifically the model includes 70 NUTS (Nomenclature of Territorial Units for Statistics) sub-national regions: 22 NUTS-2 for France, 20 NUTS-2 for Italy, 19 NUTS-2 for Spain, 5 NUTS-2 for Portugal and 4 NUTS-1 for Greece. Reader can refer to Bosello and Standardi (2015) for the detailed description of the methodology.

5. Coupling bottom-up and top-down models

Once the multiattribute objective function is calibrated using the RPM, the water allocation constraint W_g is progressively strengthened to comply with alternative water reacquisition targets, and the resulting crop portfolio x_g^{RPM}, utility U_g^{RPM} and GVA va_g^{RPM} (a function of the gross margin $z_{1,g}^{RPM}$, and hired labor $z_{4,g}^{RPM}$) are estimated. These variables contain the necessary information to reveal: i) the foregone income; and ii) the compensating variation that addresses the foregone utility. These two measures serve as a basis to assess the economy-wide repercussions of water buyback in a CGE environment. The foregone income is used to estimate the consequences on the *supply* side through a productivity shock in the representative agricultural firm; while the compensating variation is used to assess the consequences on the *demand* side through a money transfer to the representative agent in Murcia.

5.1. The supply shock

In the microeconomic model, the GVA (va_g^{RPM}) in Murcia for every reacquisition target g is obtained aggregating the corresponding gross margin ($z_{1,g}^{RPM}$) and labor income (a function of hired labor, $z_{4,g}^{RPM}$):

$$va_g^{RPM} = f(z_{1,g}^{RPM}, z_{4,g}^{RPM}) \quad [28]$$

The foregone income in Murcia for a given reacquisition target, as compared to the baseline (g = 0), can be transformed using simple calculations into a productivity shock (γ_g) (Carrera et al., 2015; Koks et al., 2015; Pérez-Blanco et al., 2016):

$$\gamma_g = \frac{va_g^{RPM}}{va_0^{RPM}} \quad [29]$$

The negative productivity shock is homogeneously distributed among the production factors (f, including labor, capital and land) of the representative agricultural firm (j = agr) of Murcia (s = MUR) in the macroeconomic model through equation [20]. The productivity shock reproduces the impact on GVA estimated by the RPM in a CGE context, for every water reacquisition target considered.

$$va_{g,agr,MUR} = F\left(\gamma_g, v_{f,agr,MUR}, \sigma_{agr}\right) \qquad f = \text{land, labor, capital} \quad [30]$$

5.2. The demand shock

The compensating variation is the amount of money that keeps the utility equal to that of the baseline scenario without buyback (g = 0). The compensating variation for a given reacquisition target CV_g is obtained in the microeconomic model as follows:

$$CV_g = e\left(U_0^{RPM}, W_g\right) - e\left(U_0^{RPM}, W_0\right) \quad [31]$$

Where e represents an expenditure function, i.e. the minimum amount of money agents would need to attain the initial utility (U_0^{RPM}) given a water constraint W_g. In the baseline scenario ($g = 0$), the expenditure function equals 0.

For consistency, the compensating variation stemming from the RPM is divided by the baseline GVA in the RPM, and the resulting percentage is multiplied by the baseline GVA in the CGE model to estimate the equivalent compensating variation in the macroeconomic context (δ_g).

$$\delta_g = \frac{CV_g}{va_0^{RPM}} \, va_{g,agr,MUR} \quad [32]$$

Compensations to irrigators are represented in the CGE macroeconomic context through an income transfer to the representative agent in Murcia (T_g). Income transfers can be operated through an annuity payment or a lump sum transfer. Since the capitalization rate that applies to agricultural assets in Spain has been volatile during the financial crisis (BOE, 2015, 2011, 2007), an annuity payment that removes the discount rate uncertainty was preferred in this case. The income transfer is a function of the compensating variation and the ability of the buyer (principal) to address information rents. Due to information asymmetry, income transfers and compensating variations typically do not equalize (Iftekhar et al., 2013), resulting in some degree of agency costs $\theta \geq 1$.

$$T_g = \theta * \delta_g \quad [33]$$

Simulations consider alternative agency costs scenarios, based on the θ values reported in the literature (Iftekhar et al., 2013; Martínez-Granados and Calatrava, 2014; Pérez-Blanco and Gutiérrez-Martín, 2017; Zuo et al., 2015). Next the income transfer is introduced in the CGE model through the equation representing regional income [27]. First, each Spanish region pays its share of the income transfer (Tr_s) based on the GDP share of the region in the national economy ($GDPsh_s$).

$$Tr_s = GDPsh_s * T_g \quad [34]$$

$$Inc_s = Cons_s + Gov_s + Save_s - Tr_s \quad ; \quad Tr > 0 \;\; , \;\; s \in \text{Spain except Murcia} \quad [35]$$

The Region of Murcia receives the total amount of the annuity for the implementation of the water buyback policy, minus its share of the income transfer payment.

$$Inc_{Murcia} = Cons_{Murcia} + Gov_{Murcia} + Save_{Murcia} + T_g - Tr_{Murcia} \quad [36]$$

The regionally-calibrated CGE model reproduces the productivity shock in the representative agricultural firm and the income transfer to the representative agent in a macroeconomic context and finds a new equilibrium. The economy-wide impacts of water buyback are estimated as the difference between the GVA of the economic sectors and regions in Spain for each water reacquisition target and that of the baseline without water buyback.

6. Results

The RPM is calibrated for the 55 AWDUs in the Murcia Region following the methodology in Section 3. The parameterization results of the utility function of each AWDU and the corresponding calibration errors are available in the Appendix. A series of simulations are run in which the water allocation constraint is strengthened in every AWDU. Limiting water availability precludes some portfolio choices and has a negative impact on the utility of agents through a reduced provision of valuable attributes, including profit. Agents readjust their crop portfolio according to their objective function and the new water constraint. For every simulation resolved, the foregone income and compensating variation are estimated.

Results from microeconomic simulations are then elaborated to obtain the productivity shock and the annuity that feed the CGE model. The macroeconomic simulation runs a comparative statics exercise to assess regional and sectoral GVA changes considering eight alternative water reacquisition targets: 50 (4% of water allocation in the baseline), 100 (8%), 150 (12%), 200 (16%), 250 (20%), 300 (24%), 350 (28%) and 400 (32%) million m^3. The economic repercussions of water reacquisitions are assessed following two alternative criteria: i) a cost-effective criterion (CE) in which priority in the reacquisition is given to those AWDUs where water is inexpensive; and ii) a proportional criterion (Pr) in which the same proportion of the initial water allocation is purchased in each AWDU. The motivation for the inclusion of these two criteria lies on the heterogeneity of water. If water was a homogeneous good with the same environmental value across Murcia's AWDUs, the first criterion should apply. However, this is not the case, and purchase tenders focusing on one or a few AWDUs may be necessary to restore/preserve critical ecosystem services. Finally, a major concern in water reacquisitions regards agency costs: due to information asymmetry, irrigators may perceive a compensation that is not consistent with the shadow price of water, increasing the cost of the buyback program and/or limiting its scope –and henceforth the extent of ecosystem services delivered. Three agency costs scenarios are defined: $\theta = 1$ (no agency costs, case 1), $\theta = 1.5$ (case 2) and $\theta = 2$ (case 3).

6.1. Microeconomic assessment

Initially, agents react to the new water allocation constraint substituting irrigated crops in the margin by less water demanding or rainfed crops that yield slightly lower utility levels. When the water reacquisition target becomes more stringent though, agents are constrained to sacrifice increasingly valuable crops and utility losses amplify. This process is visible in Figure 2, which displays the compensating variation (€/m^3) in the 55 AWDUs for 8 reacquisition targets. As utility decreases, so does income, one of the critical attributes determining utility (Figure 3).

Figure 2. Compensating variation (€/m³) in the 55 AWDUs for the 8 reacquisition targets

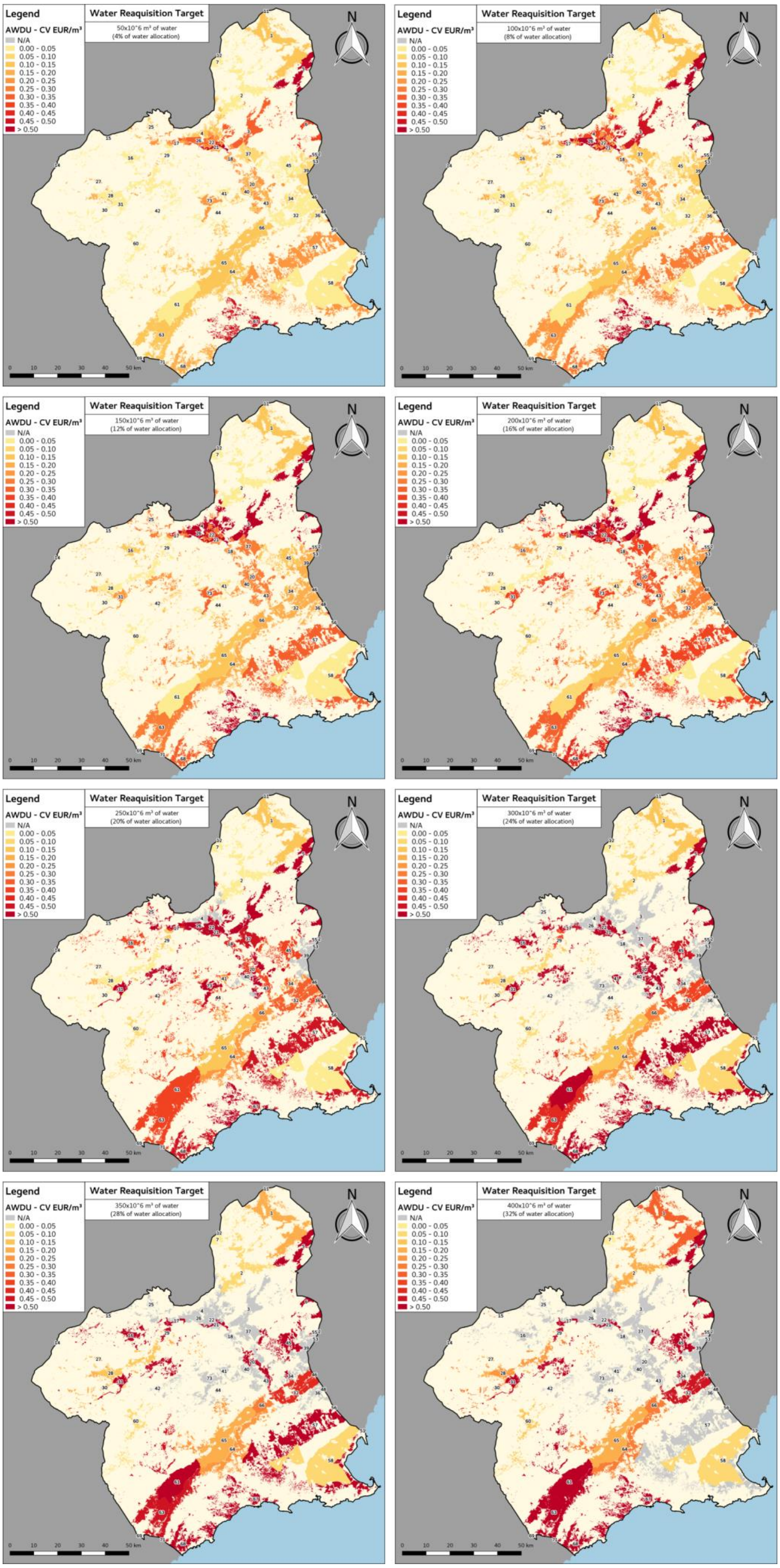
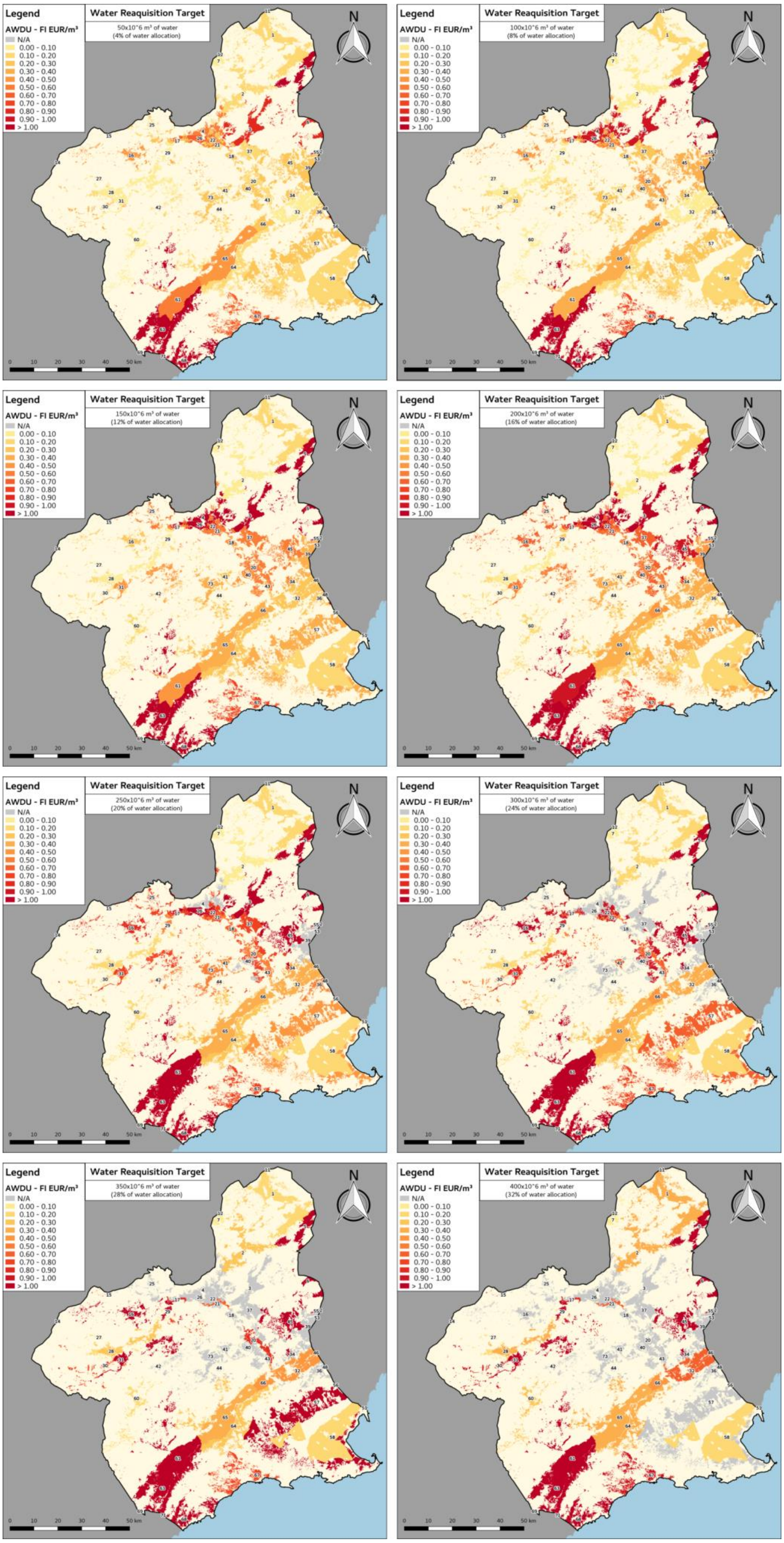


Figure 3. Foregone income (€/m³) in the 55 AWDUs for the 8 reacquisition targets



In some simulations the objective function cannot be resolved within the domain, notably as a result of ligneous crops surface thresholds ("N/A" value in the legend). This happens with 40% of AWDUs when water allocation is reduced by >32% (>400 million m3). A maximum threshold for water reacquisition targets is fixed at this value. Overall, surface water-reliant AWDUs in upstream catchments display less productive crop portfolios and lower purchase prices compared to those located downstream. Focusing water purchase tenders on upstream areas may improve environmental flows along the basin at the least cost (CE criterion). However, complementary purchase tenders may be necessary in some areas to restore the balance locally (e.g. aquifers).

The results obtained above for every AWDU are aggregated to obtain the inputs for the CGE model. Table 1 displays the foregone income and compensating variation, as a percentage of Murcia's agricultural GVA in the baseline, for alternative reacquisition targets and design (CE and Pr) in the case of no agency costs (θ=1). Not surprisingly the Pr scheme shows higher compensating variation and income losses than the CE scheme. In absolute value, income losses are greater than the compensating variation in both schemes: as the water allocation constraint is strengthened, an increasing share of land is devoted to less water intensive and rainfed crops, which yield a lower expected income but typically also higher risk and management complexity avoidance –two valuable attributes that mitigate the negative impact on utility of income losses. The opposite may happen and the compensating variation can be greater than income losses (absolute values) if agency costs are considered.

Table 1: Income losses and Compensating Variation as a percentage of Murcia's agricultural GVA in the baseline year (no agency costs case, θ=1)

	CE		Pr	
Reacquisition target (million m3)	Foregone income (%)	Compensating Variation (%)	Foregone income (%)	Compensating Variation (%)
50	-0.18	0.07	-1.16	0.52
100	-0.65	0.34	-2.69	1.35
150	-1.36	0.81	-4.69	2.66
200	-2.34	1.41	-6.81	4.12
250	-3.86	2.36	-9.55	6.02
300	-5.71	3.65	-12.78	8.64
350	-7.88	5.51	-16.37	11.70
400	-11.60	7.85	-20.48	15.25

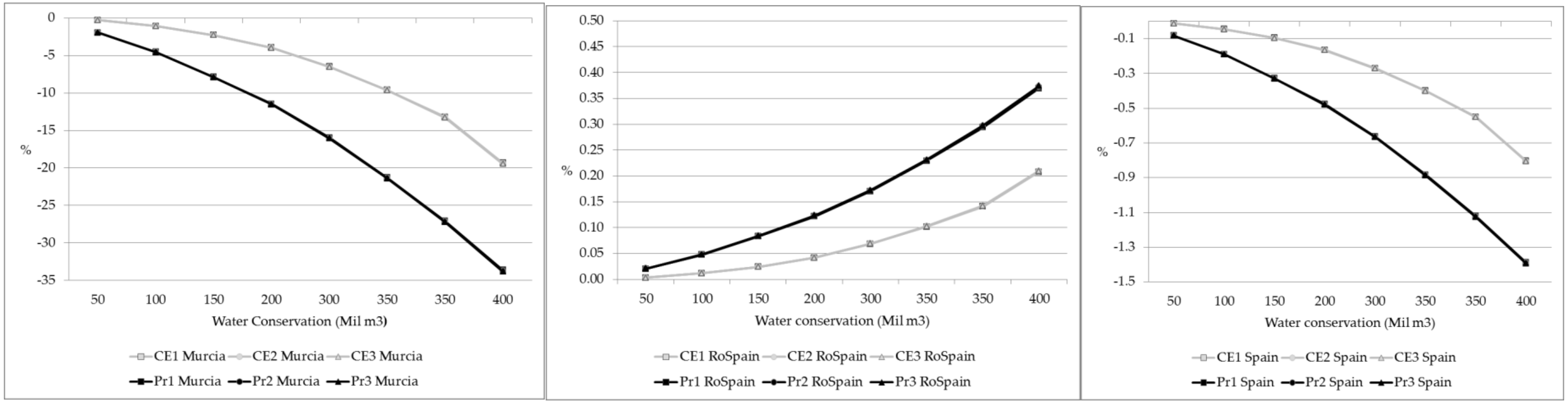
6.2. Macroeconomic assessment

In the RPM model agents' decisions are taken for a given macroeconomic scenario with exogenous prices –a reasonable assumption for the small AWDUs of Murcia (Gutiérrez-Martín and Gómez, 2011). When the productivity and income shocks stemming from the RPM are aggregated for the entire Murcia's agricultural sector and translated into the CGE model, the macroeconomic scenario is not anymore given but reacts through changes in relative prices, triggering the reaction of other economic sectors, agents and regions. Consistent with the permanent nature of the reacquisitions, the model assumes a flexible CGE setting with a medium- to long-term focus, where labor and capital are perfectly mobile between sectors and CET elasticity for labor and capital mobility within Spain is minus two. This value is consistent with previous CGE studies assuming a flexible economic system at the sub-country level (Carrera et al., 2015; Koks et al., 2015). Accordingly, regional and sectorial GVA changes in this comparative statics exercise should be also understood in a medium- to long-term context.

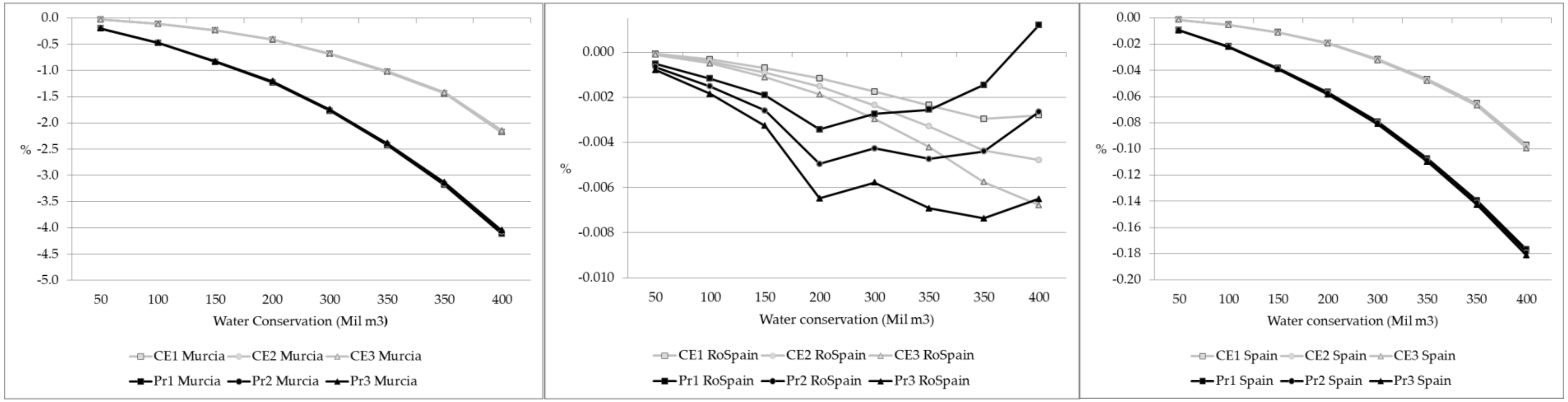
The regionalized CGE model explores the macroeconomic impacts of Murcia's water buyback programme across sectors and regions of Spain through a series of simulations. Figure 4 displays simulation results in the agriculture (A), food industry (B), services (C) and aggregate GDP (D) for all water targets (50, 100, 150, 200, 250, 300, 350 and 400 million m^3), CE and Pr reacquisition schemes, and agency cost cases 1, 2 and 3.

Figure 4: % Change in real GVA of Murcia (left), Rest of Spain (center) and Spain (right)

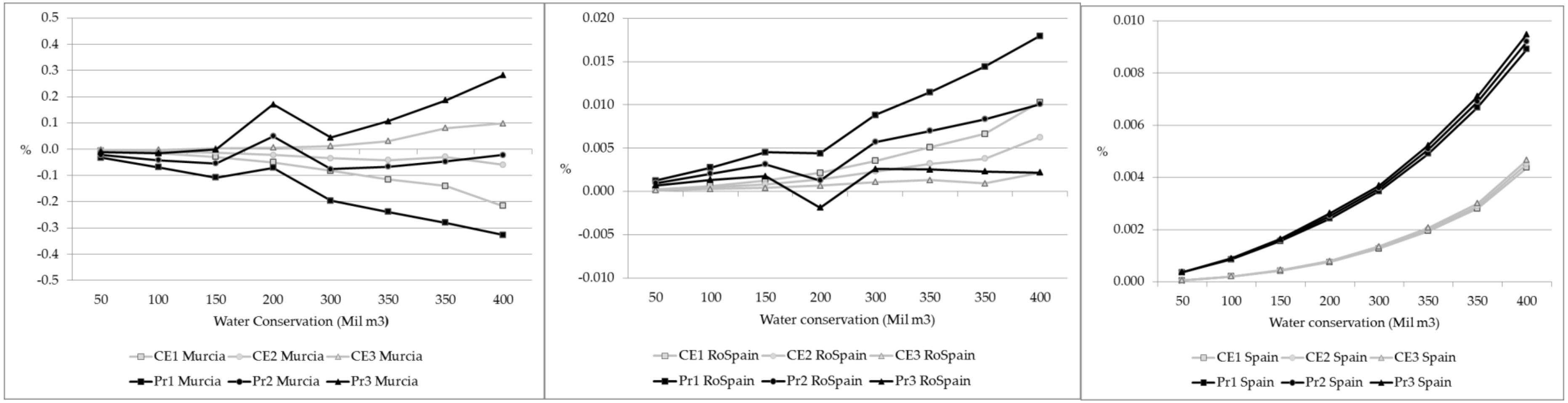
A. Agriculture



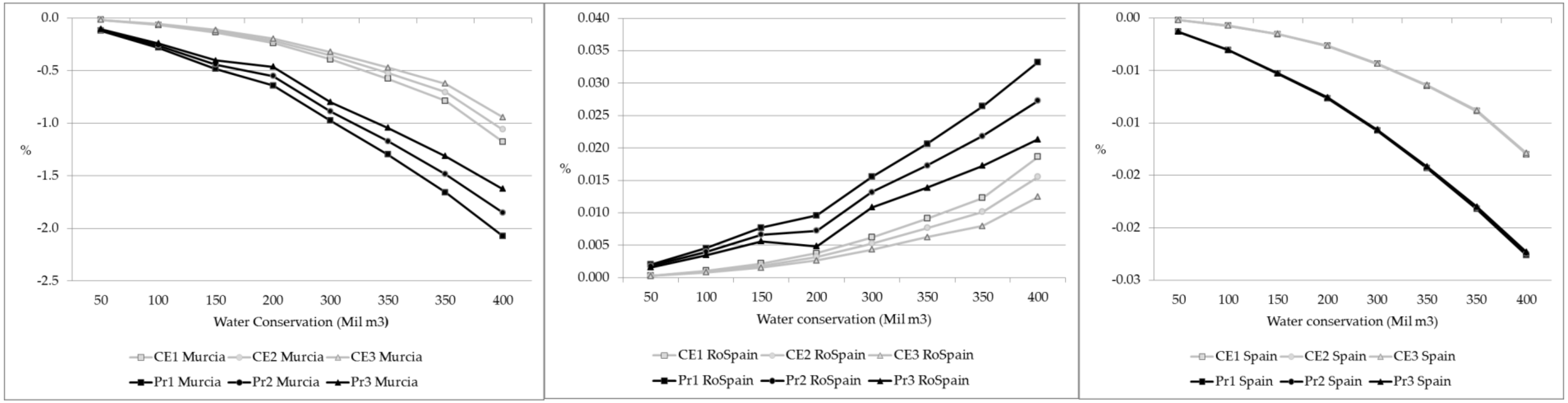
B. Food industry



C. Services



D. GDP (all sectors)

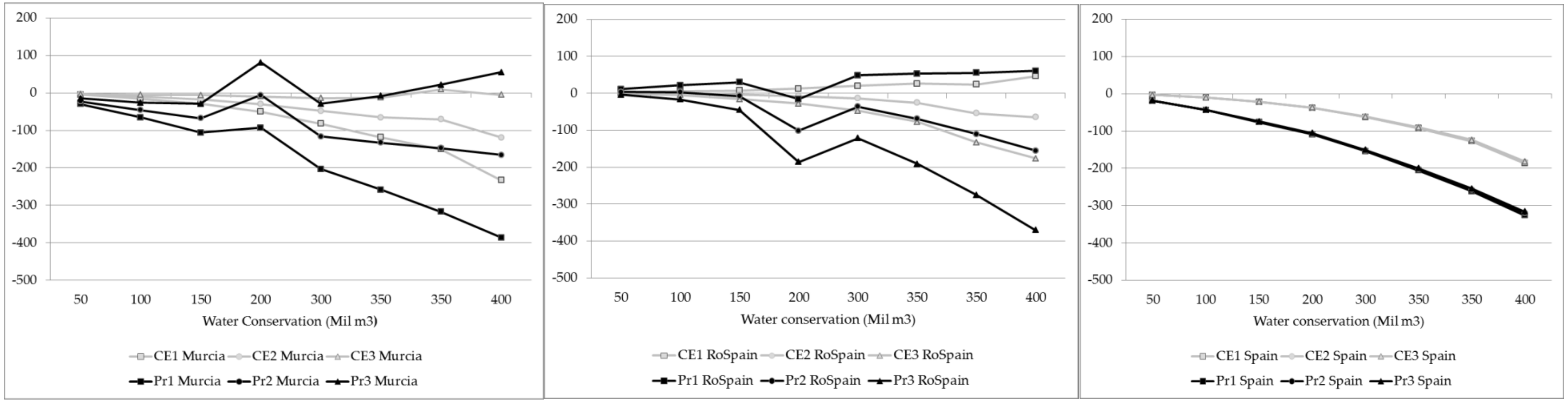


The microeconomic results in Table 1 are consistently amplified in the macroeconomic assessment. For example, for the most ambitious reacquisition target in the Pr scheme and no agency costs case, Murcia's agricultural income experiences a -33% contraction as compared to -20.5% in the microeconomic model. Sectors that are strongly linked to agriculture like food industry also experience relevant losses in Murcia (up to -4% GVA). As opposed to the GVA losses experienced by Murcia, agricultural GVA elsewhere in Spain increases by .37% and the service sector by almost .02%. This is partly the result of a *substitution effect* led by the reallocation of agricultural supply from Murcia towards other economic sectors and regions of Spain. On the other hand, the contraction of the Spanish aggregate income limits the rise of the GVA in the rest of Spain, resulting in an *income effect* that counterbalances the substitution effect. The trade-off between substitution and income effects is typical of this dynamic macroeconomic scenario where flexible prices determine the adjustment of trading flows.

The underlying reallocation of primary factors is critical to understand these effects. Consumers substitute goods from Murcia with goods produced elsewhere and not affected by the negative productivity shock, thus increasing the firms' demand for capital and labor in the rest of Spain. This leads to a shift of capital and labor force from Murcia to the rest of Spain, where capital and workers can find higher remunerations. As a result, Murcia experiences a substantial GDP loss (up to -2.1%), while GDP increases in the rest of Spain (up to +0.034%). Overall, the policy has a negative impact on Spanish GDP, although limited (up to -0.023%). Not surprisingly, the Pr scheme has a more negative impact than the CE. It is worth noting that higher agency costs do not influence the effects on Spanish aggregate GDP but have implications for its spatial distribution, mitigating losses in Murcia and diminishing gains in other Spanish regions. It should be noted that relative changes in food industry and services exhibit nonlinear and non-monotonous patterns. This is due to the reallocation of primary factors and the resultant redistribution of trade in the different scenarios. Agency costs mitigate Murcia's losses in the services sector and the overall economy, but have a negligible impact on agriculture and food industry, where results for the three agency costs scenarios are similar.

Figure 5 assesses policy impacts looking at the Equivalent Variation. Conceptually, the Equivalent Variation is similar to the Compensating Variation, but it is applied at the macroeconomic level to assess welfare impacts. It represents the amount of income that keeps the utility of the agent of the CGE model equal to that of the baseline, and is mainly driven by final consumption. A negative sign denotes a welfare loss as compared to the baseline.

Figure 5: the Equivalent Variation (vertical axis) expressed in 2007 million $ of Murcia (left), Rest of Spain (center) and Spain (right) for the 8 water reacquisition targets (horizontal axis).



Welfare effects at a regional and national level are also explained by the movements of primary factors and the re-composition of trade in the different scenarios, which depends on the Armington elasticities, whose coefficients differ for every sector. This leads to non-linear adjustment and non-monotonicity. In Murcia, the income transfer from the rest of Spain is insufficient to fully compensate the negative impact of reacquisitions, resulting in a welfare loss in most macroeconomic scenarios. Only for a few reacquisition targets (200, 350 and 400 million m^3) and for the highest level of agency costs (case 3) the income transfer leaves the representative agent with a welfare level comparable or higher to that of the baseline. The rest of Spain finds itself worse off in terms of welfare in several scenarios, despite the GDP increase. On the one hand, the income transfer in Murcia increases imports from the rest of Spain, especially agricultural products, which are cheaper since the production has not been negatively affected by the productivity shock; on the other, this is possible because the rest of Spain finances the consumption of Murcia through the income transfer, thus decreasing its own. Welfare impacts on the rest of Spain are a function of agency costs, with welfare gains where there are no agency costs and welfare losses where agency costs are high. Again, the size of agency costs does not affect aggregate welfare impacts on Spain, and the Pr scheme is more detrimental for welfare than the CE scheme.

6.3. Discussion

Applied research available on the economy-wide impacts of agricultural water buyback programmes is limited and focused on the Australian case. Dixon et al. (2011, 2012a) analyze the economy-wide impacts of the water buyback programme in the Southern Murray-Darling Basin by using a sub-national CGE model for Australia that incorporates water as a primary factor, thus making water trading feasible. Results show that the reacquisition of 1 500 million m^3 (22.8% of initial water allotments) to restore the balance in the Southern Murray-Darling Basin has a marginal impact at the national level (-0.0059% of GDP). In the Segura River Basin, restoring the balance would demand the reacquisition of 250 million m^3 (15.9% of initial water allotments). Our results suggest this policy would have a comparable impact on the Spanish GDP (-0.0107% in the Pr scheme and -0.0044% in the CE scheme), but a significantly higher cost per m^3 of water reacquired: 0.21$ in the CE and 0.51$ in the Pr, as compared to 0.05$ in Australia, in 2015 World Bank GDP values. This is largely explained by the distinct ability of the agricultural sectors in the Southern Murray-Darling Basin and Murcia to absorb the shock: following the reacquisitions, agricultural output falls by -1.3% in Southern Murray-Darling Basin as compared to between -16% (Pr) and -6.5% (CE) in Murcia. In addition, farmers in the Murray-Darling basin increase their consumption and welfare following the buyback, while the opposite situation is registered in most scenarios in Murcia.

Two elements appear crucial to explain the differences between our results and those of Dixon et al. (2012a, 2011): i) the existence of water markets in Australia; and ii) the coupling method used in our approach, which allows for a more detailed representation of the motivations and constraints faced by farmers. In a market environment, buyback constrains supply and increases water prices, and farmers can leverage on this opportunity to increase consumption and welfare. This is not the case in Europe, where water markets do not exist and "prices" are in reality administrative charges that do not respond to the scarcity value of water. The second key element is the coupling. The spatial resolution in the sub-national Australian CGE model does not offer the same level of detail than a bottom-up, locally calibrated model such as the RPM model for Murcia. The southern half of the large Murray-Darling basin (1 061 469 km^2) is divided into 13 units in Dixon et al. (2012a, 2011) while Murcia, which covers an area equaling 1% of the Murray-Darling Basin's territory (11 313 km^2), is divided in 55 units in our study. The microeconomics assessment makes possible the use of mathematical programming methods such as RPM to elicit the parameters of agents' objective functions and allows for a more detailed representation of the motivations and constraints faced by irrigators. Notably, the Australian CGE model does not consider these constraints and risks to overestimate irrigators' capacity to shift capital, labor and land from one land use to another (Hertel and Liu, 2016). As Wittwer (2012) points out, a finer regional division in CGE models is desirable for three reasons: i) more detailed regional results; ii) environmental issues such as water management often call for smaller regions that can map watershed or other natural boundaries more closely; and iii) more and smaller regions give a greater sense of geographical realism. The coupling between the bottom-up RPM and the top-down regionally-calibrated CGE model is a first step in this direction.

Although macroeconomic models have been used previously to assess the economy-wide impacts of fiscal policy schemes and water markets, to the best of our knowledge this is the first applied study of the economy-wide impacts of buyback policies outside Australia. The most plausible explanation to this is the difficulty to accurately simulate the price and value share to water, and water reallocation among users, outside of a market environment. Yet, several macroeconomic models have been developed to inform irrigation water reallocation in the EU context and elsewhere (for a review see e.g. Dudu and Chumi, 2008 and Hertel and Liu, 2016). Even if the focus of these studies is different from ours, they can provide useful insights and policy implications for our work.

For instance, insights from other macroeconomic models can be useful to inform policy sequencing in water reacquisitions. Water market scenarios for Europe unequivocally show an increase in GVA through water reallocation to more productive uses (Hertel and Liu, 2016), suggesting water trading could help mitigate the GVA losses associated to buyback programmes. On the other hand, this very mechanism increases shadow prices (Darwin et al., 1995; Dixon et al., 2012a), and thus the overall cost of buyback for taxpayers. A sensible water policy reform consistent with the cost-effectiveness rationale that governs EU water policy (EC, 2000) may need to consider alternative policy sequencings to the Australian case to enhance acceptability –e.g. commencing reacquisitions before developing full-fledged water markets.

In addition to its economy-wide impacts, water buyback can also involve wider environmental consequences beyond the target basin as a result of the spatial redistribution of production. For example, Cazcarro et al. (2014) show that a combination of water tariffs and subsidies on food production can save water in the water scarce regions of Southern Spain (Murcia and Andalusia) and enhance food production in the water-abundant regions of the North (Cantabria and Basque Country). In our assessment, water conservation targets in Murcia are achieved at the expense of a significant decrease in the agricultural output, which is replaced by higher agricultural production elsewhere. Although we are not able to precise water use patterns in the remaining Spanish regions, agricultural production increase is more pronounced in Northern regions such as Asturias, Cantabria and Aragon where water is relatively more abundant –pointing towards a pattern similar to that of Cazcarro et al. (2014).

7. Conclusions

Results show that the economy-wide repercussions of water buyback are relevant and range between -33% and -19.33% agricultural GVA losses in the Murcia Region for the most ambitious reacquisition target (400 million m^3), significantly higher than the GVA losses estimated in the microeconomic model (up to -20.5% for the same scenario). This amplification effect is the result of the reallocation of primary factors from Murcia to the rest of Spain modelled in the CGE context. Despite compensations paid to local irrigators, Murcia's supply contraction in the agricultural and related economic sectors lead to a GDP loss. The remaining Spanish regions partially fill in the supply gap and experience a net GVA gain in agriculture and a GDP increase which is nonetheless insufficient to compensate GDP losses in Murcia and results in a net GDP loss economy-widein the Spanish economy. Welfare effects can be unevenly distributed between Murcia and the rest of Spain, with winners and losers depending on the size of the agency costs. Results support the decision to develop investment plans/flanking measures to address the economy-wide impacts of buyback, particularly in affected rural economies and related economic sectors such as food industry.

Coupling the top-down CGE model with the bottom-up RPM makes feasible a detailed analysis of the tradeoffs in water conservation, from the sub-regional (AWDU) to the regional, national and supranational scale. Methods are general and replicable in other areas where water markets are non-existent or in an early stage of development and *ex-post* trading data is not readily available. Future research can focus on i) addressing the current limitations of the micro- and macro-economic models and ii) expanding the methodological framework. The current version of the RPM relies on a validated projection method, but alternative methods exist and new methods could also be explored to minimize the calibration error (Gómez-Limón et al., 2016). The calibration error could be also reduced finding alternative and/or complementary attributes in the objective function that are relevant in explaining agents' decisions. The CGE model could be improved introducing temporal dynamics in order to examine the transition pathway towards the new equilibrium and identify potential trade-offs between short and long run effects which could be relevant for policy implementation. From the data perspective, water satellite accounts at a sectorial level (where available) could be used to analyze simultaneously the macroeconomic propagation of the policy and water use changes in economic sectors (other than irrigators in Murcia), e.g. through input-output coefficients (Cazcarro et al., 2014). The current methodological framework could be also expanded including a hydrological module that accounts for catchment-specific characteristics and system dynamics (e.g. percolation, runoff) and localizes water flows and water conservation across the basin. This information is instrumental to assess the environmental outputs of the policy, and to estimate its economic benefits through non-market valuation methods.

Appendix

Table A1. Microeconomic model – calibration results

AWDU	α_1	α_2	α_3	α_4	α_5	e_x	e_τ	e
1	0.99	0.01	0	0	0	8.1%	1.8%	4.9%
2	0.88	0.12	0	0	0	2.3%	8.4%	5.3%
3	0.86	0.05	0.03	0	0.06	0.7%	2.8%	1.7%
4	0.95	0.02	0.01	0.01	0	0.4%	1.8%	1.1%
5	0.92	0.08	0	0	0	1.8%	1.8%	1.8%
6	0.95	0.03	0.02	0	0	0.2%	0.7%	0.5%
7	0.78	0.22	0	0	0	5.3%	5.9%	5.6%
12	0.8	0.2	0	0	0	4.1%	9.1%	6.6%
14	0.63	0.37	0	0	0	3.0%	2.3%	2.6%
15	0.72	0.28	0	0	0	1.5%	3.8%	2.7%
16	0.6	0.4	0	0	0	0.9%	7.7%	4.3%
17	0.85	0.15	0	0	0	8.6%	3.8%	6.2%
18	0.89	0.11	0	0	0	0.4%	1.7%	1.1%
20	0.83	0.17	0	0	0	4.3%	3.0%	3.6%
21	0.88	0.12	0	0	0	1.5%	9.2%	5.3%
22	0.83	0.17	0	0	0	2.3%	2.1%	2.2%
25	0.93	0.07	0	0	0	0.3%	1.2%	0.7%
26	0.9	0.04	0	0.02	0.03	0.6%	3.4%	2.0%
27	0.99	0.01	0	0	0	4.5%	9.3%	6.9%
28	0.94	0.06	0	0	0	1.8%	6.9%	4.4%
29	0.79	0.13	0.09	0	0	1.5%	3.8%	2.7%
30	0.49	0.51	0	0	0	3.2%	7.2%	5.2%
31	0.83	0.17	0	0	0	6.7%	5.0%	5.9%
32	0.51	0.49	0	0	0	4.5%	13.0%	8.8%
34	0.95	0.01	0	0.03	0	0.8%	1.4%	1.1%
36	0.97	0.01	0	0.02	0	0.4%	0.6%	0.5%
37	0.89	0.09	0.01	0	0.01	0.7%	2.2%	1.4%

AWDU	α_1	α_2	α_3	α_4	α_5	e_x	e_τ	e
39	0.95	0.02	0	0.03	0	1.4%	2.4%	1.9%
40	0.88	0.12	0	0	0	0.9%	3.8%	2.3%
41	0.81	0.19	0	0	0	3.2%	1.7%	2.5%
42	0.91	0.09	0	0	0	1.8%	3.3%	2.6%
43	0.9	0.08	0	0	0.02	1.3%	2.0%	1.6%
44	0.92	0.02	0.04	0	0.01	1.3%	3.5%	2.4%
45	0.74	0.07	0	0.18	0	1.5%	5.1%	3.3%
46	0.98	0.02	0	0.01	0	1.0%	3.2%	2.1%
48	0.38	0.12	0	0.36	0.14	4.3%	11.6%	8.0%
51	0.92	0.01	0	0	0.08	0.1%	0.4%	0.3%
53	0.44	0.23	0	0.34	0	6.1%	14.0%	10.1%
55	0.95	0.05	0	0	0	0.2%	0.3%	0.3%
56	0.73	0.27	0	0	0	1.6%	7.1%	4.4%
57	0.4	0.6	0	0	0	9.5%	14.3%	11.9%
58	0.48	0.52	0	0	0	10.6%	11.7%	11.2%
59	0.52	0.48	0	0	0	9.9%	13.9%	11.9%
60	0.83	0.16	0	0	0.01	3.2%	13.6%	8.4%
61	0.28	0.72	0	0	0	8.6%	15.2%	11.9%
63	0.43	0.4	0.17	0	0	1.9%	8.7%	5.3%
64	0.53	0.47	0	0	0	0.8%	4.4%	2.6%
65	0.43	0.55	0	0	0.02	2.0%	3.8%	2.9%
66	0.87	0.07	0	0	0.06	1.4%	3.3%	2.3%
67	0.39	0.39	0	0	0.22	0.6%	9.9%	5.3%
68	0.79	0.21	0	0	0	0.5%	3.4%	1.9%
69	0.34	0.66	0	0	0	1.2%	6.4%	3.8%
70	0.67	0.26	0	0	0.07	1.4%	9.2%	5.3%
72	0.4	0.21	0	0	0.39	2.5%	9.8%	6.2%
73	0.99	0.01	0	0	0	2.0%	2.9%	2.5%

Source: Own elaboration

The columns α_1, α_2, α_3, α_4 and α_5 display the parameter values in the Cobb-Douglas utility function of the attributes profit (z_1), risk avoidance (z_2), total labor avoidance (z_3), hired labor avoidance (z_4) and direct costs avoidance (z_5), respectively. e_x, e_τ and e are the crop portfolio error, attributes error and average error, respectively.

Calibration results show that the most relevant attribute driving agents' decisions is profit. Risk aversion has also a relevant role in explaining the behavior of all agents in the Murcia Region. The attributes measuring management complexities (z_3, z_4 and z_5) avoidance are relevant in 23 (42%) AWDUs. Caution must be exercised in interpreting the results. For example, it cannot be inferred that AWDUs with a higher risk aversion have a lower income variability, since choices are ultimately constrained by the domain. Nonetheless, attribute parameters offer valuable insights on agents' preferences and can serve to project behavior, provided calibration errors are low. In the case of the AWDUs of the Region of Murcia, metrics for performance evaluation are satisfactory, with low (<10% average error) errors in all but five AWDUs, which display a moderate (<15%) calibration error (Gutiérrez-Martín and Gómez, 2011; Pérez-Blanco et al., 2015a, 2016).

References

Adamson, D., Loch, A., 2014. Possible negative feedbacks from “gold-plating” irrigation infrastructure. Agric. Water Manag. doi:10.1016/j.agwat.2013.09.022

Anderson, J.E., Wincoop, E. van, 2003. Gravity with Gravitas: A Solution to the Border Puzzle. Am. Econ. Rev. 93, 170–192.

Armington, P.S., 1969. A Theory of Demand for Products Distinguished by Place of Production. IMF Staff Pap. 16, 159–178.

Avellá, L., García-Mollá, M., 2009. Institutional factors and technology adoption in irrigated farming in Spain: Impacts on water consumption, in: The Management of Water Quality and Irrigation Technologies. Dinar A., Albiac J., London (UK).

Baghersad, M., Zobel, C.W., 2015. Economic impact of production bottlenecks caused by disasters impacting interdependent industry sectors. Int. J. Prod. Econ. 168, 71–80. doi:10.1016/j.ijpe.2015.06.011

Berrittella, M., Hoekstra, A.Y., Rehdanz, K., Roson, R., Tol, R.S.J., 2007. The economic impact of restricted water supply: A computable general equilibrium analysis. Water Res. 41, 1799–1813. doi:10.1016/j.watres.2007.01.010

BOE, 2015. Real Decreto Legislativo 7/2015, de 30 de octubre, por el que se aprueba el texto refundido de la Ley de Suelo y Rehabilitación Urbana, Legislative Decree.

BOE, 2011. Real Decreto 1492/2011, de 24 de octubre, por el que se aprueba el Reglamento de valoraciones de la Ley de Suelo, Royal Decree.

BOE, 2007. Ley 8/2007, de 28 de mayo, del Suelo, Law.

Bohringer, C., Tarr, D.G., Rutherford, T.F., Turdyeva, N., 2014. The environmental implications of Russia’s accession to the world trade organization (No. WPS6957). The World Bank.

Bonfiglio, A., 2008. Evaluating Implications of Agricultural Policies in a Rural Region through a CGE Analysis (No. 328), Working Papers. Universita’ Politecnica delle Marche (I), Dipartimento di Scienze Economiche e Sociali.

Bonfiglio, A., Chelli, F., 2008. Assessing the Behaviour of Non-Survey Methods for Constructing Regional Input–Output Tables through a Monte Carlo Simulation. Econ. Syst. Res. 20, 243–258. doi:10.1080/09535310802344315

Bosello, F., Nicholls, R.J., Richards, J., Roson, R., Tol, R.S.J., 2012. Economic impacts of climate change in Europe: sea-level rise. Clim. Change 112, 63–81. doi:10.1007/s10584-011-0340-1

Bosello, F., Parrado, R., Rosa, R., 2013. The economic and environmental effects of an EU ban on illegal logging imports. Insights from a CGE assessment. Environ. Dev. Econ. 18, 184–206. doi:10.1017/S1355770X12000526

Bosello, F., Standardi, G., 2015. A Sub-national CGE model for the European Mediterranean Countries (Working Paper No. RP0274), CMCC Research Papers. CMCC, Lecce (Italy).

Brandsma, A., Kancs, d’Artis, Monfort, P., Rillaers, A., 2015. RHOMOLO: A dynamic spatial general equilibrium model for assessing the impact of cohesion policy. Pap. Reg. Sci. 94, S197–S221. doi:10.1111/pirs.12162

Cai, Y., Arora, V., 2015. Disaggregating electricity generation technologies in CGE models: A revised technology bundle approach with an application to the U.S. Clean Power Plan. Appl. Energy 154, 543–555. doi:10.1016/j.apenergy.2015.05.041

Calzadilla, A., Rehdanz, K., Tol, R.S.J., 2011. The GTAP-W model: accounting for water use in agriculture (Kiel Working Paper No. 1745). Kiel Institute for the World Economy.

Carrera, L., Standardi, G., Bosello, F., Mysiak, J., 2015. Assessing direct and indirect economic impacts of a flood event through the integration of spatial and computable general equilibrium modelling. Environ. Model. Softw. 63, 109–122. doi:10.1016/j.envsoft.2014.09.016

Cazcarro, I., Duarte, R., Sanchez-Choliz, J., Sarasa, C., 2014. An integrated MRIO-CGE model for studying water and production reallocations in Spain. Presented at the XL International Conference of Regional Studies, organized by University of Zaragoza, Zaragoza (Spain).

Ciscar, J.-C., Iglesias, A., Feyen, L., Szabó, L., Regemorter, D.V., Amelung, B., Nicholls, R., Watkiss, P., Christensen, O.B., Dankers, R., Garrote, L., Goodess, C.M., Hunt, A., Moreno, A., Richards, J., Soria, A., 2011. Physical and economic consequences of climate change in Europe. Proc. Natl. Acad. Sci. 108, 2678–2683. doi:10.1073/pnas.1011612108
Darwin, R., Tsigas, M.E., Lewandrowski, J., Raneses, A., 1995. World Agriculture and Climate Change: Economic Adaptations (Agricultural Economics Reports No. 33933). United States Department of Agriculture, Economic Research Service.
Department of the Environment, 2015. Water Amendment Bill 2015, Act.
Dixon, P., Rimmer, M., Wittwer, G., 2012a. USAGE-R51, a state-level multi-regional CGE model of the US economy. Presented at the 15th Annual Conference on Global Economic Analysis, Geneva (Switzerland).
Dixon, P., Rimmer, M.T., Wittwer, G., 2012b. Buybacks to Restore the Southern Murray-Darling Basin, in: Wittwer, G. (Ed.), Economic Modeling of Water, Global Issues in Water Policy. Springer Netherlands, pp. 99–118. doi:10.1007/978-94-007-2876-9_6
Dixon, P., Rimmer, M.T., Wittwer, G., 2011. Saving the Southern Murray-Darling Basin: The Economic Effects of a Buyback of Irrigation Water*. Econ. Rec. 87, 153–168. doi:10.1111/j.1475-4932.2010.00691.x
DSEWPAC, 2016. Progress of water recovery under the Restoring the Balance in the Murray-Darling Basin program [WWW Document]. Dep. Sustain. Environ. Water Popul. Communities. URL https://www.environment.gov.au/water/rural-water/restoring-balance-murray-darling-basin/progress-water-recovery (accessed 10.26.16).
Dudu, H., Chumi, S., 2008. Economics of irrigation water management : a literature survey with focus on partial and general equilibrium models (No. WPS4556). The World Bank.
Eboli, F., Standardi, G., 2015. Sea Level Rise in the Italian regions: a macro-economic assessment (Working Paper No. RP0251), CMCC Research Papers. CMCC, Lecce (Italy).
EC, 2015a. Technical Report on Groundwater Associated Aquatic Ecosystems (Technical Report No. 2015-093). European Commission, Brussels (Belgium).
EC, 2015b. Ecological flows in the implementation of the Water Framework Directive (Technical Report No. 2015–086, No. 31), CIS Guidance Document. European Commission, Brussels (Belgium).
EC, 2009. Guidance on groundwater status and trend assessment (Technical Report No. 2015–026, No. 18), CIS Guidance Document. European Commission, Brussels (Belgium).
EC, 2000. Water Framework Directive 2000/60/EC, Council Directive.
Eurostat, 2016. Eurostat Database [WWW Document]. Eurostat Database. URL http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes (accessed 10.5.13).
Garrido, A., Rey, D., Calatrava, J., 2013. Water trading in Spain, in: Agriculture and the Environment in Spain: Can We Square the Circle? CRC Press, Taylor & Francis, pp. 205–216.
Gómez, C.M., Pérez-Blanco, C.D., 2012. Do drought management plans reduce drought risk? A risk assessment model for a Mediterranean river basin. Ecol. Econ. 76, 42–48. doi:10.1016/j.ecolecon.2012.01.008
Gómez-Limón, J.A., Gutiérrez-Martín, C., Riesgo, L., 2016. Modeling at farm level: Positive Multi-Attribute Utility Programming. Omega. doi:10.1016/j.omega.2015.12.004
Graveline, N., 2016. Economic calibrated models for water allocation in agricultural production: A review. Environ. Model. Softw. 81, 12–25. doi:10.1016/j.envsoft.2016.03.004
GRBA, 2008. Plan Especial del Alto Guadiana. Guadiana River Basin Authority.
Gutiérrez-Martín, C., Gómez, C.M., 2011. Assessing irrigation efficiency improvements by using a preference revelation model. Span. J. Agric. Res. 9, 1009–1020. doi:10.5424/sjar/20110904-514-10
Gutiérrez-Martín, C., Pérez-Blanco, C.D., Gómez, C.M., Berbel, J., 2014. Price Volatility and Water Demand in Agriculture. A Case Study of the Guadalquivir River Basin (Spain), in: Economics of Water Management in Agriculture. Bournaris, T., J. Berbel, B. Manos, D. Viaggi, Boca Raton (US), pp. 319–348.
Hahn, R.W., 1989. Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders. J. Econ. Perspect. 3, 95–114.

Hanak, E., Stryjewski, E., 2012. California's Water Market, By the Numbers, Update 2012 (Report No. Update November 2012). Public Policy Institute of California.
Hanoch, G., 1971. CRESH Production Functions. Econometrica 39, 695–712. doi:10.2307/1909573
Hassan, R., Thurlow, J., Roe, T., Diao, X., Chumi, S., Tsur, Y., 2008. Macro-Micro Feedback Links of Water Management in South Africa. CGE Analyses of Selected Policy Regimes (World Bank Policy Research Working Paper No. 4768). Washington D.C. (US).
Heckelei, T., Britz, W., Zhang, Y., 2012. Positive Mathematical Programming Approaches - Recent Developments in Literature and Applied Modelling. Bio-Based Appl. Econ. J.
Hertel, T.W., Liu, J., 2016. Implications of water scarcity for economic growth (OECD Environment Working Papers). Organisation for Economic Co-operation and Development, Paris.
Horridge, M., Wittwer, G., 2008. SinoTERM, a multi-regional CGE model of China. China Econ. Rev. 19, 628–634. doi:10.1016/j.chieco.2008.05.002
Husby, T.G., 2016. Economic impacts of behavioural responses to flood risk (Doctoral Dissertation). Vrije Universteit Amsterdam, Amsterdam., Amsterdam (the Netherlands).
Iftekhar, M.S., Tisdell, J.G., Connor, J.D., 2013. Effects of competition on environmental water buyback auctions. Agric. Water Manag. 127, 59–73. doi:10.1016/j.agwat.2013.05.015
INE, 2017. Instituto Nacional de Estadística - INEBase [WWW Document]. URL http://www.ine.es/inebmenu/indice.htm (accessed 9.15.14).
Koks, E.E., Carrera, L., Jonkeren, O., Aerts, J.C.J.H., Husby, T.G., Thissen, M., Standardi, G., Mysiak, J., 2015. Regional disaster impact analysis: comparing Input-Output and Computable General Equilibrium models. Nat. Hazards Earth Syst. Sci. 3, 7053–7088. doi:10.5194/nhessd-3-7053-2015
Koks, E.E., Thissen, M., 2016. A Multiregional Impact Assessment Model for disaster analysis. Econ. Syst. Res. 28, 429–449. doi:10.1080/09535314.2016.1232701
MAGRAMA, 2015a. Anuario de Estadística Agraria (Agricultural Statistics Yearbook) (Report). Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid (Spain).
MAGRAMA, 2015b. Resultados técnico-económicos de explotaciones agrarias (Database). Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid (Spain).
Marchiori, C., Sayre, S.S., Simon, L.K., 2012. On the Implementation and Performance of Water Rights Buyback Schemes. Water Resour. Manag. 26, 2799–2816. doi:10.1007/s11269-012-0047-8
Martínez-Granados, D., Calatrava, J., 2014. The role of desalinisation to address aquifer overdraft in SE Spain. J. Environ. Manage. 144, 247–257. doi:10.1016/j.jenvman.2014.06.003
McCallum, J., 1995. National Borders Matter: Canada-U.S. Regional Trade Patterns. Am. Econ. Rev. 85, 615–23.
Miller, R.E., Blair, P.D., 2009. Input-Output Analysis: Foundations and Extensions, 2 edition. ed. Cambridge University Press, Cambridge England ; New York.
Narayanan, B., Aguiar, A., McDougall, R., 2012. Global Trade, Assistance, and Production: The GTAP 8 Data Base. Center for Global Trade Analysis, Purdue University.
OECD, 2015. Water Resources Allocation: Sharing risks and opportunities, OECD Studies on Water. OECD Publishing.
Pant, H., 2007. GTEM: Global Trade and Environment Model (ABARE Technical Report). Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra (Australia).
Parrado, R., De Cian, E., 2014. Technology spillovers embodied in international trade: Intertemporal, regional and sectoral effects in a global CGE framework. Energy Econ. 41, 76–89. doi:10.1016/j.eneco.2013.10.016
Pérez-Blanco, C.D., Delacámara, G., Gómez, C.M., 2015a. Water charging and water saving in agriculture. Insights from a Revealed Preference Model in a Mediterranean basin. Environ. Model. Softw. 69, 90–100. doi:10.1016/j.envsoft.2015.03.006
Pérez-Blanco, C.D., Delacámara, G., Gómez, C.M., 2015b. Revealing the willingness to pay for income insurance in agriculture. J. Risk Res. 0, 1–21. doi:10.1080/13669877.2015.1042505
Pérez-Blanco, C.D., Gutiérrez-Martín, C., 2017. Buy me a river: Use of multi-attribute non-linear utility functions to address overcompensation in agricultural water buyback. Agric. Water Manag. 190, 6–20. doi:10.1016/j.agwat.2017.05.006

Pérez-Blanco, C.D., Koks, E.E., Calliari, E., Mysiak, J., 2017. Economic Impacts of Irrigation-Constrained Agriculture in the Lower Po Basin. Water Econ. Policy 3, 1750003. doi:10.1142/S2382624X17500035

Pérez-Blanco, C.D., Standardi, G., Mysiak, J., Parrado, R., Gutiérrez-Martín, C., 2016. Incremental water charging in agriculture. A case study of the Regione Emilia Romagna in Italy. Environ. Model. Softw. 78, 202–215. doi:10.1016/j.envsoft.2015.12.016

Perry, C.J., Steduto, P., 2017. Does improved irrigation technology save water? A review of the evidence (Discussion paper on irrigation and sustainable water resources management in the Near East and North Africa), Regional Initiative on Water Scarcity for the Near East and North Africa. FAO, Cairo.

Qureshi, M.E., Shi, T., Qureshi, S.E., Proctor, W., 2009. Removing barriers to facilitate efficient water markets in the Murray-Darling Basin of Australia. Agric. Water Manag. 96, 1641–1651. doi:10.1016/j.agwat.2009.06.019

Región de Murcia, 2015. Estadística Agraria Regional [WWW Document]. Agric. Database. URL http://www.carm.es/web/pagina?IDCONTENIDO=1174&IDTIPO=100&RASTRO=c1355$m

Rose, A., Benavides, J., Chang, S.E., Szczesniak, P., Lim, D., 1997. The Regional Economic Impact of an Earthquake: Direct and Indirect Effects of Electricity Lifeline Disruptions. J. Reg. Sci. 37, 437–458. doi:10.1111/0022-4146.00063

SRBA, 2015a. Plan Hidrológico de la Demarcación del Segura 2015-2021 (River Basin Management Plan). Segura River Basin Authority, Murcia (Spain).

SRBA, 2015b. Shapefiles - Segura River Basin [WWW Document]. Segura River Basin Database. URL https://www.chsegura.es/chs/cuenca/resumendedatosbasicos/cartografia/descargas/ (accessed 10.16.15).

SRBA, 2014. Plan Hidrológico de la Cuenca del Segura 2009-2015 (River Basin Management Plan). Segura River Basin Authority, Murcia (Spain).

SRBA, 2008. Plan de Actuación en Situaciones de Alerta y Eventual Sequía de la Cuenca del Segura (Report). Segura River Basin Authority.

Taheripour, F., Hertel, T., Liu, J., 2013. Introducing water by river basin into the GTAP-BIO model: GTAP-BIO-W (GTAP Working Paper No. 4304). Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Varian, H.R., 2012. Revealed Preference and its Applications*. Econ. J. 122, 332–338. doi:10.1111/j.1468-0297.2012.02505.x

Wheeler, S., Garrick, D., Loch, A., Bjornlund, H., 2013. Evaluating water market products to acquire water for the environment in Australia. Land Use Policy 30, 427–436. doi:10.1016/j.landusepol.2012.04.004

Wittwer, G., 2012. Economic Modeling of Water - The Australian CGE Experience. Springer.

Wittwer, G., Horridge, M., 2010. Bringing Regional Detail to a CGE Model using Census Data. Spat. Econ. Anal. 5, 229–255. doi:10.1080/17421771003730695

Zuo, A., Wheeler, S.A., Adamowicz, W.L. (Vic), Boxall, P.C., Hatton-MacDonald, D., 2015. Measuring Price Elasticities of Demand and Supply of Water Entitlements Based on Stated and Revealed Preference Data. Am. J. Agric. Econ. aav022. doi:10.1093/ajae/aav022