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Regional consequences of the way land users respond to future water availability in Murcia, Spain

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Abstract

Agricultural development in the Murcia autonomous region, Spain has led to overexploitation of groundwater resources and climate change will further increase pressures. Policy options to tackle the current unsustainable situation include the development of inter-basin water transfer (IBWT) schemes from wetter regions in the north and the introduction of taxation to further control groundwater abstraction. Under these scenarios farmers with current access to water could face higher water cost, whereas farmers in areas where water was previously not available could see first time availability of water resources. In this paper we combine discrete choice based interviews (DCI) with farmers in the Torrealvilla catchment, in which they indicate how they would adapt their land use under different scenarios, with an input-output model to assess the aggregate effects of individual land use decisions on the economy and water consumption of the Murcia region. The paper presents steps taken in the development of an input-output table for Murcia, including disaggregation of the agricultural sector, accounting for sector water use, and consideration of back- and forward linkages. We conclude that appropriate taxation can lead to better water use efficiency, but that this is delicate as relatively small changes in prices of agricultural products can have significant impacts on land use and water consumption. Although new IBWT schemes would enable water to be used more efficiently, they would considerably increase regional water consumption and the regional economy's dependence on water. As this is not sustainable under future climate change, water saving development pathways need to be explored.

1. Introduction

Provision of freshwater is one of the most important ecosystem services, which has in many areas of the world been compromised by unsustainable land management practises (MA, 2005). Water resources are limited and need to be carefully managed to satisfy and safeguard continuous multiple needs of consumers, the economy and environment. Water scarcity, the temporal or spatial imbalance between available water resources and demand has been, and will increasingly become, a serious concern, exacerbated by overexploitation, environmental degradation, pollution and climate change (Hubacek and Sun, 2005).

The Spanish Region of Murcia (Figure 1), despite being hot and dry, has witnessed remarkable agricultural development over the last decades. However, its agricultural sector is premised on heavy overexploitation of groundwater resources and reliance on the Tagus–Segura inter-basin water transfer (IBWT) scheme, which was inaugurated in 1979 (Garrido et al., 2006; Grindlay et al., 2011) and is for 56 ± 15% used for irrigation (CREM, 2011) . The region has become known as a major producer of fruits and vegetables. This is reflected in the importance of agriculture in the economy (8.3% of regional employment and 5.8% of regional gross added value against 4.5% and 2.6% at the national level, respectively), but most significantly by the fact that agricultural exports make up 35.4% of Murcia's total exports (CREM, 2011). The paradoxical issue of the embedded 'virtual' water exports from a water-scarce region has drawn attention from many scholars (Ma et al., 2006; Velázquez, 2006; Dietzenbacher and Velázquez, 2007; Downward and Taylor, 2007; Guan and Hubacek, 2007; Chapagain and Orr, 2009; Zhao et al., 2009). For the past thirty years, regional water demand in the Segura basin has surpassed availability of renewable water resources as a combined effect of increased irrigation (87% of current water demand) and rapid urbanization (7%) (Grindlay et al., 2011). As a result, ironically, the IBWT scheme has only further aggravated the region's chronic water shortage.

Past and present perspectives on the region's water shortage are well-documented by Grindlay et al. (2011). Oñate and Peco (2005) address the role policies have played in transforming land management in Murcia over the years, particularly how they are perceived to have driven land degradation processes in the Guadalentín basin, both in irrigated and rainfed areas. The water thirst of the region is stressed by many authors, with Garrido et al. (2006, p.347) classifying the Segura basin as 'one of the most interesting cases of water conflicts in Spain, and perhaps worldwide'. The governance of the Tagus–Segura IBWT is based on the early summer water level of reservoirs in the headwaters of the Tagus, but does not take into account water needs in the conceding basin. Roughly 60% of the natural flow of the upper Tagus is committed to the Tagus–Segura IBWT, and as a consequence the minimum discharge is now less than 6 m^3/s compared to 30 m^3/s before the IBWT became operational (Hernández Soria, 2003). The rationale for developing the IBWT was that cities and tourism on the Mediterranean coast needed water to grow and irrigated agriculture in the sub-tropical zones of southern Spain achieves higher water productivity than in the interior regions. However, due to reduced flow levels, the Tagus is now among the most polluted European rivers (Hernández Soria, 2003), and growing water needs in the conceding region have led to bitter disputes. Ambitious but similarly highly contested plans for a further Ebro–Segura IBWT scheme have for the time being been put on hold. Instead, desalinisation has been embraced as an alternative way forward as the capital and energy expenses have come down in recent years (Downward and Taylor, 2007). Simultaneously, the European Water Framework Directive (WFD) prescribes that water should be priced at full-cost recovery and water resources and fluxes should be systematically monitored. The WFD further stresses institutionalising environmental water demands at par with societal and economic water demands. As a consequence, the Tagus–Segura IBWT may be limited by allocating more water within the conceding basin (Martínez-Santos et al., 2008), and prices of groundwater extraction would also rise (Garrido et al., 2006). In this context, water users generally have great uncertainty over water availability and regulations governing its use.

Whereas much research has focused on potential policy options to decrease water dependency, these options and the likely responses of individual land managers have rarely been analysed at both the farm and regional scale. These interconnections are important as policies will affect different farm types differently – with social and environmental consequences (e.g. de Graaff et al., 2008); studies focusing at the regional scale can only assume how farmers will react. As the agricultural sector is embedded in the regional economy, shifts in competitiveness of land uses can have important knock-on effects on other sectors; exclusively farm scale studies cannot take these effects into account. In this paper, we combine discrete choice based interviews (DCI) with an input-output model to attempt such integration. This combination not only allows assessing the direct aggregate effects of individual land use decisions, but also of indirect effects on the regional economy and associated water use. In the remainder of this paper, we first introduce the methods used in the study. Subsequently, results are presented and discussed, and conclusions drawn.

<<<Figure 1 about here>>>

2. Methodology

Two methods are used to assess regional effects of local responses: an input-output (I/O) model and discrete choice based interviews (DCI). The former requires several intermediate steps which are explained in more detail in the first seven sub-sections (2.1-2.7). Data requirements and assumptions are indicated in various places, but have also been brought together in a data appendix (provided as supplementary material). The DCI were obtained from a farm survey among farmers in the Torrealvilla catchment (Figure 1). The definition of DCI scenarios and upscaling procedure are provided in sub-sections 2.8 and 2.9. After these procedures, the effects of the DCI-elicited land use change scenarios can be assessed with the I/O model. Sub-section 2.10 explains how virtual water multipliers in an I/O framework will be used to triangulate the DCI responses.

2.1. Input-Output model

I/O analysis, initially developed by Wassily Leontief (1936) and still widely used today, is a method to analyse interrelations between sectors of an economy. To perform I/O analysis, one needs to construct an I/O matrix (usually provided by national statistical offices) which represents the intersectoral flows of products (usually in monetary terms and for a specific time period – i.e. a year) from each of the sectors (producer) to each of the sectors (purchaser) (Miller and Blair, 2009). These intersectoral flows are relatively stable: e.g. to produce a unit worth of margarine a more or less fixed quantity of oilseeds is needed. The stability of unitary intersectoral flows, which have become known as inter-industry technical coefficients, is a fundamental assumption of the I/O model. In addition to flows between industries there are sales to exogenous purchasers (e.g. household, government and foreign exports – together indicated as final demand). In the production process, a sector also pays for elements that are not purchased from other sectors (e.g. labour, capital and imports – the total of which is referred to as value added). Once an I/O matrix is constructed, I/O modelling entails the analysis of changes in final demand, inter-industry coefficients or value added through a system of linear equations. For a fuller introduction to I/O analysis, the reader is referred to Miller and Blair (2009). Subsequent developments to IO analysis have included social and environmental extensions and applications (Leontief and Ford, 1970). Guan and Hubacek (2008) review the application of input-output models to water resources, and present a body of research that has developed since the 1980s.

The general structure of an input-output model is given by:

$$X = (I-A)^{-1} f \qquad (1)$$

Where:
X = n x 1 vector of gross outputs
I = n x n identity matrix
A = n x n matrix of inter-industry technical coefficients
f = n x 1 vector of aggregate final demand

Matrix A consists of elements a_{ij} (the technical coefficients) which characterise the percentage of sector j's inputs that are provided by sector i. In the above model, $(I\text{-}A)^{-1}$ is commonly known as the Leontief inverse matrix. The sum of each column in the Leontief inverse matrix represents the output multiplier for that sector. Leontief multipliers consider the combined effects of direct sector output and any indirect effects generated by increased demands for inputs from all sectors of an economy which are required to meet an increase of one unit in final demand for that sector. Leontief multipliers are thus demand-driven and quantify the backward linkages of a sector.

It is also possible to quantify forward linkages using a supply-driven specification of the economy:

$$X = (I\text{-}B)^{-1} pi \qquad (2)$$

Where:
B = n x n matrix of inter-industry distribution coefficients
pi = n x 1 vector of primary inputs

The matrix $(I\text{-}B)^{-1}$ is the so-called Ghosh inverse matrix. Matrix B is made up of distribution coefficients b_{ij} representing the percentage of sector i's gross output that is sold to sector j. Matrices A and B and their inverses can be calculated from an I/O table of intersectoral transactions. The remainder of the methodology will focus on the Leontief I/O model variant. The relation between matrices A and B and Leontief (L) and Ghosh (G) inverses is straightforward (Dietzenbacher, 2002):

$$A = \hat{X}\ B\ \hat{X}^{-1} \quad \text{and} \quad L = \hat{X}\ \mathrm{G}\ \hat{X}^{-1} \qquad (3)$$

Where the hat symbol (^) denotes that the vector X is diagonalized.

A symmetrical set of I/O tables is available for Spain for 2005. It is produced by the National Statistics Institute (INE, 2009). The set of tables contain 73 x 73 sectors and report on total production, domestic production and import data respectively. Also calculated are technical coefficients and inverse matrix coefficients, both based on domestic and total inputs respectively.

I/O tables have been constructed for many Spanish autonomous regions, but not for Murcia. Therefore we needed to construct a regional I/O table based on the national one. A well-known problem in constructing regional I/O tables is that inter-industry technical coefficients are prone to be exaggerated as the propensity of sectors to import is inversely related to the size of the economy considered (Boomsma and Oosterhaven, 1992; Harris and Liu, 1998; Flegg and Tohmo, in press). We applied the method described by Flegg and Tohmo (in press), building on earlier work by the same author(s), which takes this issue into account. We subsequently tested the method by comparing the output multipliers from non-survey I/O tables based on various location quotient approaches with those from survey-based I/O tables which are available for the neighbouring autonomous regions Valencia and Andalucía.

The following sections briefly explain the steps followed in constructing the regional I/O table.

2.2. Aggregating the 73-sector national level I/O table into 26 sectors

The regional statistics office has data for 2005 on the Gross Domestic Product (GDP) of the regional economy subdivided in 26 sectors: 2 primary sectors (agriculture and fisheries), 15 secondary sectors (comprising 14 industrial sectors and construction), and 10 tertiary service sectors (CREM, 2011). By relating the national I/O table to the CNAE93 system of accounts (INE, 2009) it was possible to produce a national I/O table considering the same 26 sectors as used for the regional economic accounts.

2.3. Constructing regional I/O table based on location quotients

The method described by Flegg and Tohmo (in press) requires the subsequent estimation of the local inter-industry technical coefficients using several location quotient approaches: SLQ, CILQ, FLQ and AFLQ.

SLQ (Simple Location Quotient) is defined as (Miller and Blair, 2009):

$$SLQ_i = \left[\frac{V_i^R / V^R}{V_i^N / V^N} \right] \qquad (4)$$

Where V_i^R and V^R represent employment in sector i in region R and total employment in region R respectively, while V_i^N and V^N are employment in sector i in the whole country and total employment in the whole country.

If the SLQ_i is greater than or equal to one ($SLQ_i \geq 1$), it implies that sector i is at least as concentrated in region R as in the nation as a whole. In this case, the SLQ_i is not used to update the national coefficient. Hence, for row i of the regional table (Miller and Blair, 1985):

$$a_{ij}^R = \begin{cases} a_{ij}^N \, (SLQ_i^R) & \text{if } SLQ_i^R < 1 \\ a_{ij}^N & \text{if } SLQ_i^R \geq 1 \end{cases} \qquad (5)$$

CILQ (Cross-Industry Location Quotient) is a variant of the SLQ which takes into account the relative sizes of sectors *i* and *j* (Miller and Blair, 1985):

$$CILQ_{ij} = \frac{SLQ_i}{SLQ_j} = \frac{V_i^R / V_i^N}{V_j^R / V_j^N} \qquad (6)$$

In analogy to the SLQ, CILQ is only used when smaller than one:

$$a_{ij}^R = \begin{cases} a_{ij}^N \, (CILQ_{ij}^R) & \text{if } CILQ_{ij}^R < 1 \\ a_{ij}^N & \text{if } CILQ_{ij}^R \geq 1 \end{cases} \qquad (7)$$

The FLQ ('Flegg LQ') proposed by Flegg et al. (1995) and refined by Flegg and Webber (1997) uses the *SLQ* and *CILQ* calculated as follows:

$$FLQ_{ij} = CILQ_{ij} \cdot \lambda^* \quad \text{for } i \neq j \qquad (8a)$$

$$FLQ_{ij} = SLQ_i \cdot \lambda^* \quad \text{for } i = j \qquad (8b)$$

Where:

$$\lambda^* = \left[\log_2\left(1 + V_{tot}^R / V_{tot}^N\right)\right]^\delta \text{, with } 0 \leq \delta < 1 \qquad (9)$$

This method combines the CILQ and SLQ approaches and adds a scaling factor λ^* to take into account the relative size of regional purchasing and supplying sectors and the relative size of the region compared to the national level when determining the adjustment for interregional trade. The parameter δ is an unknown influencing the degree of convexity of the scaling factor λ^* (Flegg and Webber, 1997). CILQ is used everywhere in the matrix but on the diagonal (where the CILQ scaling factor equals to 1); here the SLQ is used instead as a more realistic approximation.

Another modification can be made; this is the augmented FLQ (AFLQ) described in Flegg and Webber (2000), and evaluated in Flegg and Tohmo (in press). This method adds a specialization term to Equation (8a), allowing regional input coefficients to surpass the corresponding national coefficients in case of regional specialization:

$$AFLQ_{ij} = CILQ_{ij} \cdot \lambda^* \cdot \left[\log_2\left(1 + SLQ_j\right)\right] \qquad \text{for} \begin{cases} i \neq j \\ SLQ_j > 1 \end{cases} \qquad (10)$$

The national level inter-industry coefficients are multiplied by the quotients obtained by employing the various approaches (SLQ, CILQ, FLQ, AFLQ) as discussed above to arrive at regional coefficients.

2.4. Selecting the most appropriate location coefficient-based I/O approach

Different theoretical considerations and empirical evidence exist to evaluate available approaches (Flegg and Tohmo, in press). Given the sometimes conflicting conclusions, and the fact that we cannot validate the approaches in absence of a survey-based I/O table for Murcia, we opted to apply the same methods described above to neighbouring Spanish autonomous regions Andalucía and Valencia for which I/O tables do exist: IEA (2010) and IVE (2008), respectively. We evaluated the approaches based on their relative success in estimating regional output multipliers using the following two methods:

$$\mu_1 = (100/n) \cdot \sum_j \left(\hat{m}_j - m_j\right) / m_j \qquad (11)$$

$$\mu_2 = (100/n) \cdot \sum_j \left|\hat{m}_j - m_j\right| / m_j \qquad (12)$$

Where $\hat{m}_j$ is the estimated output multiplier for sector *j* using the various location quotients, m_j is the survey-based multiplier (as provided by IEA, 2010 and IVE, 2008), and *n* is the number of sectors in the symmetrical regional I/O table (n = 63 for Andalucía and 67 for Valencia).

The measure μ_1 can identify whether a multiplier is systematically under- or overestimated but may average out (large) positive and negative errors. The measure μ_2 accounts for all (positive and negative) deviations but cannot identify the direction of a possible bias. Note that we are interested in the best approximation of *each* multiplier, not a comparison of average estimated and survey-based multipliers for which a paired *t*-test would be appropriate.

2.5. Disaggregating the agricultural sector of the regional I/O table

We are interested in the effects of agricultural land use changes and therefore need to subdivide the single agricultural sector into a series of agricultural subsectors. These are defined based on importance of land use, extent of recent changes and differences in water use and economic dissimilarity: 1) grains and other annual field crops; 2) horticulture and fruit trees; 3) grapes; 4) olives and almonds; and 5) livestock. Various regional agricultural statistics were used to achieve this in the following steps:

- First, the technical coefficients for sectors *i* supplying inputs to the agricultural sector were multiplied with the total value of agricultural output.
- Second, total output from the newly defined 5 agricultural sectors was calculated from the aggregation of different individual agricultural enterprises and groups of enterprises.
- Third, a list of quantities of the most important intermediate consumption categories was available (CREM, 2011). Items such as feed (36.8%), seedlings (2.8%) and veterinary costs (2.4%) could easily be attributed to specific subsectors. In other cases, agricultural statistics and secondary data (CARM, 2005; 2007; Fleskens, 2005) were employed to distribute intermediate consumption items such as fertilizer (8.5%), phytosanitary products (7.4%) and energy/lubricants (6.6%) over relevant subsectors.
- Fourth, for smaller categories of intermediate consumption for which no further data was available, with a known value of total agricultural output (from step 1), the regional I/O table with a single agricultural sector was (with some assumptions, i.e. proportionate allocation) used to balance remaining expenditure on intermediate consumption in the five subsectors.
- Fifth, using subsector total output, the quantities of inputs were converted into technical coefficients.
- Finally, constructing input to non-agricultural sectors from the 5 agricultural subsectors was relatively straightforward as the sum of subsector technical coefficients was required to remain equal to that of the non-disaggregated agricultural sector technical coefficient for each column. The distribution over subsectors for key-sectors with high volumes of agricultural inputs (i.e. agro-food, textile and leather, lumber and cork, and paper industries, and hotels) was informed by a comparison with data for the neighbouring Valencia autonomous region. The sub-matrix of distribution coefficients was used to balance the inter-industry input coefficients.

2.6. Estimating regional final demand and sector output

Most required final demand data for Murcia were obtained from CREM (2011). National sector final demand scaled down using employment data was used to fill regional data gaps. For example, regional household final consumption was found to correlate very well (r^2 = 0.996; μ_1 = 0.8%; μ_2 = 3.8%) with national data for an aggregated number of consumption goods and services. Therefore, disaggregated household final demand could be obtained from the scaled down national data. One exception is the sector hotels and restaurants where the significantly lower regional household expenditure data was inserted. Similarly, capital formation for industries was derived from the scaled national data, and the entire expenditure structure of national public administration was used in deriving individual sector totals from the regional aggregate total. Importantly, good regional data on exports were available. As expected, the regional and national level data bear little relation, both in overall size (regional exports were 20 times larger than the scaled national data) and structure (r^2=0.07). After deciding on the location quotient method to employ, the regional total final demand vector (f) was entered in Equation (1) to estimate total regional output. Incomplete sector output data was available from CREM (2011), but appeared to be inconsistent in its definition of sectors and in relation to final demand. Agricultural sector output data was an exception, and these were used in further analyses (Equations 13-19) together with simulated output for industrial and service sectors.

2.7. Creating water I/O table

Some regional water statistics were available as a basis to calculate sectoral water use (CREM, 2011). Water statistics for agriculture were available for 2005, breakdown of industrial water use was only available for 1999, and specified water use of the service sector could not be found at all. To circumvent these incomplete data, data for 2007 from the piped water distribution network used in economic sectors yielded some piecemeal information, and the available statistics were used together with equivalent data from Andalucía (Consejería de Medio Ambiente, 1996) and Spain (INE, 2010) to calculate Direct Water Consumption (DWC) and to harmonise sectoral water consumption (Table 1).

$$DWC = w_j / x_j \qquad (13)$$

Where w_j is the quantity of water directly used in sector *j* and x_j the total output of sector *j*.

Agricultural water productivity in Murcia is high in comparison with Andalucía and Spain. In the case of Murcia, grains and olives and almonds are hardly irrigated. The bulk of water is used in producing high value fruit and vegetable crops. The high DWC in Andalucía may stem from significant water use in low value crops (grains) and relatively wasteful irrigation techniques: 45% of irrigation is by gravity (Dietzenbacher and Velázquez, 2007). In contrast, in Murcia 85% of water is supplied to crops by drip irrigation (CREM, 2011). The exception to relative water use efficiency is the livestock sector which is intensive in Murcia and presumably less so in Andalucía (also note that the latter figures are considerably older).

Data for industrial sectors for 1999 was updated by estimation of the 2005 level output using the input-output model. Total sectoral water use was subsequently updated where sector growth (positive or negative) had been such that DWC calculated with the 1999 water use would become questionable in comparison to national data. The largest water consumers are the agro-food and chemical industries, although DWC is equally high in rubber and plastics and metallurgy. At the national level, DWC's for industrial sectors are generally lower, although electricity, gas and water stands out as a relatively heavy water user. The very high DWC's of the paper (including publishing and printing), chemical, and other manufacturing industries reported for Andalucía were not found in Murcia.

Water use of the service sectors was redistributed according to the relative importance of water consumption of these sectors in Andalucía, while respecting the total service sector consumption for Murcia. Like with industrial sectors, the DWC's thus obtained are lower than those in Andalucía. Water consumption is largest in the hotel and restaurants and real estate sectors, with the former having the largest DWC amongst the service sectors.

A matrix Q is defined with water inter-industry input coefficients q_{ij} calculated as:

$$q_{ij} = \frac{w_i / x_i}{w_j / x_j} \cdot a_{ij} \qquad \text{(if } w_j > 0\text{)} \qquad (14)$$

In analogy to Equation (1), the column totals of the inverse matrix $(I\text{-}Q)^{-1}$ give the backward linkages water multipliers. Forward linking water distribution coefficients l_{ij} are calculated as:

$$l_{ij} = \frac{w_j / x_j}{w_i / x_i} \cdot b_{ij} \qquad \text{(if } w_i > 0\text{)} \qquad (15)$$

The elements l_{ij} constitute matrix L; the row sums of the inverse matrix $(I\text{-}L)^{-1}$ give the forward linkages water multipliers. Backward linkages water multipliers represent how much water is used indirectly in a given sector by considering the water consumption for its intermediate consumption in relation to direct water use. Forward linkages water multipliers represent the ratio of additional water use in purchasing sectors relative to the direct water consumption 'embedded' in output from the supplying sector considered.

<<Table 1 about here>>

2.8. Water scarcity scenarios and farmers' land use responses in Torrealvilla catchment

Interviews were administered with farmers within the Torrealvilla catchment (266 km^2) of the Guadalentin Basin in Murcia. In total 110 interviews were carried out but in the end 11 responses were discarded as they were incomplete. Sampling was done using the snowball method, making sure all land uses were covered and an endeavour was made to represent the heterogeneity of farmers in the area (Table 2). In terms of land use, in the sample livestock, vegetables and fruits, and grapes are overrepresented relative to Torrealvilla and the Murcia region as a whole. Small farms (< 2 ha) are heavily underrepresented, and medium farms (5-20ha) and fairly large farms (30-50 ha) overrepresented. Any bias in the sample is thus towards viable farms which could serve the purpose of this research well given that the number of farms in Murcia reduced by 29% between 1995 and 2005 (CREM, 2011). The final number of respondents was 7 for grains, 24 for almonds and olives, 32 for grapes, 24 for horticulture and fruits and 12 for livestock. If we take agricultural census data of the Murcia region as a basis for estimation, the total number of farmers in the Torrealvilla catchment (which is unknown) could be 810. As extensive land uses are over- and intensive land uses underrepresented in the catchment relative to the region the average farm size is likely larger and the number of farmers smaller. The average farm size of our sample is 25 ha, against 17 ha across the Murcia region. Using this figure, the total number of farms in Torrealvilla would be lower, around 560. Our sample of 99 farmers interviewed thus represents at least 12% and perhaps 18% of the total population.

In part, the interviews were intended to capture farmers' responses to hypothetical scenarios that reflect future uncertainty of water availability. The scenarios were developed based on insights gained through discussions with farmers in the area during preliminary site visits. On the one hand, concern over groundwater depletion overshadows the future of the irrigated farming community. On the other hand, there have been a lot of discussions about farmers in the region desperate for more water to be transferred from the North. As such, different scenarios were presented to farmers who currently have access to water and those who do not. The former group of farmers was asked how the following will affect the future of their current principal land use:

- Scenario A – No access to water for agricultural use (total water depletion – this could occur as a physical lack of water locally, or as water quality deteriorates beyond maximum tolerable salinity levels);
- Scenario B – Government imposes tax on groundwater abstraction resulting in a water price higher than maximum willingness to pay for water (WTP – lowest €0.20 m^{-3}; highest €0.60 m^{-3}; average €0.31 m^{-3}; standard deviation €0.08 m^{-3}) by individual farmers; and
- Scenario C – Government imposes tax on groundwater abstraction resulting in a water price of up to the individual farmer's maximum WTP.

The tax on water in scenarios B and C was presented as implying a higher price of water, a situation that could also be brought about without government intervention as farmers may need to pay more to obtain water in sufficient quantity and of sufficient quality. In the context of this paper the maximum WTP refers to a threshold beyond which the maintenance of present farming activity is perceived by individual farmers as no longer viable, making drastic change such as agricultural abandonment is highly likely. Individual WTP was used as cut-off point to avoid presenting multiple (fixed) price scenarios to each farmer and is justified by the fact that our purpose was not to elicit farmer WTP, but to explore potential land use change along a gradient of physical water scarcity (Scenario A), economic water scarcity (Scenario B) and economic water insecurity (Scenario C). Farmers' responses were: 1) no change; 2) conversion to other agricultural land uses; and 3) stop farming/abandonment. At this point it is important to note that respondents have an incentive to understate their WTP for water and/or to overstate land use changes (Carson and Groves, 2007; Schläpfer, 2008). As stated above, eliciting the WTP itself is not an objective of this paper, and is not critical in the analysis. The fact that we ask farmers to state their hypothetical land use change decisions relative to self-declared WTP minimizes the risk of exaggeration (Schläpfer, 2008). Although the incentive to exaggerate may be more pronounced for water price than for land use change effects of scenarios, we cannot rule out that (some) responses are exaggerated; therefore the results presented should be regarded as potentially extreme land use change effects.

In contrast, farmers who currently do not have access to water were asked how their principal agricultural land use may alter if water became available, e.g. through IBWT. This led to a fourth scenario (D):

- Scenario D1 – Water becomes available to previously non-irrigable areas.

At this stage, we found that grain farmers demonstrated little dynamism as compared to olive and almond farmers. This is counter-intuitive, as conversion costs are considerably lower for the former group. As grain farmers may have been underrepresented in the sample, we therefore also defined an adjusted hypothetical scenario:

- Scenario D2 – as Scenario D1, but for the grain farmers we adopted weights of conversion to irrigated farming as elicited from olive and almond farmers (resulting in increasing propensity of grain farmers to change).

The responses registered in Scenarios D1 and D2 were: 1) no change; 2) increase production (expansion); and 3) conversion to irrigated agriculture. Note that for the purposes of expansion we assumed scrubland and fallow to be available, but not forest and other land uses. The effective area within the Torrealvilla catchment is thus reduced to the 140 km^2 of UAA. Further details about the study area and the interviews can be found in Nainggolan et al. (in this issue).

<<<Table 2 about here>>>

2.9. Upscaling local scenario responses to the Murcia region

As all interviews were conducted within the Torrealvilla catchment area, we must take into account the relative shares of each land use when upscaling to the Region of Murcia. We thereby assume that there are no differences in the agricultural production structure of subsectors between the local and regional area.

A matrix of land use changes from land use *i* to land use *j*, is constructed with elements ΔS_{ji} defined as:

$$\Delta S_{ji} = P_{ji} \cdot S_i^{INIT} \quad (16)$$

Where P_{ji} is the expected probability of a change of current land use *i* to future land use *j* and S_i^{INIT} is the initial area under that land use.

The new area under land use *j* is subsequently obtained by summing over columns:

$$S_j^{NEW} = \sum_j \Delta S_{ji} \quad (17)$$

A vector of agricultural subsector output change as a consequence of stated land use change can then be obtained by multiplying the difference in area with the output per area unit x_i^*:

$$\Delta x_i = \left(S_i^{NEW} - S_i^{INIT}\right) \cdot x_i^* \quad (18)$$

Regional effects of the DCI-elicited responses to water uncertainty scenarios can now be assessed with the I/O tables. We use equations (1) and (2) with vector *X* given by elements Δx_i . Total regional effects are defined as the sum of direct effects (i.e. *X*) and the combined backward and forward indirect effects (Grêt-Regamey and Kytzia, 2007):

$$(f - X) + (di - X) \quad (19)$$

An analogous procedure (Equations 18-19) is followed to assess the direct and indirect effects of the changed total sector water demands Δw_i .

2.10. Effect of increased water cost on sector unitary output prices

With the preceding steps, we can now simulate the impact of increased water costs on sector unitary output prices. We will assume that increased costs for water only apply to agricultural water use, assuming that other sectors already pay more for water (e.g. twice as much in neighbouring Almería province – Downward and Taylor, 2008).

$$VWM' = DWC_p' \, (I\text{-}A)^{-1} \quad (20)$$

Where the vector VWM is the Virtual Water Multiplier (the accent (’) indicates transposition) found by multiplying the vector DWC_p – consisting of DWC for sectors where the water price will be raised (i.e. agricultural subsectors) and 0 for other sectors – with the Leontief inverse matrix. The VWM can subsequently be used to calculate a price increase by simple multiplication (the VWM can directly be interpreted as representing a price increase of €1). We will present the effects of a price increase of €0.10 m^{-3} – equal to the average incremental WTP (€0.04 m^{-3}) plus one standard deviation (€0.06 m^{-3}) to account for possible understatement (the range of incremental WTP was €0.00–0.25 m^{-3}). The cumulative effects of the water price increase, through water input-output relations, on product prices can help to understand farmer responses to the discrete choice scenarios.

3. Results

3.1. Regional I/O Table for Murcia

The regional I/O table constructed for Murcia was evaluated by applying the same method to neighbouring autonomous regions for which survey-based I/O tables were available: Andalucía and Valencia. Table 3 shows the results of different methods. The average regional multiplier is overstated by the SLQ and CILQ methods (in line with findings by others – Boomsma and Oosterhaven, 1992; Flegg and Tohmo, in press), but more so for Valencia than for Andalucía. In contrast, FLQ and AFLQ methods lead to a general understatement except at low values of δ. The absolute average deviations from the regional multiplier show an error of 13.2-16.5% for SLQ and CILQ. FLQ and AFLQ methods with appropriate scaling factor δ can moderately reduce this error to about 12%. Contrary to findings by Flegg and Tohmo (in press), the AFLQ outperforms the FLQ in these two cases, although overall error reductions are not as large as these authors suggest. When zooming in on the accuracy of predicting the regional output multiplier for the agricultural sector, the overstatement errors of the conventional SLQ and CILQ approaches are larger than for the total regional economy. Both the FLQ and AFLQ can greatly reduce errors in estimating the agricultural output multiplier, to about 1%. Higher values of the scaling factor δ attain largest error reductions, whereby AFLQ is more prone to exaggerating the multiplier than FLQ. Taking into account: a) the need to have a low average absolute deviation of the average regional multiplier; b) a preference for a slight underestimation of the average regional multiplier; c) the trend observed in literature that smaller regions (such as Murcia) have a higher propensity to have a lower optimal value for δ; and d) that such a trend would place an optimal δ for Murcia’s agricultural sector in the FLQ approach below 0.15; as well as e) that the average absolute percent error for the six data rows in Table 3 is lowest for FLQ with δ = 0.10 (see overall rank), we applied FLQ with δ = 0.10 to develop a non-survey based regional input-output table for Murcia.

<<<Table 3 about here>>>

3.2 The regional I/O Table with disaggregated agricultural sector

Table 4 shows details about the disaggregation of agriculture in five subsectors at the regional scale. All subsectors except livestock occupy sizeable shares of the region's agricultural area (11-36%). However, in terms of output value, grains (2%), grapes (5%) and olives and almonds (5%) contribute only modestly compared with livestock (22%) and especially vegetables and fruits (66%). As a result, productivity per area unit ranges widely. Production structures of the subsectors are therefore also expected to vary considerably. The backward output multipliers of individual subsectors of the disaggregated I/O table varied between 1.22 for vegetables and fruits and 1.86 for livestock (Table 5). The first reflects that relatively little economic activity is generated by producing an Euro worth of horticultural produce, whereas the opposite holds for livestock. The disaggregated I/O table was also tested for its similarity with the aggregated version: when scaling the five subsectors, its combined agricultural sector backward output multiplier is in both cases 1.38. Similarly, the forward output multiplier of the current (2005) sector configuration is 1.60. Individual agricultural sectors have forward multipliers of 2.11-2.28, which demonstrates that much of their produce is sold to upstream industries. The vegetables and fruits subsector (1.31) is an exception, as produce is not processed in agro-industries but marketed to consumers and – importantly – exported. For all agricultural subsectors, forward linkages are higher than backward linkages. Agro-food industries and construction are sectors with high backward linkages, whereas construction materials and lumber industries have high forward linkages.

<<<Table 4 about here>>>
<<<Table 5 about here>>>

3.3. Regional I/O Table of water use

Agriculture consumes about 80% of total ('blue') water use in Murcia: households consume about 15%; and other economic sectors together account for only 5%. Not surprisingly, technical coefficients of water use are a fraction of the technical coefficients based on the monetary value of intermediate consumption (cf. Equation 14). The water multipliers (both backward and forward) of the agricultural subsectors are thus low in comparison to output multipliers (Table 5). Livestock is the subsector with the highest backward water multiplier (1.65): its intermediate consumption relies on water-intensive inputs. Grains have the highest forward multiplier (1.28): the sectors grains are supplied to use a considerable amount of water, whereas water needs for grains are relatively low. Similarly, vegetables and fruits have the lowest non-zero forward water multiplier (1.03). Very little additional water is used to produce output in processing sectors (which moreover absorb only a limited part of total vegetables and fruits output).

The modest water multipliers for agricultural subsectors contrast with some of the water multipliers in industries and services. Backward multipliers are very high for lumber and cork industries (33.71), agro-food industries (13.60), and paper, printing and publishing (10.74). These sectors thus require water-intensive inputs totalling several times their direct water demand. Machineries and mechanical equipment (23.06) and financial brokerage (18.46) have very high forward water multipliers: their output is produced with relatively low amounts of water, but the output of purchasing sectors requires a multiple factor total water input.

3.4. Discrete choices and land use change scenarios in Torrealvilla

When farmers with current access to water were asked what their strategy would be if water resources would be completely depleted, the vast majority would give up farming (Figure 2, Scenario A). A sizeable minority (43%) of olive and almond farmers would not change land use, a strategy also followed by 3% of vineyard managers (these crops can be grown without irrigation, obviously with reduced productivity; for vineyards a change from table to wine grapes may be involved, as well as introduction of supplementary drip irrigation). Remaining farmers would resort to rainfed cropping. A similar pattern emerged when the same group of farmers was confronted with high (perceived) water taxation (Scenario B); again the most common response was abandonment. Continuation of the current land use was the preferred strategy of 36% of olive and almond farmers, 17% of livestock farmers, 12% of vineyard managers and only 2% of horticulturalists and fruit growers. Some vineyards and fruit orchards would convert to olive and almond groves and grains, respectively. Under low (perceived) water taxation (Scenario C) the majority (67% and 64%) of livestock and olive and almond farmers would continue current land use. However, 54% of vineyard managers and 52% of horticulturalists and fruit growers stated that they would abandon their enterprises. In both cases, 40% would continue. Some 17% of livestock farmers and 8% of horticulturalists and fruit growers would opt for a change to grains, and 5% of vineyard managers would switch to olives and almonds. These three discrete choice scenarios show that water availability and affordability is a crucial factor for all with current access to water. Horticulture and fruit growing, vineyards and livestock farming are the least likely to flourish under physical or economic water scarcity.

Figure 2 also shows scenarios presented to farmers who currently do not have access to water. If a new IBWT project would be realized, some unused land would start to be cultivated to grains (8%) and olives and almonds (5%). Olive and almond groves would see considerable conversion to horticulture and fruit growing (24%) and vineyards (21%). Moreover, 14% of grain fields would be developed to vineyards. Overall, olive and almond farmers demonstrated the most dynamic choices. If the changes expressed above were to occur, land use in the Torrealvilla catchment would change as shown in Table 6.

<<<Figure 2 about here>>>

<<<Table 6 about here>>>

3.5. Regional effects of land use change scenarios

When we simulate the effects of the discrete choice scenarios in the input-output model, the land use change scenarios driven by uncertainty in water supply result in diverging effects on regional economy and water demand (Figure 3). The total water depletion scenario almost eradicates the agricultural sector, and when taking into account forward and backward linkages leads to a shrinking of the regional economy of 14%. As all irrigated agriculture disappears in this scenario, this scenario reduces the demand for water to about 18% of the current level. A high water tax has just slightly lower impact. A low water tax impacts the regional economic output by 7% while reducing water demand to almost half the current level. A new water transfer may lead to 4-5% economic growth while requiring 23-30% more water compared to current regional demand. The ratio of economic impact to water demand reveals interesting results. When left to abandonment because of a total depletion of water, with the loss of each cubic metre of water output decreases by €5.57. When introducing a high water tax this ratio is reduced to €5.36 per m^3, whereas a low water tax results in a loss of €4.85 per m^3. Increased water availability similarly augments regional economic output by €5.63-5.86 per m^3.

<<<Figure 3 about here>>>

3.6 Water price effects

Table 7 shows the effects of 'acceptable' agricultural water price increase on the product price of each sector. Although the horticulture and fruits subsector uses more water, it produces more output per unit of water and hence the effects of water price increases are not as pronounced as for grapes and olives and almonds. The 'acceptable' water price increase represents almost 50% of the currently paid average price and leads to agricultural product price increases between 0.6 and 5.6%, with three out of five subsectors being affected by over 3%. Agro-food (0.4%) and lumber and cork (0.1%) industries are the two non-agriculture sectors where a price effect is notable.

<<<Table 7 about here>>>

4. Discussion

The I/O table for Murcia needed to be constructed first in order to enable subsequent scenario analyses. We evaluated several location quotient methods: SLQ, CILQ, FLQ and AFLQ. Our results concur with other studies that find conventional SLQ and CILQ methods to overestimate multipliers. Because the agricultural sector in Murcia and – to lesser extent – neighbouring regions is so dependent on exports, extra prudence proved to be required, and the appropriate scaling method (value of parameter δ = 0.10) for FLQ was well below the usual range (0.25 ± 0.05) reported by Flegg and Tohmo (in press), supporting their remark that individual cases need special scrutiny. Without availability of survey-based I/O tables for neighbouring regions, we would probably have run a high risk of substantially overstating impacts of scenarios. The methods described for disaggregating the agricultural sector and constructing the water I/O table can, given similar data availability, more confidently be applied in other contexts.

The ratio of economic impact to water demand (Figure 3) can be interpreted as follows: when confronted with high barriers to water use (total depletion, high water tax), farmers tend to give up farming. In these cases the economic consequences are high in relation to changes in regional water demand. However, the introduction of a low water tax prompts a significant number of farmers to change land use instead of abandonment. As a consequence, reductions in water use are obtained, resulting in about 10% lower impact on the regional economy per unit of water saved than under a higher water tax scenario. Potential water savings are impressive: a low water tax can reduce total water demand by almost 50% (note this is only considering responses by agricultural agents) at a 7% cost to the regional economy. Tax revenues could be used to stimulate further water savings, or to develop economic activities with a low water use. Important gains can be achieved in setting the water tax level right: our study suggests that significant water savings can be achieved at relatively low expense to the regional economy by incentivising self-organizing capacity of the agricultural sector – i.e. through land use changes as described above. Stronger intervention (through higher taxation) fails to take advantage of this self-organizing capacity and although it may generate higher tax revenues, much of it will be necessary to recover from the inefficiency it created in the first place.

There may however be limits to the capacity of the system to self-organize and adapt to groundwater scarcity if this scenario is combined with future climate change. Increased temperatures would increase evaporation and evapotranspiration rates and hence further increase water demand. If climate change leads to reduced rainfall inputs, this would not only reduce groundwater recharge rates, perhaps hastening groundwater scarcity, but also limit the viability of switching from irrigated to rainfed agriculture.

Given the questionable sustainability of groundwater extraction rates, it is of particular concern that agriculture in Murcia has become so heavily dependent on this finite and dwindling resource. Our results show that without groundwater and IBWT, about two-thirds of the region's agricultural area would be abandoned. Agricultural output would be decimated to less than 5% of its current value. Even the introduction of a low water tax would still lead to about 35% of the agricultural area being abandoned, with an associated loss of more than half of the current output. Whereas our farmer survey using discrete choice scenarios may have led to exaggerated responses, this clearly illustrates how vulnerable respondents feel to uncertainty in water supply. Our data do not show margins on crops grown, but the intermediate consumption of the five subsectors we distinguished varied between 16% (horticulture and fruits) and 50% (livestock) of output value. When adding labour costs and imports, margins may be narrow. Any water taxation (or scarcity, for that sake) can under these circumstances lead to heated debate. Surprisingly, results of increased water prices (Table 7) have the highest impact on grapes and almonds and olives. This contrasts with the land use decisions elicited from DCI interviews, where horticulture and fruits are the first to be abandoned or switched. Although our results are not conclusive, this could indicate that the latter crops are perceived by farmers as more sensitive to water shortages.

Additional water supply through IBWT may lead to a 10% expansion of the agricultural area, with an associated increase in agricultural output of 26-35%. Given the high export orientation and strong regional agro-food industry it is not unreasonable to assume this additional produce could be effectively handled (cf. Sánchez-Chóliz and Duarte, 2000). The ratio of economic impact to increased water demand of such an expansion is high (€5.63-5.86 per m^3), suggesting that additional water will be used efficiently and an accelerated growth may result. The economic multiplier is, at 1.75, higher than currently obtained, reflecting the combined effect of water and extra land as production factors. Although this sounds promising, it further increases water-dependency of the regional economy. It should be noted though that the assumption of stable technical coefficients inherent to input-output models might be too optimistic here as the best land is probably already irrigated and land onto which irrigation can be expanded may not be as productive as the currently irrigable area. Strikingly, the farmers' discrete choices may reflect this fact, with only a minority of grain farmers and slightly over half of olive and almond farmers envisioning land use changes to horticulture and fruits or vineyards.

We can also take a closer look at the currently operational Tagus–Segura IBWT scheme (Figure 4). In 1994/5 and 2005-7, the amount of water transferred was greatly reduced as a consequence of the distribution rules in place to cap transfer if the conceding basin experiences water shortage. In the latter period, the contribution of the IBWT to total irrigation dropped to 8% from 54% in 2002/3. This massive reduction is partly compensated for by increased pumping of groundwater resources, which are already heavily overexploited. The drop in total irrigation may point at a number of potential issues: a) pumping capacity installed is too low to fully compensate for significant reductions in IBWT water; b) not all areas benefiting from the IBWT can switch to groundwater resources if required; or c) the economic cost of pumping exceeds (€0.12 – €0.54 m^{-3}) by far the price (€0.09 m^{-3}) paid for IBWT water (Tobarra González, 2002). Although a mix of these issues may have occurred, and farmers may also have adapted in anticipation of lower water availability, the clear peak of local irrigation (levelling off since 2008) clearly suggests that a sizable number of farmers have been willing to pay an additional €0.03 to €0.36 per m^3 water. This is in good agreement with our field data. Alternative mobilisation of additional water resources is more expensive: the most cost-effective desalinisation plants may produce water at a cost of €0.45 m^{-3}, and the Ebro–Segura IBWT would charge an average of €0.31 m^{-3} along the pipeline, rising to an expected €0.75 m^{-3} in Almeria (Downward and Taylor, 2008). Desalinisation could be partly subsidised by the government as it can relieve social and environmental problems associated with the current IBWT and groundwater overexploitation. However, average energy demands of desalinisation are more than a factor of 3 higher than for the Tagus-Segura IBWT and lead to an increased environmental cost of CO_2 emissions of €0.07 per m^3 of desalted water (Melgarejo and Montano, 2011), as well as increased coupling of water to volatile energy prices.

<<<Figure 4 about here>>>

As most of the additional output resulting from IBWT will leave the region with exports as virtual water, it is from an environmental perspective a questionable development pathway. Currently, the economy of Murcia produces €39.26 per m^3 of water used – over 8 times as efficient as would be achieved with new IBWT development. As a consequence, the regional economic output per cubic metre of water would drop below €30. Compare that with the over €90 per m^3 that results from the low water tax and it is clear that better alternatives are available. Admittedly, the first option leads to regional economic growth of 4.4% while the latter to a contraction of 6%, but intermediate solutions should be available that warrant growth while improving water use efficiency.

5. Conclusion

Agriculture in the Region of Murcia has increasingly become dependent on blue water resources. Current water availability for irrigation is threatened by continuous overexploitation of groundwater resources, increased competition from non-agricultural (and in some cases illegal) uses, and conflicts over inter-basin water transfer – all in the context of global environmental change. The regional government has a tremendous challenge to reduce overexploitation of water resources and reduce vulnerability of the regional economy to water scarcity. At the same time, the region's farmers feel trapped in water-dependent productivity and fear any reform that negatively affects their resource base. We evaluated the effects of farmers' responses to discrete choice scenarios on the regional economy and water demand by means of input-output modelling. Our results confirm that agriculture is heavily dependent on blue water resources, and farmers see no option to continue farming if confronted with complete water depletion (physical water scarcity) or high levels of water taxation (economic water scarcity). These scenarios would lead to very large reductions in water use by agriculture, but also result in a contraction of the regional economy by more than 13%. A low water tax scenario indicated that some farmers may change land use as a result. Although still leading to a contraction of the regional economy by 7%, this scenario suggested that the agricultural sector has a self-organizing capacity to deal with some of its water use inefficiency. Any water tax reform should take stock of this capacity and create synergy between incentives for water use efficiency and government intervention. Resolving water scarcity through new IBWT development may lead to regional economic development (4-5%) but only increases the region's dependency on water. By linking survey-based data from individual land users and an input-output model, a regional impact analysis can be performed. In doing so, we were able to show that although water taxation only has relatively minor effects on product prices, it has the potential to lead to dramatic land use changes with considerable economic impact. Likewise, considerable environmental benefits seem within reach as reduced water use in the economy will benefit areas of ecological importance and might replenish some of the depleted groundwater resources, which could be crucial to prepare for future environmental change.

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Table 1. Direct water consumption of sectors.

Sectors	Water consumption calculated with available data			Harmonized water consumption data	
	Murcia*	Andalucía*	Spain*	Murcia	
	DWC (litre $€^{-1}$)			DWC (litre $€^{-1}$)	DWC (10^3 m^3)
Agriculture	274	-	395	274	563,096
Grains	190	1833	-	190	6,979
Horticulture and fruits	345	683	-	345	468,832
Grapes	505	695	-	505	52,440
Olives and almonds	179	655	-	179	17,836
Livestock	37	15	-	37	17,009
Fisheries	0	0	0	0	0
Industry	2.4	-	0.7	2.1	21,770
Extractive industries and combustibles [a]	1.2	-	0.9	0.9	757
Electricity, gas and water [a]	-	1.2	2.1	1.6	1,589
Agro-food industries	3.5	3.3	0.9	3.3	9,242
Textiles and leather industries	0.9	3.3	0.4	0.6	347
Lumber and cork industries	0.1	3.6	0.2	0.3	27
Paper, printing and publishing	0.3	38.3	0.4	0.2	90
Chemical industry	8.1	25.0	1.3	4.5	6,374
Rubber and plastics	3.6	2.0	2.1	4.7	1,038
Construction materials (non-metal) [b]	-	4.7	0.8	1.7	262
Metallurgy	2.4	3.6	0.5	2.6	1,692
Machineries and mechanical equipment [b]	0.2	1.5	0.2	0.1	71
Electronics and optical products [b]	-	0.4	0.2	0.1	26
Manufacturing of transport materials [b]	-	1.5	0.3	0.1	81
Other manufacturing industries	0.3	9.5	0.3	0.6	174
Construction	-	2.4	0.2	0.2	208
Services	1.5	-	0.7	1.5	31,209
Trade (incl. servicing of vehicles)	-	1.7	-	0.4	1,173
Hotels and restaurants [c]	10.4	18.3	-	3.8	8,358
Transportation and communications	-	4.2	-	0.9	2,094
Financial brokerage	-	0.9	-	0.2	214
Real estate and enterprise services	-	5.0	-	1.0	6,703
Education [d]	-	5.0	-	2.0	2,018
Health and social services [d]	-	5.0	-	2.0	3,173
Public administration [d]	2.0	4.7	-	2.0	3,288
Other community and personal services	-	13.3	-	2.8	4,188
Domestic personnel	0	0	-	0	0

* Sources: Murcia – authors' calculations based on available statistics (CARM, 2010); years of estimates vary: 2005 for agriculture, 1999 for industry, and 2007 for services. Andalucía – based on Consejería de Medio Ambiente (1996), using a conversion rate of 1 EUR = 166 ESP. Spain – based on INE (2010).

[a] Combined estimate for extractive industries and electricity, gas and water

[b] Combined estimate for machineries and 'other' industries

[c] If all water for services attributed to hotel sector

[d] Estimate for public administration includes education and health services

Table 2. Characterization of the farm sample in relation to local and regional land use and regional farm size distribution.

	Sample	Torrealvilla	Murcia
UAA (km2)	25	140	5924
Land use (%)			
Livestock	2.7	1.0	1.7
Vegetables & fruits	21.6	10.3	18.9
Grapes	10.1	2.7	3.8
Olives & almonds	18.4	27.2	17.5
Grains	18.5	35.2	10.2
Non-used UAA	28.8	23.4	45.9
Farm size class (%)			
< 1 ha	6.1	na	21.5
1 – 2 ha	8.1	na	18.1
2 – 5 ha	29.3	na	27.2
5 – 10 ha	23.2	na	12.6
10 – 20 ha	17.2	na	9.5
20 – 30 ha	4.0	na	3.6
30 – 50 ha	7.1	na	3.2
50 – 100 ha	3.0	na	2.6
> 100 ha	2.0	na	1.9

Source: calculated from farm survey data (sample), satellite imagery (current land use Torrealvilla) and regional statistics (Murcia).

Table 3. Performance of location quotient methods in predicting regional multipliers from national I/O data.

	Location Quotient method, and value of δ if applicable									
	SLQ	CILQ	FLQ				AFLQ			
			0.20	0.15	0.10	0.05	0.20	0.15	0.10	0.05
Average percent error of the estimated regional multiplier [a]										
Andalucía	2.32	7.09	-11.30	-9.13	-5.34	-1.50	-10.26	-7.33	-3.88	**0.22**
(rank)	(3)	(6)	(10)	(8)	(5)	(2)	(9)	(7)	(4)	(1)
Valencia	7.29	12.06	-10.23	-6.67	-2.33	3.01	-8.01	-4.08	**0.95**	7.06
(rank)	(7)	(10)	(9)	(5)	(2)	(3)	(8)	(4)	(1)	(6)
Average percent error of the sum of absolute deviations from the regional multiplier										
Andalucía	13.18	13.37	13.77	12.59	11.76	11.84	13.23	12.10	**11.67**	12.12
(rank)	(7)	(9)	(10)	(6)	(2)	(3)	(8)	(5)	(1)	(4)
Valencia	15.03	16.45	13.67	12.55	12.26	13.30	12.85	**12.25**	12.91	15.01
(rank)	(9)	(10)	(7)	(3)	(2)	(6)	(4)	(1)	(5)	(8)
Percent error of the output multiplier from the agricultural sector										
Andalucía	14.29	14.79	**-1.00**	1.50	5.07	9.21	1.50	4.57	8.64	13.29
(rank)	(9)	(10)	(1)	(3)	(5)	(7)	(3)	(4)	(6)	(8)
Valencia	18.61	13.87	-3.21	**-0.51**	2.92	7.45	-1.09	2.12	6.42	11.75
(rank)	(10)	(9)	(5)	(1)	(4)	(7)	(2)	(3)	(6)	(8)
Avg abs% error	11.79	12.94	8.87	7.16	**6.61**	7.72	7.82	7.07	7.41	9.91
Overall rank	(9)	(10)	(7)	(3)	(1)	(5)	(6)	(2)	(4)	(8)

Source: authors' calculations based on IVE (2008), INE (2009), and IEA (2010).

[a] Bold numbers indicate best performance.

Table 4. Summary data of agricultural subsectors.

	Output[a] (M€)	Area (10^3 ha)	Productivity (€ ha^{-1})	Water use (Mm^3)	(m^3 ha^{-1})	(m^3 $€^{-1}$)
Livestock	455.5	10.0[b]	45550[b]	17.0[c]	1701	0.04
Vegetables & fruits	1357.1	111.9	12129	468.8	4190	0.35
Grapes	103.9	34.2	3041	52.4	1535	0.50
Olives & almonds	99.7	103.9	960	17.8	172	0.18
Grains	36.7	60.6	606	7.0	115	0.19
Total	2052.9	311.1		563.1		

Source: based on various regional statistics (CREM, 2011) and secondary data.

[a] Agricultural services (2.2%) have been added proportionally over categories and 1.4% output from non-attributable land use (plantations) was divided equally over categories (except livestock).

[b] Livestock farming is intensive (i.e. not land-based, two-thirds of output value is pork) and does not appear in regional land use statistics. A nominal area of 10,000 ha has been assumed for this subsector.

[c] Water use for livestock estimated based on per animal water needs (eco-efficiency data on CREM, 2011).

Table 5. Output and water multipliers for regional economy of Murcia.

Sectors	Output multipliers		Water multipliers	
	Forward	Backward	Forward	Backward
Agriculture (current land use configuration)	1.60	1.38	1.09	1.06
Grains	2.28	1.48	1.28	1.17
Horticulture and fruits	1.31	1.22	1.03	1.02
Grapes	2.18	1.36	1.07	1.10
Olives and almonds	2.27	1.41	1.14	1.11
Livestock	2.11	1.86	1.23	1.65
Fisheries	1.15	1.27	1.00	1.00
Industry				
Extractive industries and combustibles	1.75	1.41	5.81	1.47
Electricity, gas and water	1.79	1.56	4.80	1.43
Agro-food industries	1.31	1.80	1.81	13.60
Textiles and leather industries	1.29	1.30	2.15	3.50
Lumber and cork industries	1.96	1.60	10.40	33.71
Paper, printing and publishing	1.76	1.41	11.50	10.74
Chemical industry	1.50	1.41	2.71	1.26
Rubber and plastics	1.68	1.53	1.89	1.50
Construction materials (non-metal)	1.90	1.60	1.49	1.51
Metallurgy	1.74	1.49	2.51	1.35
Machineries and mechanical equipment	1.45	1.34	23.06	4.89
Electronics and optical products	1.40	1.16	12.43	6.30
Manufacturing of transport materials	1.18	1.25	4.36	5.28
Other manufacturing industries	1.28	1.61	2.22	3.88
Construction	1.44	1.77	3.13	4.60
Services				
Trade (incl. servicing of vehicles)	1.31	1.41	11.49	3.59
Hotels and restaurants	1.08	1.25	1.05	1.74
Transportation and communications	1.65	1.45	3.66	1.65
Financial brokerage	1.58	1.28	18.46	2.31
Real estate and enterprise services	1.51	1.25	2.35	1.36
Education	1.04	1.12	1.12	1.18
Health and social services	1.07	1.29	1.14	1.36
Public administration	1.00	1.26	1.00	1.30
Other community and personal services	1.26	1.37	1.28	1.52
Domestic personnel	1.00	1.00	1.00	1.00

Source: input-output model results; see main text for procedures and assumptions made.

Table 6. Current and future land use (area percentage) in Torrealvilla and Murcia under different scenarios.

	Percentage of total land					Percentage of current land use (=100)				
	A	B	C	D1	D2	A	B	C	D1	D2
Torrealvilla:										
Livestock	0.0	0.2	0.7	2.0	2.8	0.0	19.7	68.9	196.7	275.4
Vegetables & fruits	0.0	0.2	4.2	17.1	23.1	0.0	1.9	40.3	164.0	221.5
Grapes	0.1	0.3	1.1	13.4	13.4	3.6	10.9	40.1	488.0	488.0
Olives & almonds	12.1	9.9	17.6	15.3	15.3	44.5	36.4	64.7	56.2	56.2
Grains	36.0	35.6	36.2	31.8	24.9	102.3	101.2	102.9	90.4	70.8
Non-used UAA	51.8	53.8	40.2	20.5	20.5	221.2	229.8	171.7	87.6	87.6
Murcia:										
Livestock	0.0	0.3	1.1	2.3	2.5	0.0	17.8	65.1	136.2	148.0
Vegetables & fruits	0.0	0.4	7.6	23.1	24.9	0.0	2.1	40.2	122.2	131.8
Grapes	0.2	0.7	2.3	10.9	10.9	3.5	12.1	39.9	188.9	188.9
Olives & almonds	8.2	6.6	11.6	11.4	11.4	46.7	37.6	66.1	65.0	65.0
Grains	11.7	11.0	12.0	12.0	10.0	114.3	107.5	117.2	117.2	97.7
Non-used UAA	79.9	81.1	65.3	40.2	40.2	174.2	176.8	142.4	87.7	87.7

Source: scenario results calculated from discrete choice interviews. See main text for description of scenarios.

Table 7. Impact on output price as a result of price increases for agricultural water use.

Sectors	Virtual Water Multiplier (litre €$^{-1}$)	Impact on product price of a water price increase of €0.10 m^{-3} (%)
Agriculture		
Grains	221.96	2.22
Horticulture and fruits	353.95	3.54
Grapes	558.36	5.58
Olives and almonds	379.69	3.80
Livestock	62.12	0.62
Fisheries	0.43	0.00
Industry		
Extractive industries and combustibles	0.03	0.00
Electricity, gas and water	0.05	0.00
Agro-food industries	43.50	0.44
Textiles and leather industries	1.13	0.01
Lumber and cork industries	11.81	0.12
Paper, printing and publishing	1.84	0.02
Chemical industry	0.30	0.00
Rubber and plastics	0.97	0.01
Construction materials (non-metal)	0.12	0.00
Metallurgy	0.09	0.00
Machineries and mechanical equipment	0.05	0.00
Electronics and optical products	0.03	0.00
Manufacturing of transport materials	0.04	0.00
Other manufacturing industries	0.89	0.01
Construction	0.20	0.00
Services		
Trade (incl. servicing of vehicles)	0.60	0.01
Hotels and restaurants	2.69	0.03
Transportation and communications	0.13	0.00
Financial brokerage	0.05	0.00
Real estate and enterprise services	0.17	0.00
Education	0.25	0.00
Health and social services	0.25	0.00
Public administration	0.38	0.00
Other community and personal services	1.01	0.01
Domestic personnel	0.00	0.00

Source: input-output model results; see main text for procedures and assumptions made.

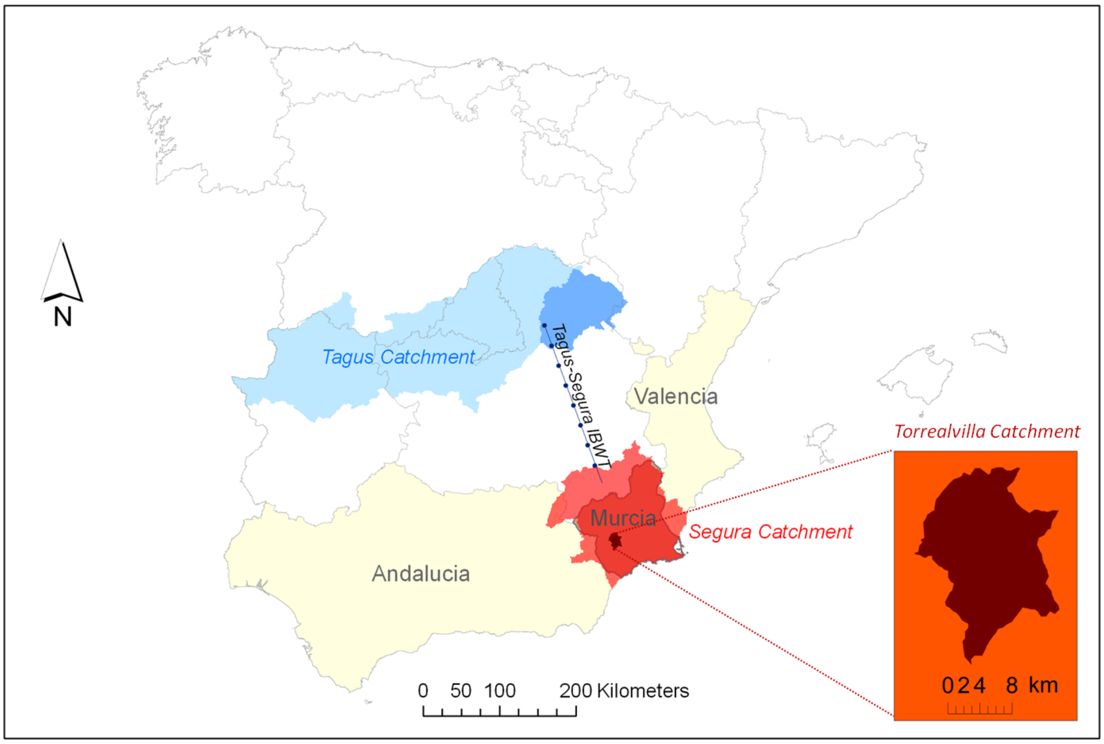

Figure 1. Location of Murcia Region and the neighbouring autonomous regions of Andalucia and Valencia in Spain. Also indicated are the Tagus (Spanish share) and Segura catchments, the upper Tagus subcatchment feeding the Tagus-Segura IBWT, and the field case study area – the Torrealvilla (sub-)catchment.

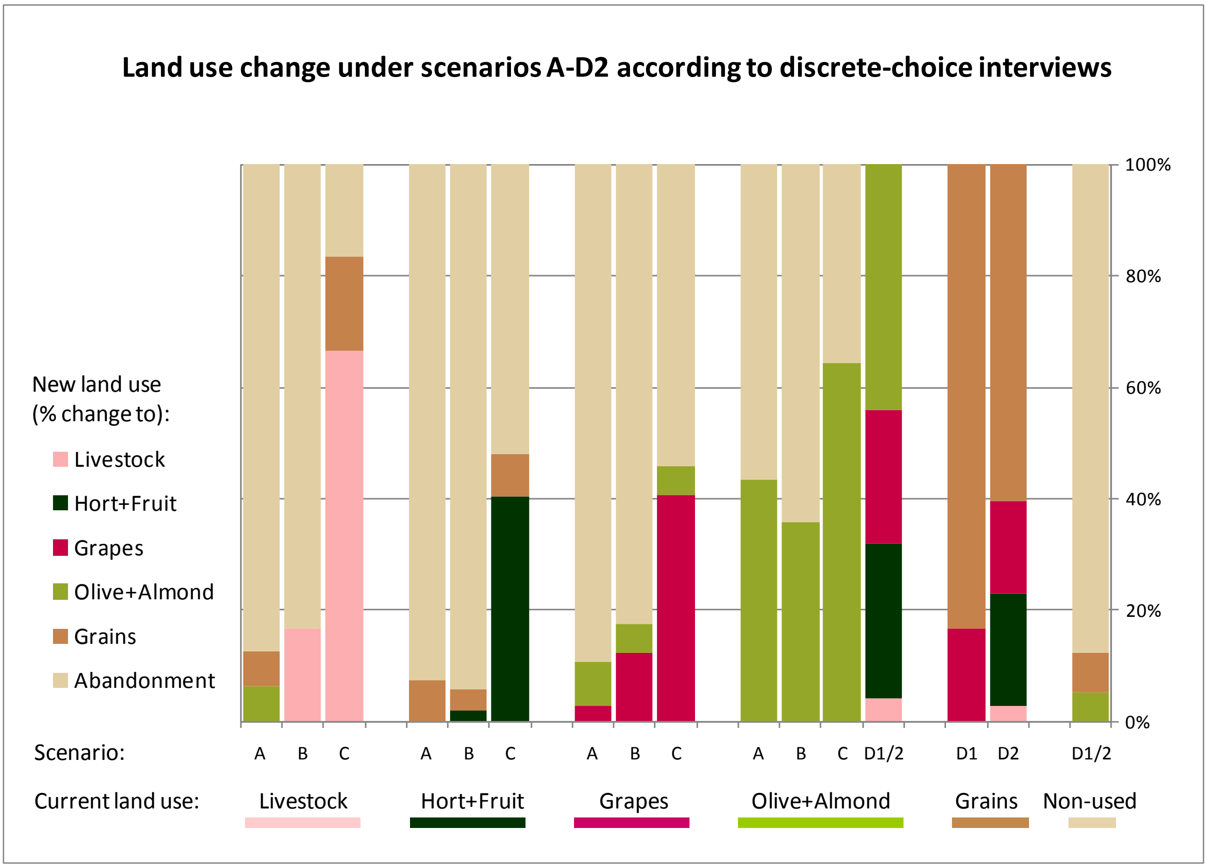

Figure 2. Land use changes under different scenarios in Torrealvilla catchment as recorded from individual discrete-choice interviews. Changes are expressed in percentages of current land use that changes to (or remains) livestock farming (pink), horticulture and fruits (dark green), grapes (magenta), olive and almond (olive), grains (pale brown) and non-used UAA (ecru). Scenarios: A. Total water depletion; B. Higher water tax; C. Low water tax; D1/D2: Water transfer to new areas (for further details see main text).

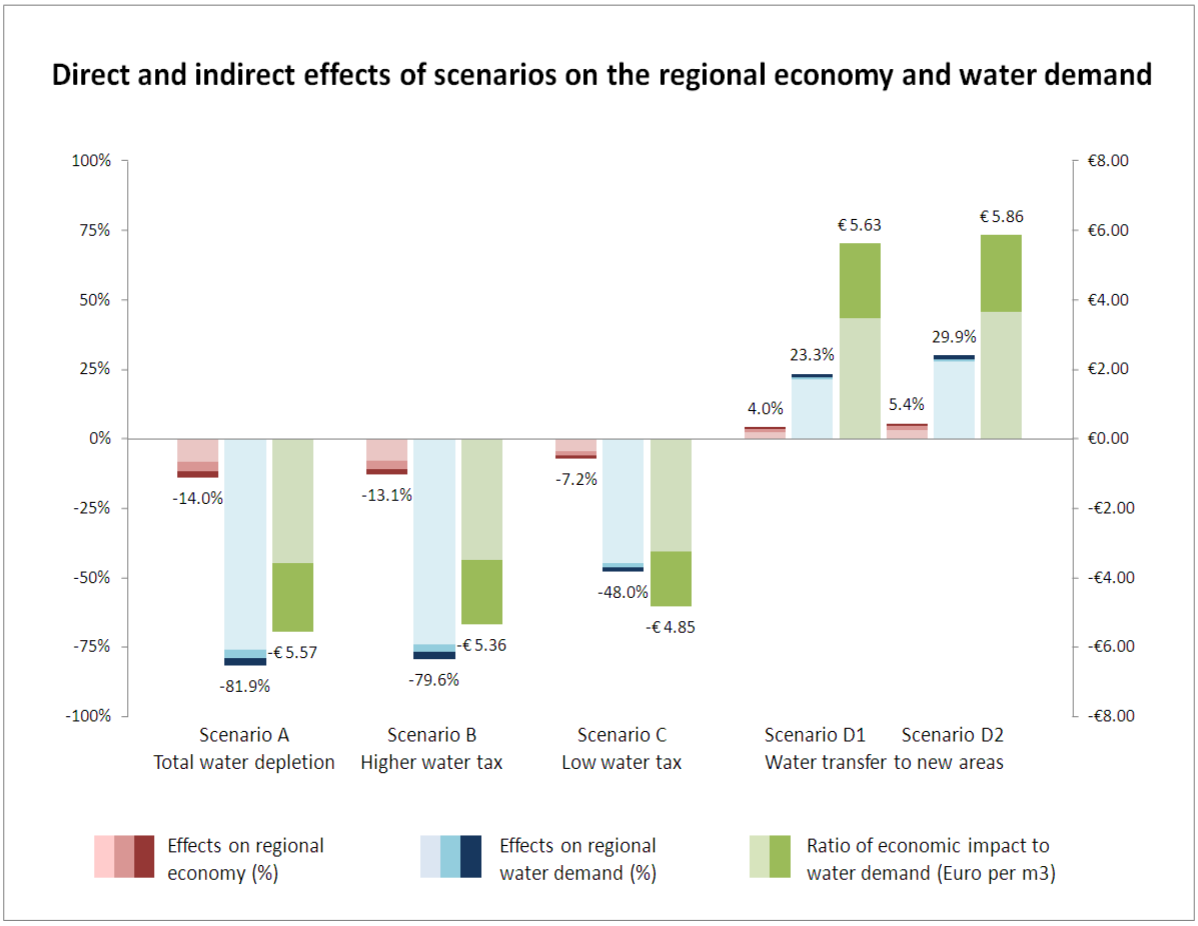

Figure 3. Direct and indirect effects of scenarios on the regional economy and water demand. Pale, medium and dark colours represent direct, forward- and backward multiplier effects respectively (forward and backward multiplier effects are combined for ratio of economic impact to water demand).

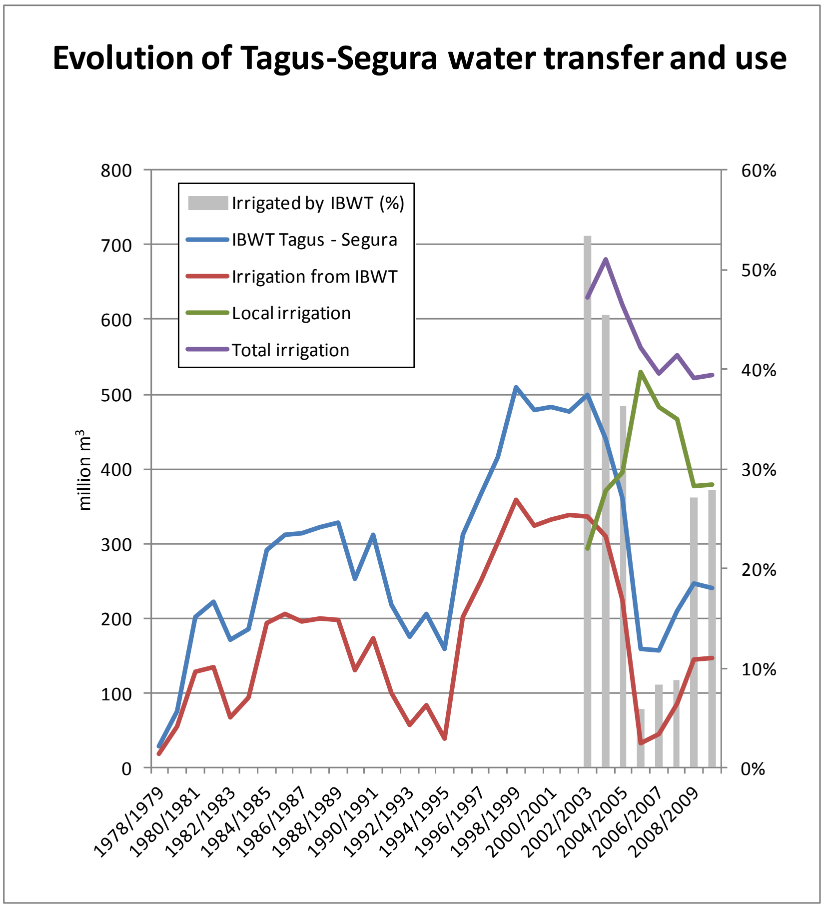

Figure 4. Historical data of water obtained from inter-basin water transfer Tagus–Segura. Source: CREM (2011).