A never-ending debate: Demand versus supply water policies. A CGE analysis for Catalonia

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Abstract

Water scarcity is a long-standing problem in Catalonia, as there are significant differences in the spatial and temporal distribution of water through the territory. There has consequently been a debate for many years about whether the solution to water scarcity must be considered in terms of efficiency or equity, the role that the public sector must play and the role that market-based instruments should play in water management.

The aim of this paper is to use a Computable General Equilibrium (CGE) model to analyze the advantages and disadvantages associated with different policy instruments, from both a supply and a demand viewpoint, which can be applied to water management in Catalonia. We also introduce an ecological sector in our CGE model, allowing us to analyze the environmental impact of the alternative policies simulated. The calibration of the exogenous variables of the CGE model is performed by using a Social Accounting Matrix (SAM) for the Catalan economy with 2001 data. The results suggest that taking into account the principle of sustainability of the resource, the policy debate between supply and demand in water policies is obsolete, and a new combination of policies is required to respect the different values associated with water.

Resumen

La escasez de agua es un grave problema en Cataluña, debido a los importantes desequilibrios en la distribución espacial y temporal de agua a lo largo del territorio. Durante los últimos años se ha generado un debate acerca de si la solución al problema del agua debe basarse en términos de eficiencia o equidad, así como cuál debe ser el papel que el sector público y los mecanismos de mercado deben jugar en la gestión regional del recurso hídrico.

El objetivo de este trabajo es analizar mediante un modelo de equilibrio general aplicado (MEGA) las ventajas y desventajas de diferentes instrumentos de política

económica, basados tanto en una perspectiva de oferta como de demanda, que pueden ser aplicados a la gestión del agua en Cataluña. Nuestro modelo contempla un sector ecológico que permite analizar los impactos medioambientales de las medidas planteadas. La calibración de los parámetros del modelo está basada en una matriz de contabilidad social de la economía catalana del 2001. Nuestros resultados sugieren que desde un punto de vista de la sostenibilidad del recurso el debate existente entre las políticas de oferta *versus* las políticas de demanda de agua es obsoleto y una nueva combinación de políticas es necesaria para respetar los diferentes valores asociados al agua.

1. Introduction

The water issue is a problem with a long history in Catalonia, and divides the territory into two areas: in the east, the Internal Basins;[1] and in the west, the Intercommunity Basins.[2] Although the both areas are of practically equal size, there is a significant difference in both the provision of water and the uses for which it is intended.

The Internal Basins account for 92% of the population and generate 95% of Catalonia's gross value added. Water demand is about 1,187 hm^3 per year, with 64% allocated to domestic and industrial uses. However, water resources are scarce and the situation will worsen in the future: the expected growth of population is about 20% in 2025, and the climate change scenario foresees a reduction of contributions to surface and recharge aquifers of around 5% (ACA, 2010). By contrast, the Intercommunity Basins have more water resources to supply a smaller population and a less dynamic economy, where 95% of the total water demand (1,937 hm^3) is used for agriculture. Despite the evidence that there is a structural water deficit in Catalonian's Internal Basins, there has been no consensus-based response to resolving the problem.

In the early 1990's, a long drought in Spain brought the issue to the forefront of political debate. In 1993, the socialist government designed a Draft National Hydrological Plan, which included a water transfer of 850 hm^3 from the Ebro River to the Internal Basins of Catalonia, but the weakness of the last parliamentary government of Felipe González led to a delay in its approval. Some years later, during the absolute majority of the conservative government of José Maria Aznar, a new National Hydrological Plan was approved in 2001. It was based on the idea that conservation measures and improvements in water use efficiency could not meet demands for water in all basins, and called for the construction of new dams and allocated 200 hm^3 from the Ebro River to the Internal Basins of Catalonia.

Despite long period of time spent trying to advocate a national plan, the lack of political and social consensus on water policy had been increasing. As a result, one of the first actions taken by the socialist government of José Luís Rodríguez Zapatero in 2004 was to abolish water transfers from the Ebro River and replace them with the construction of desalination plants along the coast. However, when Catalonia experienced an extraordinary drought in early 2008 and made it difficult to supply water to the Barcelona metropolitan area, a decree law was passed that allowed it to build the necessary infrastructure to transfer water from the final stretch of the Ebro River. However, the decree law was suspended when the rains came in the summer and the drought alarm ended.

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[1] The Internal Basins are those of rivers that are entirely in Catalonia, such as are the river Llobregat, Ter, Muga, Daró, Fluvià, Francolí, Foix, Besòs, Gaia, Tordera and Riudecanyes. These rivers supply 52% of the territory, including the Barcelona metropolitan area. The responsibility for developing and enforcing water planning falls exclusively on the Government of Catalonia.

[2] The Intercommunity Basins refers basically to the Catalan part of the Ebro River Basin. The Government of Catalonia is responsible for some policies related to water (e.g. sewage, agricultural planning), but the Spanish government, through the Ebro Hydrographic Confederation, is responsible for water planning.

All these changes point to a lack of consensus among the various political parties on which water management model should be applied. This lack of understanding can be explained by the conflicts of interest created by the various options and the difficulty of changing the formal and informal rules that shape the traditional institutional framework for water policy. However, it basically shows a lack of consensus in the world of ideas about the appropriate water policy in Catalonia.

One approach to water policy is called "supply model", which was traditionally used in Catalonia and Spain during the twentieth century. Its starting point is that water is a scarce commodity, but simply a problem of spatial and temporal distribution. The solution is to build water infrastructures that increase water supply in those areas where water is scarce. Given the nature of water and the general interest, it is reasonable for the State to assume the cost of this infrastructure (Costa, 1911; Embid, 2002).

A second approach, which emerged in the 60's, is the "demand model" of water management. The main change is that it considers that water to be a scarce commodity, and as such measures to reduce consumption and increase efficiency of use are required. In this approach, the price of water transmits signals and reflects the scarcity of the resource. It aims to reduce the role of public sector in water management, limiting it to the development of a legal and institutional framework conducive to efficient functioning of formal water markets (Easter *et al*., 1998; Dinar, 2000; Johansson *et al*., 2002).

The 1980s saw the emergence of a third approach or "model of sustainable use". Water is still considered a scarce commodity, but social, ecological and cultural values are now also attributed to it. To achieve this objective, the price of water should transmit signals reflecting the scarcity and cost of use, but should also include the externalities generated. The possibility of market failures calls the appropriateness of certain economic instruments into question, because water has many values outside the logic of the market. In other words, the problem of lack of price signals, which had been used to argue against the "supply model", was countered by the idea that the use of market instruments raises doubts about its efficiency and equity, and makes public involvement in water management essential (EU Water Framework Directive, 2000; Arrow *et al*., 2004; Garrido & Llamas, 2010).

The diversity of approaches to the issue of water has shown that any instrument used in water management is biased: public planning leads to failures in the assessment of costs and direct benefits from water use, whereas the market has difficulties in assessing indirect costs and benefits of water uses, and may create problems of equity in the distribution of resource (Dinar, 1998).

In this paper we use a computable general equilibrium model, following the tradition of Shoven & Whalley (1992), to analyse the economic and environmental effects of alternative water policies on water research that have been suggested by the literature, and which have also been advocated by various governments to solve the water problem in Catalonia in recent decades. First, we analyse the effects of a traditional supply policy, such as a new public investment to increase the availability of water resources in the region. Second, from a demand approach, we study the effects of a public awareness campaign to reduce final water consumption, which also could be

interpreted as a reduction of losses in Catalonian water distribution networks. Third, and also from a demand approach, we analyse the effects of a modernization of irrigation systems, which implies greater water efficiency in agriculture (less water requirements). Finally, we apply a tariff to water that increases water's effective price and, this simulation therefore analyses the impact of implementing the principle of cost recovery advocated by the EU Water Framework Directive for achieving sustainable water use.

In all these cases, we analyse the effect of water measures on regional prices (production and consumption prices), on regional production (real GDP), on private welfare (equivalent variation) and we also analyse the effects of the measures on water variables (water demand, water production and water price). We complete the analysis by calculating the ability of each water policy to generate water savings that can be used to increase the river's environmental flow. As our model shows not only the traditional (economic) effects captured by the CGE approach but also the environmental effects on water ecosystems, the analytical framework used therefore integrates both the economic and the ecological relationships taking place in water uses.

The general equilibrium analysis, which takes into account the optimization rules of the economic agents, consistently captures the interaction and interdependence between all markets. As the CGE analysis combines individual (microeconomic) behaviour with the aggregated (macroeconomic) identities of an economy, it provides a large set of economic variables, including prices, quantities, unemployment and GDP. The CGE models have also recently been expanded to analyse environmental and other related fields, such as gas emissions, waste generation, energy consumption and water needs.

There is an extensive literature that uses the CGE models to analyse water issues. For example, Berck *et al*. (1991) used the CGE approach to study the effects of reducing water inputs on sectorial output, gross domestic production, employment and land use in the San Joaquin Valley. Seung *et al*. (1998) used computable general equilibrium (CGE) techniques to analyse the economic effects of water transfers in the Walker River Basin of Nevada and California. Goodman (2000) compared the economic impacts of an increase in water storage with temporary water transfers between rural and urban communities in the Arkansas River Basin. Seung *et al*. (2000) used a dynamic CGE model to evaluate the impacts of water reallocation in Churchill County, Nevada. Hewings *et al*. (2005) evaluated the impact of water reallocation from agriculture to other productive sectors in a model that fully captured the feedback effects between sectors. Velázquez *et al*. (2005) used a computable general equilibrium model to study the effects that an increase in the price of the water delivered to agriculture would have on the efficiency of water consumption. They also analysed the possible reallocation of water to other productive sectors in the Spanish region of Andalusia. Berrittella *et al*. (2007) showed the potential of CGE analysis in analysing sustainable water supply uses by using a global multi-regional model with water as a differentiated factor of production. Lennox & Varghese (2007) used a CGE approach to analyse water uses in Canterbury. More recently, Lennox & Diukanova (2011) used the general equilibrium framework to determine the regional effects of water reallocation in Canterbury. Finally, Cardenete & Hewings (2011) analysed sectorial water reallocation in Andalusia using a regional CGE model.

The structure of the paper is as follows. The next section presents the CGE model used and the third section describes the database used to calibrate the parameters of the functional forms. Section 4 shows the main results of the different water measures simulated and, finally, a conclusion section ends the paper.

2. The model

In the CGE model, the definition of equilibrium is based on the Walrasian notion, and includes not only producers and consumers, but also government and foreign agents. The equilibrium is determined by a vector of prices, a vector of activity levels and a set of macroeconomic indicators that clear all markets and allow all agents to achieve their optimization plans. Mathematically, the model is defined as a set of equations containing the equilibrium conditions in all markets.

2.1. Production

Each sector of production, $j = 1,...,16$, obtains a homogenous good by a nested constant-returns-to-scale function. Following the Armington hypothesis (Armington, 1969), we assume that imports and domestic production are partially substitutive. In specific terms, the total production in each sector (Q_j) is a Cobb-Douglas aggregator combining domestic production (X_{dj}) and regional imports (X_{Mj}):

$$Q_j = \delta_j X_{dj}^{\gamma_j} X_{Mj}^{1-\gamma_j}, \qquad\qquad j = 1,...,16, \qquad\qquad (1)$$

where δ_j is a scale parameter. As our aim is to simulate the effects of water policies, the production and distribution of water is reflected in the model as an individual sector ($j = 3$) separated from the other activities.

In the second level of the production function, the domestic output follows a Cobb-Douglas aggregator with constant-returns-to-scale:

$$X_{dj} = \lambda_j X_{1j}^{\varphi_{1j}} X_{2j}^{\varphi_{2j}} ... X_{16j}^{\varphi_{16j}} VA_j^{\varphi_{vj}}, \qquad j = 1,...,16, \qquad \sum_{j=1}^{16} \varphi_{kj} + \varphi_{vj} = 1 \quad (2)$$

In expression (2), X_{kj} is the amount of k used in the domestic production of j, λ_j is a scale parameter and VA_j is the value added in sector j.

Finally, the third level of the production function calculates the sectorial value added according to the expression:

$$VA_j = \beta_j L_j^{1-\alpha_j} K_j^{\alpha_j}; \qquad j = 1,...,16, \qquad\qquad (3)$$

where β_j is a scale parameter and L_j, K_j are the quantities of labour and capital, respectively, used by sector j.

Producers are competitive in both the input and the output markets and their objective consists of minimising production costs, subject to a given level of output. This leads to the inputs demand functions in each sector and as we assume constant-returns-to-scale, the corresponding sectorial benefits will be zero.

2.2. Consumers

The model shows a generic household with a logarithmic Cobb-Douglas utility function that combines consumption and saving (or future consumption):[3]

$$U = \sum_{h=1}^{10} \gamma_h \ln c_h + \gamma_s \ln c_s; \quad \gamma_h, \gamma_s > 0; \quad \sum_{h=1}^{10} \gamma_h + \gamma_s = 1, \quad (4)$$

where c_h is the consumption of good h and c_s is the private saving. Among the consumption goods, $\gamma = 3$ shows the final demand of water and it is exclusively made up of the deliveries that water production makes to the final demand. In other words, the water consumed by households is exactly the same as the output of the water production sector.

The budget restriction of consumers (expression (5)) imposes that the total for the final consumption and saving cannot exceed the household's disposable income. Private income comes from the household's endowments (of labour and capital) and transfers (from government and abroad). All these revenues are subject to direct taxation on income.

$$\sum_{h=1}^{10} P_h(1+t_h)c_h + P_I c_s \le (wL + rK + PTcpi + ETP_F)(1-\tau). \quad (5)$$

The left side in (5) is the final consumption amount: t_h is the effective tax rate on the consumption of h and P_h is the associated price. Additionally, private saving is valued at the investment price: P_I. The right side in (5) shows the disposable income: wL is the labour income (w is the wage and L is the amount of labour or total supply), rK is the capital income (K is the endowment of capital and r is the corresponding price), PT_{cpi} shows the public transfers (indexed with the consumption price index: cpi), and ET are the external transfers from abroad (indexed with the price of external sector P_F). Finally, τ is the effective tax rate on household's income.

The consumer's behaviour, consisting of maximising the utility function subject to the budget constraint, leads to the demand functions for both consumption goods and private saving.

2.3. Government

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[3] The model distinguishes between production and consumption goods. The consumption goods are obtained by a conversion matrix of fixed coefficients that consequently defines a direct (and linear) relationship between production prices and consumption prices.

The government demands public goods and public services that have previously been produced by the public sector. Our model assumes a Leontief utility function for the government, which combines public consumption and public investment in fixed proportions:

$$U^G = \min\left[C_{16}^G, \gamma^G C_I^G\right] \qquad (6)$$

where C_{16}^G is the amount of public consumption (in the model, sector 16 corresponds to the public services production) and C_I^G is the public investment. The parameter $\gamma^G > 0$ shows a fixed proportion between public consumption and public investment.

The government's budget stipulates that public consumption and public investment cannot exceed public revenues. The amount of public transfers to households must be deducted from these revenues, which come from the taxation system. Specifically, the public budget is defined as:

$$P_{16}C_{16}^G + P_I C_I^G \leq I^G + \omega_I^G P_I . \qquad (7)$$

In expression (7), ω_I^G is the amount of debt that government can issue in the event of deficit and I^G is the income from taxation, which corresponds to:

$$I^G = VAT + DT + PrT + SST - PT_{cpi}, \qquad (8)$$

where VAT is the indirect taxation on consumption ($VAT = \sum_{h=1}^{10} p_h t_h c_h$). The direct taxation on private income (DT) is calculated as $DT = (wL + rK + PTcpi + ETP_F)\tau$. Additionally, $PrT = \sum_{j=1}^{16} s_j \left(\frac{P_{dj}X_{dj}}{(1+s_j)}\right)$ is the taxation on domestic production, with s_j being the tax rate on domestic production. Finally, the social security contributions $SST = \sum_{j=1}^{16} ss_j wL_j^D$, with ss_j the social security contribution rate in j, and L^D_j the sectorial labour demand, complete the tax figures of the model.

2.4. Foreign agent

The model defines the relations of the economy with abroad using an aggregated agent, which includes all the regional transactions with the external markets. This agent produces a traded good by using the regional exports with a fixed coefficients technology. The economy can both receive transfers from abroad and make transfers abroad at the same time.

The model allows a situation of external deficit that must consequently be balanced with the corresponding foreign agent's saving, in order to preserve the macroeconomic equilibrium between total savings and total investment in the economy.

2.5. Ecological sector

An interesting feature of our CGE model is that it shows the changes in the water not used by the economic activity, and this allows us to analyze the changes in the amount of water that maintains healthy ecosystems (environmental flow). The level of activity in the ecological sector is calculated by defining the natural restriction between total water endowments and total water uses, as follows:

$$1 = w_3 Y_3 + w_e Y_e,\qquad(9)$$

where w_3 is the fraction of total water endowments that the economy uses in the production process (consumed by producers and consumers), w_e is the fraction of ecological water (i. e. the amount of water not used by economic activity that is returned to nature). Additionally, Y_3 and Y_e are the level of activity in the water production and in the ecological sector, respectively.[4]

3. Database

In the CGE model, all the exogenous variables have been obtained by applying the standard calibration procedure, which allows to reproduction of an initial equilibrium (benchmark situation). In this situation, all the prices and activity levels are unitary and the solution of the model coincides with the empirical information shown in the social accounting matrix (or SAM) database used to calibrate the parameters of the model.

A SAM is a double-entry square matrix in which each agent is represented in a row and a column. This database contains not only the economic transactions within the production system (as an input-output table) but also the other transactions of the circular flow (factorial and personal income distribution). By agreement, the rows of a SAM show the revenues of the economic agents and the columns show the corresponding expenditures. To preserve the accounting equilibrium, the value of income must be equal to the value of expenditure in each agent, i.e. the total of a row must be equal to the total of the corresponding column.

[Table 1. List of accounts in the SAMCAT]

Given the information deficiencies at the regional level, the 2001 SAM for the Catalan economy (SAMCAT) has a very simple structure.[5] The production system is divided into 16 sectors, one of which shows the production and distribution of water. Additionally, the SAMCAT shows ten consumption goods, and one of them is the final consumption of water. The regional database also shows two production factors, labour and capital, and a generic account containing the income relations of private consumers. In the SAMCAT, the capital account shows all the sources of saving and investment in the regional economy, and the government accounts involve four different taxes (on

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[4] Taking into account that the levels of activity in the benchmark equilibrium are unitary, we then calibrate the proportions as: $w_e = 1 - w_3$.

[5] The construction process of the SAMCAT is described in Llop (2011).

production, on income, on consumption and, finally, Social Security contributions) and an account that contains the income flows of public administration. Finally, the foreign agent is aggregated into a consolidated account showing imports, exports and income transactions of the regional economy with abroad.

4. Results

In the first stage, the computation of the model involves the calculation of the reference equilibrium (benchmark situation), in which all the prices and activity levels are unitary and the model reproduces the numerical information contained in the social accounting matrix. The simulation analysis consists of making four alternative modifications to the benchmark equilibrium.

Before showing the effects of the simulations, some additional aspects of the analytical context used should be considered. First, given that the Walras law implies that one of the equations in the model is redundant, we have taken the wage as numéraire and the price of labour is consequently unitary in all the simulations performed. In the new equilibriums the prices are therefore in fact relative prices with respect to the numéraire. We also used the same macroeconomic closure rules for the government and the foreign sector, consisting of a variable activity level of government and a fixed public deficit, and a variable activity level of foreign agents and a fixed trade deficit. Table 2 shows the main outcomes and indicators obtained in the different simulations.

[Table 2. Changes in production prices, water variables and other indicators (%)]

The first scenario, based on the "supply model" of water, simulates the effects of a new investment in public water infrastructure, to enable a 25% increase in total water availability.[6] The result of the increased supply of water is to reduce the price of water (21.77%) and an increase in the quantity of water demanded (31.3%) for both intermediate and final consumption. Water is therefore an input into the production process that shows a high elasticity of substitution, which leads to increased use when it is cheaper and can additionally drive real GDP growth (0.21%).

However, this increase in the water supply and its more intensive use as an intermediate input has a adverse effect: as predicted by the "tragedy of the commons",[7] in the absence of environmental constraints there is an overexploitation of resources

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[6] Catalonia is making investments to increase water availability in nearly 400 hm^3/year by 2015, from the desalination of sea water (190 hm^3/year), water recycling and reuse (101 hm^3/year), aquifer recoveries (43 hm^3/year) and other activities to improve supply infrastructures (55 hm^3/year). This expected increase in the amount of water available would cover about 15% of current demand (ACA, 2010).

[7] The "tragedy of the commons" (Hardin, 1968) explains how, in a context of open access to a limited common resource, individuals' behaviour based on their own self-interest will ultimately deplete the shared resource. Consumption beyond the limits of sustainable use will therefore be generated.

because the signals are relaxed market shortages. This tends to reduce the ecological flow (10.4%).

The second modification to the benchmark equilibrium follows the "demand model" of water and consists of analysing the effects of a 25% reduction in the final demand for water, whether it is driven by greater consumer awareness for more sustainable use and water savings,[8] or by efforts to mitigate the losses in water distribution networks.[9] This simulation will give us some idea of how a change (reduction) in final water consumption will affect not only the economy but also water variables.

The result we observe is that there is a substantial decrease in the demand for water for domestic use (41%) and consequently a reduction in the price of this resource (9.63%). However, the indirect effect of lowering the water demand is that it becomes more attractive as a production factor, and the demand for intermediate use increases (8.77%). However, the net result is a reduction in water demand in the country as a whole (8.71%), generating a surplus that increases water resources for the maintenance of the environmental flow (2.9%).

The most important result of this simulation is the impact of reducing domestic water on real GDP. Relaxing the pressure of the final consumer on the availability of water allows a cheaper and a reallocation of resources to other uses with higher added value, creating a knock-on effect on consumption and achieving real GDP growth (1.71%).

The third simulation is also based on the demand approach to water and examines the effects of a modernization process of irrigation that achieves a reduction of 25% of the water used in agriculture.[10] A result is that the increased efficiency of water use in agriculture leads to a reduction in the amount of intermediate water consumed (0.78%), enabling a reduction in the costs and prices of agricultural products (1.05%). However, as noted by King's Law, the lowering of agricultural product prices only leads to a small increase in the quantity produced (0.73%). In fact, this greater variability in prices reflects not only the low price elasticity of demand for agricultural products, but also explains the uncertainty about the expected returns associated to technological change, and it helps to understand the resistance to technological change traditionally common among farmers.

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[8] According to water research, involving end consumers in water saving is an effective way of ensuring water availability and has been an important argument used by local and regional authorities in recent years. In 2004, water final demand was 18.13% of total water use in Catalonia. During the most recent drought in 2007-2008, users were allowed to save up to 20% of the water that was spent before the drought (ACA, 2008).

[9] Municipal networks in Catalonia are normally longer, older, and operate at a working pressure, which tends to cause greater losses. The upstream supply systems in Catalonia thus lose only between 2% and 4% of the flow transported, but the leaks in municipal distribution systems lead to a loss of between 5%-25% (ACA, 2008).

[10] Agriculture is the leading water user in Catalonia, accounting for over 70% of total water demand. One attempt to release water to other resources is the Catalonian Irrigation Plan, which involves upgrading more than 150,000 hectares of traditional irrigation to become pressurized irrigation systems, reducing water consumption by nearly 35% (ACA, 2008).

This simulation also shows that despite an increase in efficiency in water use in agriculture by 25%, the total water demand reduced very slightly (-0.44%) and there were negligible increases in the environmental flow (0.02%). As noted by Jevons' paradox, technological improvements increase the efficient use of resources, but do not necessarily reduce their consumption, and may even increase it.

The fourth and final modification to the benchmark equilibrium involves a 25% tax on the price of water. This measure involves increasing the price of water in different uses, but is consistent with the principle of cost recovery that the European Water Framework Directive (WFD) advocates[11] and allows water scarcity signals to be passed on to users.

The result of this simulation is that the increase in water prices would reduce both the intermediate consumption (24.63%) of water and its final consumption (21.87%). the price increases therefore lead to a reduction in total water consumption, but increase the volume of water for environmental purposes (7.8%).[12]This would thus be a significant step towards fulfilling the objectives set by the WFD: achieving a good qualitative and quantitative status of all water bodies by 2015.

However, the political viability of this measure has always been doubted. The fundamental reason is the negative effect it would have on the agricultural sector, not only due to the potential impact on its competitiveness but also because of its impact on the multifunctional role of farmers as suppliers of public goods to society.

Nevertheless, the results of our simulation suggest that the price of water has a limited impact on the costs of agricultural production, generating an increase in the price of agricultural production by 0.11%. In other words, the traditionally low price paid for water has meant that it is not a key component of sector costs, and that farmers are quite insensitive to the taxation of water in those price levels. However, at the aggregate level of the economy the impact of the rising price of a production factor such as water is reflected by a 0.23% increase in the CPI. This increase in consumption prices leads to a negative impact on consumers' welfare, which is quantified in the model with a negative equivalent variation of 194.7 million Euros.

Finally, if we compare the results of the four simulations, there is an obvious trade-off between ecological water and water uses. However, it is not apparent that a simple increase in water availability would imply a solution to this trade-off. In other words, our results suggest that an increase in the water supply per se does not provide an overall better situation from both an economic and ecological points of view. Indeed, the result we obtain is that the supply policy does not generate a better result from an

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[11] The average price paid for water in Catalonia is 1.7€/m^3. Recent studies suggest that a strict application of the principle of cost recovery of the Water Framework Directive, would lead to an increase in the price of water to 3.30€/m^3 (ACA, 2010).

[12] This result is not trivial. A cost recovery policy, especially in agricultural sector, will only be effective when prices rise above a certain price threshold, since below this price level water demand is completely inelastic and there is no change in the pattern of water consumption or the type of crop cultivated. In fact, ex-ante, an increase in water prices to recover costs could have an ambiguous effect on aggregate water savings: as a result of higher water prices, the supply of the final product could be reduced and therefore the presumed rise in its price could reverse the decline in irrigation water demand and reduce its elasticity to price changes.

environmental point of view, and the cost recovery policy applied to all uses and users (simulation 4) is the best option for the environmental flow.

Although at a sectorial level there are some differences between the gains or losses associated with each simulated water policy scenario, the effects tend to be minimal. The most important aspect is that apart from potential winners or losers, there are some clear differences as to the effects at the aggregated level in each simulation. The results show that policies that succeed in relocating more use-based water rights to higher value-added activities are those that obtain the best result from the point of view of economic growth and individual welfare. When we simulate a reduction in the final uses of water (situation 2), the decrease in water final demand thus generates an income effect that substantially raises regional consumption and shows the greatest increase both in real GDP (1.70%) and in the equivalent variation (751.6 million Euros).

5. Conclusions

In this paper, we have provided some empirical evidence of the alternative modifications that could be applied to water policy in Catalonia. Our analysis involves the use of an applied general equilibrium model that reflects all the connections and interactions between the economic agents. The general equilibrium framework provides a complete representation of the economic relations and captures not only the direct effects of changes in the economic scenarios, as the partial equilibrium approach does, but also the indirect impacts due to the interdependences in the economy. Additionally, an interesting characteristic of the model used is that it shows the effects of water measures on the environmental flow of water, providing information of the ecological consequences of each water intervention. Our analytical approach therefore provides interesting results that can help policymakers define and implement policies on water resources.

One objective of our analysis is to highlight the differences between demand and supply water policies. Contrary to traditional assumptions that any change in water prices and water quantities would lead to important economic and social effects, our results suggest that the water interventions would have practically no effects on the main economic indicators at a sectorial level, although they may be relevant at the aggregated level.

A second result we obtain is that the traditional debate between efficiency and equity, which has framed the regional political dispute between supply and demand of water, is overcome when aspects of sustainable resource use are incorporated. A comparative analysis of the different water policies shows that the most important aspect is the trade-off between prioritizing the economic or the environmental values associated with water.

This conclusion leads us to open a future line of research, aiming to analyze which water policy mix allows us to design a win-win strategy, to overcome the dichotomy between economic growth and environmental protection. This paper is an initial attempt to capture the main features of water in terms of the economic, social and ecological perspectives that involves any analysis of water resources. Future research should also be undertaken in order to incorporate certain restrictions in the model,

reflecting the operating in the formal water markets in Catalonia, such as the presence or absence of networking between different parts of the territory, the order of priority uses and restrictions on volume and timing in water use rights transfer. This will confirm how the institutional framework determines the effects of different water policies.

Acknowledgements

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Tables

Table 1. List of accounts in the SAMCAT

Production Sectors	1. Agriculture
	2. Energy
	3. Water distribution
	4. Chemistry
	5. Metals and electric equipment
	6. Automobiles
	7. Food production
	8. Textiles
	9. Paper
	10. Other industries
	11. Construction
	12. Commerce
	13. Transports and communications
	14. Finance
	15. Private services
	16. Public services
Factors of production	17. Labour
	18. Capital
Consumers	19. Consumers
Saving-investment	20. Capital account
Public sector	21. Production taxes
	22. Social Security taxes on employers
	23. Direct taxes on income
	24. Consumption taxes
	25. Government
Sector exterior	36. Foreign sector

Table 2. Changes in production prices, water variables and other indicators (%)

	Situation 1	Situation 2	Situation 3	Situation 4
SECTORS	Changes in production prices (%)			
1. Agriculture	-0.10%	-0.01%	-1.05%	0.11%
2. Energy	-0.55%	-0.02%	-0.07%	0.56%
3. Water distribution	-21.77%	-9.63%	-0.02%	27.89%
4. Chemistry	-0.11%	-0.01%	-0.07%	0.11%
5. Metals and electric equipment	-0.07%	0.03%	-0.06%	0.07%
6. Automobiles	-0.07%	0.02%	-0.03%	0.07%
7. Food production	-0.08%	-0.01%	-0.06%	0.08%
8. Textiles	-0.08%	-0.01%	-0.08%	0.09%
9. Paper	-0.07%	-0.01%	-0.06%	0.07%
10. Other industries	-0.08%	0.01%	-0.07%	0.09%
11. Construction	-0.05%	0.12%	-0.03%	0.06%
12. Commerce	-0.06%	-0.01%	-0.05%	0.07%
13. Transports and communications	-0.08%	-0.01%	-0.03%	0.09%
14. Finance	-0.02%	-0.01%	-0.02%	0.02%
15. Private services	-0.05%	0.04%	-0.03%	0.05%
16. Public services	-0.09%	0.22%	-0.02%	0.09%
	Changes in water variables (%)			
Final water demand	27.76%	-41.34%	-0.05%	-21.87%
Intermediate water demand	33.88%	8.77%	-0.78%	-24.63%
Water production	31.30%	-8.71%	-0.44%	-23.43
Ecological water	-10.40%	2.90%	0.02%	7.80%
	Changes in prices, GDP and household welfare (%)			
CPI	-0.20%	-0.05%	-0.09%	0.23%
Real GDP	0.21%	1.70%	0.06%	-0.03%
Equivalent Variation (million Euros)	193.2	751.6	72.9	-194.7

Situation 1: 25% increase in total water resources

Situation 2: 25% reduction in the final water consumption

Situation 3: 25% reduction in water consumption of agriculture

Situation 4: 25% tax on water price