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EFFICIENCY IMPROVEMENTS AND WATER POLICY IN THE BALEARIC ISLANDS: A GENERAL EQUILIBRIUM APPROACH

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We use an Applied General Equilibrium Model of the Balearic Islands to explore the impact of increasing the technical efficiency of water use in the tourism sector. We show that water efficiency measures do not reduce economic pressures on water ecosystems. Consequently water price increases and reductions in water withdrawals are needed as ancillary measures. This water policy package opens a menu of possible outcomes in terms of conservation of water resources and the production of market goods. We also provide information about distributional impacts that should be considered to determine the convenience of implementing water saving programs.

Keywords: applied general equilibrium, water economics.

(*JEL* Q25, D58)

1. Introduction

As a result of the progressive deterioration of water ecosystems and the increasing demand for environmental quality, the protection and restoration of water resources have become major targets of the European water policy. For instance, the Water Framework Directive

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(2000) aims to achieve a good water status for European surface waters and groundwater by 2015 in terms of environmental quality and availability of water for human uses.

Given this new focus finding those policies with the most favourable trade-offs between potentially competing objectives has become a priority. Emphasis on environmental quality contradicts the traditional approach of coping with water scarcity by the mean of increasing supply and asks for the articulation of other water management policies in order to find an adequate balance between the ecological targets and the provision of water services for production and consumption activities. Most of the measures available for water demand management consist in reducing the water services requirements of the different economic activities by somehow improving the efficiency with which water is used.

In the specific case of the Balearic Islands, pressure over water resources is above what is needed to obtain a good status of the water ecosystems, and also to guarantee water supply in adequate quality and quantity in the recurrent dry periods and even in future (Olsen, 2001). This is already recognized by the local authorities since the Hydrological Plan for the Balearic Islands (GIB,1999) establishes that a 25 hm^3 reduction of groundwater withdrawals is needed to guarantee future sustainability of water extractions. According to Olsen (2001) this situation is mostly due to the growth of the tourism sector (now the most important economic activity in the Balearic Islands), which has become one of the main water users and has also stimulated higher water demand from other sectors. Water saving measures in the accommodation facilities (hotels, apartments and so on) such as improvements in the efficiency of plumbing fixture (more efficient taps, water closets, etc.) or the establishment of recycled water systems may have quantitatively important effects on water demand for the whole economy. According to White (2001), this kind of measures, jointly with an adequate price policy, could yield reductions in water consumption that would amount to 35% or even 40% of current levels.

Given their potential benefits this paper analyzes the effects of water efficiency measures implemented in the tourism sector of the Balearic Islands by using an Applied General Equilibrium Model (AGEM)[1]. Although some published works have compared alternative water pol-

[1] The model used in this paper is an extension of the AGEM of the Balearic Islands developed by Gómez, Tirado and Rey-Maquieira (2004).

icy scenarios[2] by using AGEM, no one, as far as we know, has used this tool to explore the implications of water efficiency measures for the management of water resources and for the whole economy.

The exposition plan is as follows, in section two the concept of water efficiency measures is clarified and it is argued that the traditional cost-effectiveness analysis is only one of the steps in their assessment. Section three presents the basic facts to understand the water management problems of the Balearic economy, introduces the general equilibrium model, and presents the baseline simulation results of the implementation of water efficiency measures in the tourism sector of the regional economy. The characteristics of drinking water supply in the Balearic Islands render these measures ineffective in terms of ecological improvements. However, as it is shown in section four, the combination of a drinking water efficiency program with an appropriate reduction in water withdrawals (with the corresponding increase in drinking water prices), makes it possible to meet the ecological targets and produce an income increase that would at least partially compensate for the social costs of implementing those measures. In fact, the policy package opens a menu of possible outcomes in terms of improvements in the economic and environmental welfare dimensions. For instance, the combination of water saving measures in the tourism sector (10% savings of current water consumption) with a 10% increase in the water price allows for a reduction of 7.79 Hm^3 in water extractions and an increase of 1.06€ per capita in real income (not considering the implementation costs of the water efficiency measures). Section five

[2]For instance, Berck, Robinson and Goldman (1991) who use an AGEM to study the reduction of water use in San Joaquim Valley as an efficient alternative to solve drainage problems. Dixon (1990), Horridge *et al.* (1993), Decaluwé *et al.* (1999) and Thabet *et al.* (1999) analyse the impact and efficiency of water prices. Seung *et al.* (1998) study the welfare gains of transferring water from agricultural to recreational uses in the Walker River Basin. Seung *et al.* (2000) combine a dynamic AGEM with a recreation demand model to analyse the temporal effects of water reallocation in Churchill County (Nevada). With an AGEM Diao and Roe (2000) show how the liberalization of agricultural markets creates the necessary conditions for the implementation of efficient water pricing. Goodman (2000) shows how temporary water exchanges provide a lower cost option than the building up of new dams or the enlargement of the existing water storage facilities. Cassells and Meister (2001) and Xie and Satzman (2000) use AGEMs to analize the economic impacts of different policies for the control of water quality in New Zealand and China, respectively. Finally, in this paper we use an AGEM already used in Gómez, Tirado and Rey-M. (2004) to analyze the implementation of a water market in the Balearic Islands.

presents a sensitivity analysis to test the robustness of some of the previous results. Section six shows that the water policy measures have small effects on the different productive sectors but for tourism, that is positively affected, and agriculture, whose Gross Value Added may increase or fall depending on how the water policy balances the economic and environmental benefits. Finally, the main conclusions are exposed in section seven whereas a technical description of the model is presented in the Appendix.

2. Water efficiency measures for water demand management

By efficiency measures we must understand any action allowing to reduce the minimum quantity of water uses needed to provide society with a certain quantity of water services including, for example, improvements of irrigation systems that reduce the water needed to obtain a given level of agricultural output, the recirculation of waste water for some particular uses or the substitution of water-using domestic appliances[3]. Efficiency measures are usually considered to be effective ways to obtain the same level of water services with lower water withdrawals and a better ecological quality of the water sources[4].

A water demand management policy based on efficiency measures requires identifying a desired ecological status of the water ecosystem and conducting a cost effectiveness analysis of the whole set of water efficiency measures that may contribute to the policy target. From this perspective, the above mentioned measures may be ordered according to their respective marginal cost, so as to obtain the cheapest combination of measures used to reach a given target reduction in water pressures over the ecosystem (White and Howe, 1998). However cost effectiveness analysis is not enough for a complete evaluation of water policy and should at least be complemented with the following considerations:

First, there is the implicit assumption that water savings from efficiency measures implementation will automatically translate into a

[3] For instance, in EEUU, California has been a leader in water efficiency experiments through the development and implementation of water saving and efficiency programmes in urban (Best Management Practices, BMP) and agricultural (Efficient Water Management Practices, EWMP) uses.

[4] A reduction of water withdrawals increases the stock of water in the water source and therefore helps to reduce salinisation and the concentration of contaminants and nutrients.

reduction of water extractions and then into an improvement in the relevant parameters measuring the ecological quality of the water source (for example into an increased water flow or a lower concentration of contaminants). This is not necessarily true since the effects on water withdrawals will depend on how the economic agents in the demand and supply side react to the efficiency measures[5]. The common wisdom according to which improving water efficiency is all we need to increase the amount of water left in the natural environment may be as wrong as concluding that a higher labour productivity is a way to increase unemployment in the economy.

Second, a complete evaluation of water efficiency measures must consider not only the consequences for water withdrawals but also their effects on input productivity. In fact, a water efficiency measure is one of the many possible resource saving technical changes that may occur in the economy. In other words, once the saving measures are applied, the economy will be able to produce more final goods with the same endowment of inputs as before the technical change. Therefore water savings obtained by water efficiency improvements are not only available to improve ecological quality but also to increase the production of many other goods and services that are relevant for people's welfare.

Finally, in case significant water efficiency measures are implemented in relevant economic activities, such as the tourism industry in our model, the adaptation of the economy may result in significant changes in output and water demand in other sectors and in the entire economy. These general equilibrium effects are relevant not only because of distributive reasons but also because of their role in determining the overall effect on water demand.

3. A case study in the Balearic Islands

Some basic facts may be useful to understand the importance of water scarcity as an economic management problem in the Balearic Islands. The Mediterranean weather makes rain water supply uncertain and highly variable through time. Geology and topography are also responsible for the lack of permanent rivers and of any other relevant surface water source. Under these conditions, as shown in Table 1, underground water is the main natural source of raw water and reservoirs

[5] The possibility that efficiency improvements in the use of natural resources could not result in the expected reduction in resource use is generally called the Jevon's paradox or rebound effect (see Alcott, 2005).

represent only a small fraction. But even underground water availability depends on very irregular rainfalls and during dry hydrological years reserves may fall down to 30% or 50% with respect to average years. A last important reason for water stress in the Balearic economy is the temporal decoupling between natural water supply, with 65% of rainfall concentrated in winter, and water demand reaching its peak in summer, which is the dry season.

TABLE 1
Total raw water use and water sources per sector (Hm^3/year)

	Ground -water	Desalinization	Water Reservoirs	Waste water	Total	Consumption share (%)
Public Consumption	100.7	3.73	7.2	1.8**	113.43	38.8
Irrigation	159.5	-	-	15.03	174.53	59.7
Industry*	0.7	-	-	-	0.07	0.2
Golf irrigation	0.8	-	-	2.94	3.74	1.3
Total	261.7	3.73	7.2	19.77	292.04	
Supply share (%)	89	1.03	2.5	6.7		

Source: elaborated from data of the PHIB, Govern de les Illes Balears (1999).
*Private uses not connected to the public water network.
**Used to irrigate public gardens and parks.

For obvious reasons, physical scarcity is the source of a potential conflict among water uses, mainly between the demand from a seasonal population of tourists (up to 34% of total population and 30% of total drinking water consumption) and water demand for irrigation in the agricultural sector which has a disproportionately large share of water withdrawals rights and water consumption with respect to its economic weight. The traditional solution to deal with conflicts produced by water scarcity, which consists in finding ways to put more water in the economy, has led to a well documented overexplotation and salinisation of groundwater resources. The supply-side strategies to manage water scarcity pursued by local authorities have included water imports from the continent and since 1994 the addition of 34 hm^3 of desalinisated seawater[6].

In our general equilibrium model, we assume a fixed underground raw water supply, the property rights of which have been previously distributed by the governments among farmers (who use water for irrigation)

[6] As a final product desalinisated water is similar to the traditional output of the drinking water industry. Nevertheless desalinisated water is more expensive to produce and the plant is only active in a case of severe droughts. Since the simulations in this paper refer to a normal year, desalinization plays no role in the results.

and drinking water supply firms. Farmers and firms need to extract water at certain energy and labour cost. As they are not initially allowed to buy or sell these water rights to each other water becomes a not transferable production factor between irrigation and drinking water production[7]. Drinking water is produced and distributed by using other production factors according to a Leontief production function and it is used as a final good by consumers or as an intermediate good by the other sectors of the economy. In the model, we assume flexible prices and clearing markets (See Appendix).

Let us assume a situation in which, provided a given set of water efficiency measures is implemented, the tourism industry could produce the same current level of tourism services and use 10% less drinking water than it is currently using, thus saving 3,9 cubic hectometres of water. Imagine now that these efficiency measures have been taken (changing the drinking water demand in the economy) and that the quantity of water withdrawals permits remains stable along with the water supply. If we use the general equilibrium model to simulate the way the entire economy adapts to the new situation we will reach the obvious conclusion that water demand will simply adapt to the previous level of water supply and the improved water efficiency will not result in any positive reduction of overall water consumption. Although the policy was designed to improve the ecological status of water sources there have been no such improvement. Water savings obtained this way imply an increase in the availability of water services in the economy, and the market economy takes advantage of these new conditions to create more wealth through the production of a better set of market goods, a category in which the ecological quality of water sources is not included. In other words, because water rights are given to drinking water firms for free and in the quantity decided by water authorities, the supply of these property rights is inelastic. With an inelastic water supply, the reduction of the tourism sector's water requirements is compensated by the boost in water demand due to the fall in the price of drinking water. As can be seen in Table 2 below as the price falls, there is an increase in the use of drinking water by households and intermediate uses. Moreover, the initial 10% reduction in the tourism sector is partially compensated by the price adjustments

[7] Apart from technical improvements of water uses the other option to reduce water pressures is by allowing the voluntary trade of water property rights between the rural and the urban sector. This kind of institutional arrangement is studied in Gómez, Tirado and Rey-Maquieira. (2004).

and once the new market equilibrium is reached, the sector only saves 7.5% of its initial water requirements.

4. Policy packages *vs.* policy measures

In fact, the previous result implies that some other measures need to be implemented so that the effect of higher water efficiency leads to a water source improvement. A reduction in the quantity of groundwater withdrawals while increasing the marginal value of raw water, and then the equilibrium price of drinking water, is a necessary condition to improve water sources[8].

When a water policy package is considered, the problem of water savings and environmental improvement can now be viewed from a social choice perspective. An improvement in the technical efficiency of water use is an opportunity to improve economic welfare through the provision of both market goods and better environmental quality. Society then has the opportunity to choose what combination of both kinds of goods to obtain as a final result. We have already seen how, if no action is taken over water markets prices or quantities, all water saved will be used to increase the provision of final market goods and the ecological quality of water will remain unchanged. However, reductions in the supply of raw water withdrawal permits would allow for different outcomes with an effective fall in water demand and an improvement in environmental quality. In any case, the market driven welfare gains may be valued through the Hicksian equivalent variation[9] or the quantity of money that will produce the same welfare improvement[10]. Figure 1 plots different possible combinations of market gains and environmental improvements for the case of a 10% reduction in the drinking water needed to provide the current activity

[8] The supply of water withdrawal permits in the Spanish context is exogenously determined by the Hydrological River Basin Authorities who are also in charge of controlling that drinking water average prices are close to the average financial costs of producing it. In the institutional Spanish framework the additional measures considered in this paper consist in both reducing the total supply of water withdrawals permits and in setting a price above the financial costs of providing drinking water in such a way that excess demand is prevented and the environmental costs of extracting water from underground is to some extent internalised.

[9] Calculated as the product of the monetary income in the baseline scenario and the proportional change of the Hicksian welfare index provided by the MPSGE.

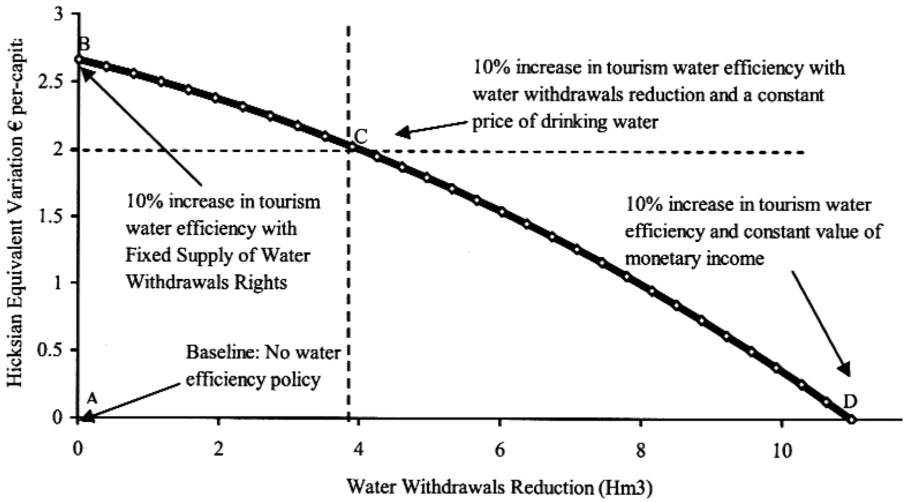
[10] In this paper, this measure only considers the effect on welfare of marketable goods and services.

level of the tourism sector in the Balearic Islands, whereas Figure 2 shows the water price set for each scenario.

TABLE 2
Drinking water consumption in baseline and different water policy scenarios

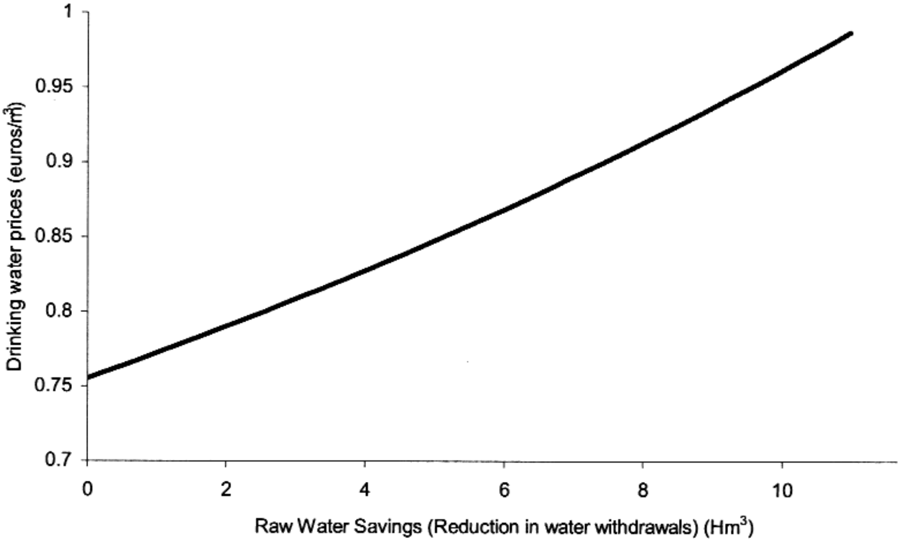
	BASELINE	With Fixed Water Supply			With Constant Drinking Water Price			With Constant Market Income		
	Hm³	Hm³	variation Hm³	% variation	Hm³	variation Hm³	% variation	Hm³	variation Hm³	% variation
Consumer's use	45,33	47,75	2,41	5,33	45,34	0,01	0,02	41,13	-4,21	-9,28
Intermediate uses:										
Tourism	39,01	36,08	-2,93	-7,51	35,12	-3,89	-9,97	33,28	-5,73	-14,69
Services	16,06	16,50	0,44	2,72	16,06	0,00	0,01	15,22	-0,84	-5,20
Stockbreeding & fishing	0,25	0,26	0,01	2,71	0,25	0,00	0,01	0,24	-0,01	-5,20
Energy	0,12	0,13	0,00	2,71	0,12	0,00	0,00	0,12	-0,01	-5,20
Water production & distribution	0,60	0,60	0,00	0,00	0,58	-0,02	-3,58	0,54	-0,06	-10,08
Industry	2,43	2,49	0,07	2,71	2,43	0,00	0,00	2,30	-0,13	-5,21
Builiding construction	0,09	0,09	0,00	2,72	0,09	0,00	0,01	0,08	0,00	-5,20
Irrigated agriculture	2,01	2,01	0,00	0,04	2,01	0,00	0,00	2,00	0,00	-0,11
TOTAL WATER SAVED			0,00			-3,90			-10,99	

FIGURE 1
Water use efficiency and the trade off between REAL income and ecological quality



As shown in Figure 1, there is a clear trade off between market gains (measured by their equivalent variation in the vertical axis) and environmental quality improvements (measured by reductions in water withdrawals). Point A is the baseline situation, where no water efficiency action is taken. Point B shows the effect of a water saving program when raw water supply is constant and the drinking water price is flexible (in this case, the price of drinking water falls by 8.5% and equilibrium water consumption remains unchanged). In contrast, point C represents the situation where the 3,9 Hm^3 initially saved are transferred to nature by reducing water withdrawals permits and this way preventing the fall of drinking water equilibrium price. As we can see in the figure, once the water initially saved by increasing the efficiency in the tourism industry is completely transferred to the environment there is still some remaining welfare improvement through the provision of market goods of around 2€ per capita. This benefit has a simple explanation. An input efficiency increase has two different sources of welfare improvements. The first one comes from the increase in production per unit of input that results in the sector where the efficiency improvements take place. The second comes from the reallocation of water and other factors according to the new relative prices and marginal costs. Transferring water savings to the environment eliminates the first effect from the market but not the second.

FIGURE 2
Relationship between water price and ecological benefits



The rest of the frontier in Figure 1 shows other possible combinations available for the society to choose. Provided a proper combination of water management measures is taken, interaction between technical efficiency improvements and water price policy schemes may be a powerful way of enhancing the environmental improvements. As we see in point D of this figure[11], the maximum reduction of water withdrawals which guarantees the preservation of the previous aggregate welfare level is higher than the quantity of water initially saved in the tourism sector. In the Balearic Islands example, if the efficiency improvement were costless, the initial reduction of 3.9 Hm^3 of current water requirements in the tourism industry could be converted in a reduction of more than 10 Hm^3 without reducing the real income of the overall economy. In this case, as Figure 2 shows, the price of drinking water would be 20% higher than that of the baseline scenario.

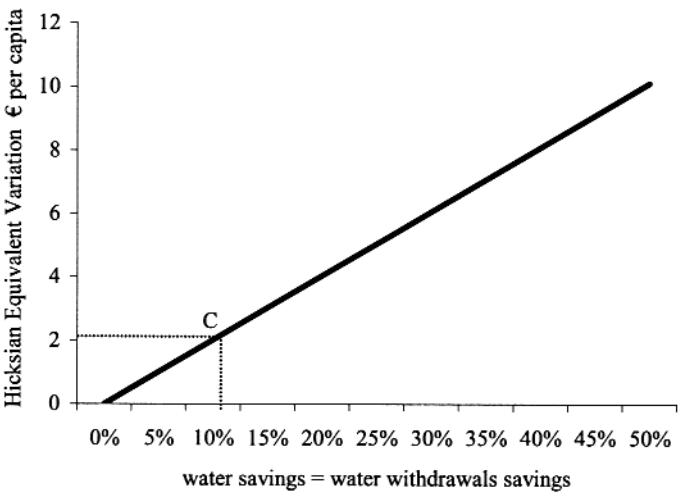
Such an increase in water price may seem politically difficult to implement. However, our simulations show that more moderate price increases would also substantially improve the ecological benefits of water efficiency measures. For instance, a 10% increase in water price leads to a reduction in water withdrawals of 7.79 Hm^3, twice the amount of water saved in the tourism sector just thanks to technical measures, and there still remains an increase of welfare from consumption of marketed goods equivalent to around 1.06€ per capita. Of course, the proper combination between market and non-market goods and services that must result from the water management plan can only be determined by public participation and stakeholder involvement.

The possibility of obtaining not only ecological benefits from the policy package but also higher production is an important result once the fact that efficiency measures are costly is considered. Our analysis shows then that a properly designed policy package could meet the ecological targets and produce an income increase that would at least partially compensate for the social costs of implementing those measures. In fact, in our analysis the Hicksian equivalent variation sets a lower bound to the real willingness to pay for enhancing the water efficiency of the economy since it does not include the social value of the environmental benefits.

[11] Point D is obtained considering a reduction in water extractions that compensates, in terms of utility, the efficiency improvements. The policy package implies, therefore, a zero equivalent variation.

Figure 3 is a generalisation of this previous result and represents the market gains of several water efficiency measures in the tourism sector in the case where initial water savings are completely transferred to nature through an equivalent reduction in water withdrawals[12].

FIGURE 3
Markets gains of water efficiency measures in tourism sector when initial savings are used to reduce water withdrawals in the same amount



Of course, even if the water efficiency measures were efficient and could be presumed to be socially desirable, their implementation needs to cope with an incentive problem because of two reasons. First, the water policy ecological benefits are externalities and no rational firm is willing to spend money on saving water for the sake of preserving the common environment. Second, some of the market advantages and disadvantages will be enjoyed and suffered by firms and consumers different from the one that becomes more efficient in the use of water. Therefore, for the policy maker it would be interesting to find the water policy instruments to capture this additional income in order to finance the efficiency measures.

[12] To be clear, in Figure 1 the efficiency measures are the same for every scenario, but the water price varies (Figure 2). In Figure 3, water efficiency measures of different degrees are applied whereas water price is properly set to ensure that the initial impact of those measures fully results in a reduction in water withdrawals.

5. Sensitivity analysis

The previous results may be highly dependent on the values of the parameters used to calibrate the general equilibrium model. These parameters are shown in Table 3. In order to test the robustness of the results a sensitivity analysis over those parameters that are potentially the more relevant has been implemented. Specifically, we have considered different values of the elasticity of substitution between drinking water and capital in the production sectors of the economy $\left(\sigma_s^{kap}\right)$ and of the price elasticity of tourism demand (ε).

TABLE 3
Parameters of the Balearic AGEM

Elasticities	Values
Substitution Elasticity in the Irrigated Agricultural sector	
Capital and Land [a]	$\sigma_{reg}^{kt} = 0.3$
Aggregate Capital-Land and Aggregate Water for crops	$\sigma_{reg}^{ka} = 0.2$
Land and Aggregate Capital-Land-Water for Crops [a]	$\sigma_{reg}^{va} = 0.7$
Substitution Elasticity in the Non-irrigated Agricultural Sector	
Capital and Land	$\sigma_{sec}^{kt} = 0.3$
Labour and Aggregate Capital-Land	$\sigma_{sec}^{va} = 0.7$
Substitution Elasticity in Other Sectors	
Capital and Water	$\sigma_s^{kap} = 0.3$
Substitution Elasticity Between Imported and Domestically Produced Goods [b]	$\sigma_g^{ar} = 4$
Substitution Elasticity between irrigated and non-irrigated agricultural products	$\sigma_{agr} = 1$
Price Elasticity of Export demand for Tourism [c]	$\varepsilon = -2$
Transformation Elasticity of production [d]	$\Omega_{agr} = \Omega_s = 2$

[a] Boyd and Newman (1991) and Seung *et al.* (1998).
[b] Rutherford and Paltsev (1999) y Goodman (2000).
[c] Blake (2000).
[D] Equal to all sectors and obtained as the average of the transformation elasticities considered in Seung *et al.* (1998).

TABLE 4
Sensitivity analysis over the Hicksian equivalent variation (€ *per-capita*)

			Price elasticity of export demand for tourism				
			-1	*-1,5*	*-2*	*-2,5*	*-3*
With Fixed Water Supply	*Substitution elasticity capital-water*	*0,1*	2,00	2,56	2,89	3,10	3,25
		0,2	1,72	2,38	2,76	3,01	3,18
		0,3	1,51	2,24	**2,66**	2,94	3,13
		0,4	1,34	2,13	2,59	2,88	3,09
		0,5	1,21	2,04	2,52	2,84	3,06
With Constant Water Price	*Substitution elasticity capital-water*	*0,1*	1,16	1,71	2,03	2,23	2,38
		0,2	1,16	1,70	2,02	2,23	2,38
		0,3	1,15	1,70	**2,02**	2,23	2,38
		0,4	1,15	1,70	2,02	2,23	2,38
		0,5	1,15	1,70	2,02	2,23	2,37

To present this sensitivity analysis we have chosen two single policy options as reference points to test how the Hicksian equivalent variation changes when the model is calibrated and simulated with other values of the selected parameters. Both policy options assume the implementation of the efficiency package in the tourism industry but the first one considers a fixed supply of raw water (that is point B in figure 1) and the second assumes constant drinking water prices (point C in figure 1). Table 4 shows the Hicksian equivalent variation for different values of those parameters (we use columns for the different values of the price elasticity of tourism demand and rows for both the policy options and values of the substitution elasticity).

Market driven welfare gains are higher the lower the elasticity of substitution $\left(\sigma_s^{kap}\right)$. A low elasticity of substitution implies that other production sectors have less capacity to absorb the water surplus from the tourism sector. For this reason, the new equilibrium requires a higher reduction in drinking water prices leading to higher welfare gains. In the opposite situation, if prices are not allowed to change, the value of the substitution elasticity is not relevant to determine welfare gains. The equivalent variation is more sensitive to changes in the price elasticity of the demand for tourism services. In general, welfare gains are higher the bigger is that elasticity. Improving water efficiency increases tourism supply and, a higher price elasticity of demand means a lower reduction in equilibrium prices and a higher increase in tourism income. All results are in the same order of magnitude and the qualitative results presented above seem robust.

6. Distributional effects of water savings measures

Our general equilibrium approach allows a detailed analysis of the specific effects of water policy options on the different production sectors as well as a calculation of distributional effects.

As an illustration, Figure 4 shows changes in Gross Value Added of tourism and agriculture, the most affected by the policy package, resulting from the combination of a 10% increase in water efficiency in the tourism industry and different levels of reductions in water withdrawals with their associated price increases. Figure 5 shows the remaining sectors where the impact is low and less significant.

FIGURE 4
Effects of a 10% increased efficiency in the tourism sector over gross value added (GVA) of agriculture and tourism as a function of reductions in water withdrawals

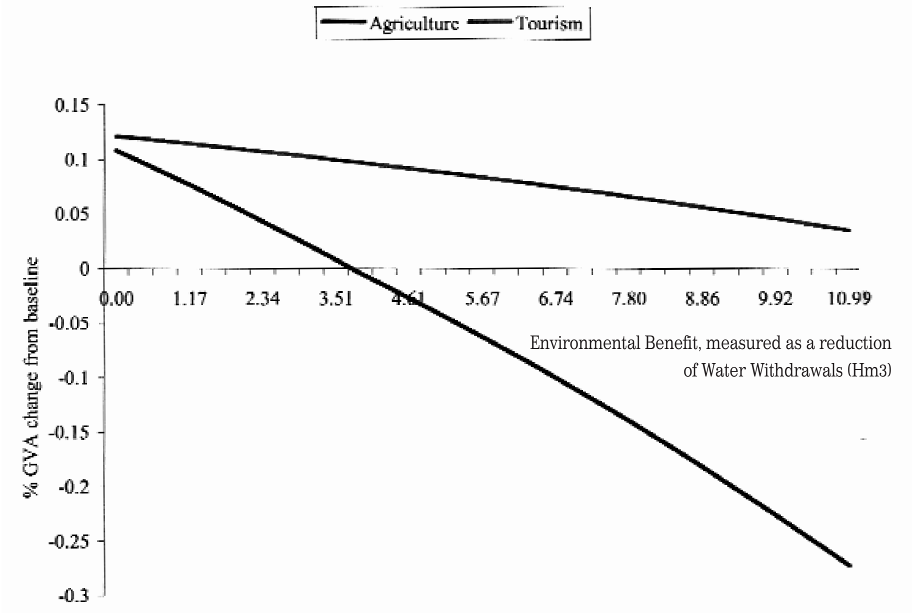
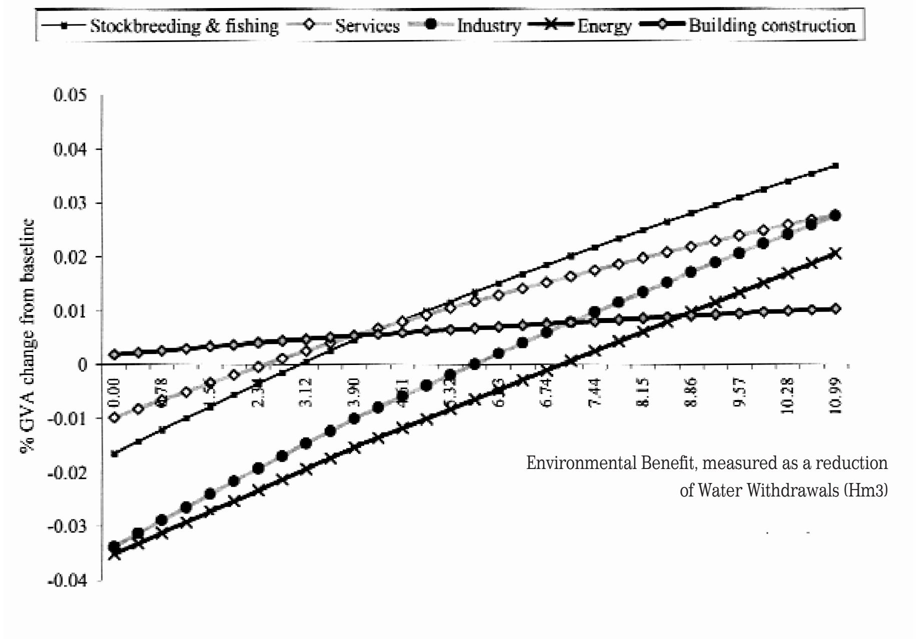


FIGURE 5
Effects on gross value added (GVA) of the other sectors of a 10% increased efficiency in the tourism sector with water price measures



Given its enhanced water productivity the tourism output is always higher with respect to the baseline scenario. On the contrary, the agricultural sector will only get some positive benefits provided the water price increase is not very high and not much water is transferred to nature. This large sensitivity of agriculture is due to low substitution possibilities between drinking water and other inputs in the agriculture technology. Drinking water is less important as a production input in the remaining sectors of the economy. This way the impact of the considered set of water policy options is almost completely determined by the reallocation of other production factors from or to tourism and agriculture. Thus, as shown in Figure 5, most of the productive sectors reduce their output when water withdrawals are constant and water prices are low (in order to provide the factors demanded by the expansion of agriculture and tourism), and have positive output effects when water withdrawals are lower and drinking water prices higher (in order to absorb those inputs that became redundant in the agricultural sector). In any case the output effect does not seem to be significant.

FIGURE 6
Effects of a 10% increased efficiency in the tourism sector over the functional income distribution

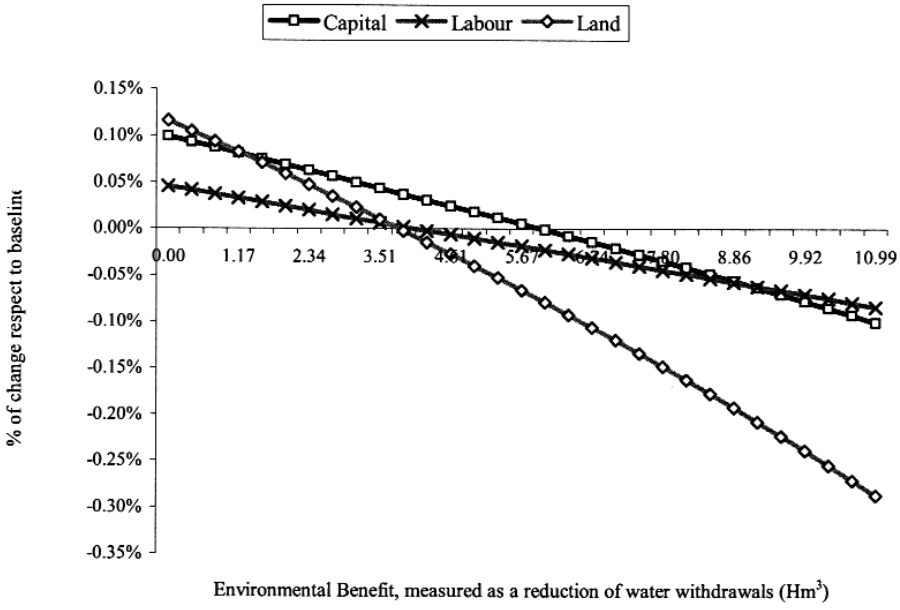


Figure 6 shows the impacts of the different policy options over the functional income distribution. The water policy package will have a positive effect on labour, capital and land revenues, provided not much of the water is transferred to nature[13]. Consistently with Figure 4, agricultural land income is the most affected by the water policy measures, while labour income is the least sensitive due to high labour mobility between different sectors.

7. Conclusions

The challenge of simultaneously guaranteeing the ecological quality of water ecosystems and maintaining an adequate provision of water services for human uses requires the identification of those policies with the most favourable trade-offs between these two potentially competing objectives. Using an Applied General Equilibrium Model for the Balearic Islands we show how a general equilibrium methodology may be a useful tool for the analysis of some water policy options. Specifically, for the Balearic Islands it is shown that the efficiency measures alone may not be effective to reduce pressures on water ecosystems. However, their combination with an appropriate reduction in the supply of water withdrawals permits, and the proper increase in drinking water price provides the policy maker with a menu of market and ecological benefits. For instance, the combination of realistic water saving measures in the tourism sector (10% savings of current water consumption) with moderate water price increases (10% increase) could yield sizable reductions in pressures on water resources (7.79 Hm^3 reduction of water withdrawals) and still leave the opportunity to increase the real income of the economy (in 1.06€ per capita).

Of course, water efficiency measures are costly and the net effect on income of the policy package could be negative. Therefore this information should complement data on the costs of implementing water efficiency measures to calculate the net costs of achieving a good ecological status of the water ecosystems. Finally, it is shown that this policy has distributional effects that vary depending on the specific combination of ecological and monetary benefits chosen by the policy maker.

[13] Land only refers to agricultural land. Income of urban land is considered to be a part of capital income.

Appendix A1. The general equilibrium model of the balearic economy

A1.1 Description of the model

The model considers ten economic activities including rain fed agriculture, irrigated agriculture, the rest of primary activities (livestock, mining, fishing, etc.), energy, manufacture, construction, tourism, services and two complementary sectors of drinking water, the traditional one and the one based on desalinisation of sea water (however, the desalinisation does not activate for any of the considered scenarios).

The economy uses five production factors: land, capital, labour, water and seawater. Land is only used in agriculture and is mobile among both the irrigated and rain fed crops. Capital is specific of any sector except agriculture where it is mobile between irrigated and nonirrigated. Labour is mobile. Farmers and water supply firms own some water rights over groundwater and these rights are not mobile across sectors. Raw water is a primary non-transferable production factor that must be extracted. Drinking water is produced and distributed by using raw water, capital, labour and intermediates.

There are four agents in the economy: consumers, firms, government and the rest of the world. Consumers are identical and they own the initial endowments of land, labour, capital, and raw water. There is also a representative firm in any economic sector and the only activity of the public sector consists in collecting the tax revenues and distributing them to consumers as lump-sum income transfers. The Balearic Islands are assumed to be a small open economy and, consequently, import demand and export supply of any good or service but tourism are determined by world prices.

Consumers maximize a Stone-Geary utility function with a minimum subsistence level of drinkable water demand. Consumer income is obtained by the sum of primary factors revenues and lump sum transfers. Consumption expenditure is obtained after deducing investment and net saving from consumer income.

Investment is exogenous and is defined by a Leontief aggregate of traded and non-traded goods. Import demand and export supply are determined by external prices and are both defined by using the normal Armington assumptions. The foreign demand for tourism services presents constant substitution elasticity.

We model both irrigated and nonirrigated crop production technologies as nested multilevel CES. The first level uses a CES function to aggregate inputs specific to agriculture to obtain a capital-land composite, and a Leontief function to get extracted raw water using energy and groundwater (in the nonirrigated sector this nest does not apply). In a second level these composites are combined using a CES to obtain an aggregate, to be combined with labour in a third level. Finally, all these factors are combined with intermediate inputs using a Leontief technology to obtain the final output. This structure includes all the available possibilities of substitution between primary factors. Additionally the overall crop production is an aggregate of irrigated and nonirrigated outputs with a constant elasticity function. Following the Armington methodology we assume a constant elasticity of transformation for this tradable good.

The water production and distribution sector extracts water and transforms it into drinking water using capital, labour and intermediate inputs in fixed proportions.

The rest of production technologies are specified by a three level nested production function. At the first level, capital and drinkable water are combined using a CES. This composite is combined, at the second level, with labour using a Cobb-Douglas technology. Then, this aggregate is mixed in fixed proportions with intermediate inputs to produce the final good.

A1.2 Model data

The basic data comes from the 1997 Input Output table of the Balearic Islands (G.I.B, 2004).

Agricultural data comes from the National Agrarian Accounting Network (M.A.P.A., 1999) and the Balearic Labour income was obtained by adding wages and social security payments. Land rents were obtained from data provided by the land price survey of 1997. For simplicity, we treat tourist consumption as exports.

Water endowments were obtained from the *Hydrological Plan of the Balearic Islands* (G.I.B. 1991). The agricultural endowment has been calculated from the effective water consumption data of *Plan National of Irrigated Land* (M.A.P.A., 2001), considering a return flow of 22%, and from data of hectares irrigated for the different corps in 1997.

For the water desalinization sector we use the estimated cost of 0.58 euros in 1997 per cubic meter of drinking water (provided by the water supply authority of Palma de Mallorca- *EMAYA*) with an installed capacity of producing 30 cubic hectometres (we assume this to be the endowment of sea water in the baseline scenario) and capital and supplies costs provided by CEDEX (1995) and Torres (2001).

A1.3 Model calibration

The model has been calibrated by using the MPSGE (*Mathematical Program System for General Equilibrium*) module of the GAMS (*General Algebraic Modelling System*) programming platform (*GAMS*, 2001).

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Resumen

Utilizamos un modelo de equilibrio general aplicado de las Islas Baleares para explorar las implicaciones de mejoras de eficiencia en el uso del agua por el sector turístico. Se demuestra que estas medidas de eficiencia no son útiles para mejorar la calidad de las aguas si no se acompañan de disminuciones efectivas en las extracciones y de aumentos en el precio del agua. Este paquete de medidas abre un abanico de posibilidades en términos de calidad ambiental y producción de bienes de mercado. El modelo permite también obtener resultados sobre efectos distributivos relevantes en la gestión de los recursos hídricos.

Palabras clave: equilibrio general aplicado, economía del agua.

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