Cost analysis for water distribution in agriculture

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Abstract:

This paper uses a *Translog* form to estimate the water distribution cost for an irrigation consortium. The consortium operates under conditions of the under-utilization of facilities; thus, to achieve *full cost recovery*, water charges must be set at a higher level than efficiency. As a consequence, farmers may decide to reduce their use of the public irrigation service and instead exploit groundwater. The estimated Translog function explains the costs of water services throughout the irrigated area, and identifies items for which pricing does not accentuate the competition between the use of surface water and groundwater. Based on the estimated coefficients, a hypothesis is hence presented for pricing water provided by the consortium.

Keywords: irrigation, water pricing, Translog, cost analysis

1. Introduction

EC Directive 2000/60 *(Directive)* is the main framework for water management in the EU, whether inland surface waters, transitional water, coastal water or groundwater. Its principle is to protect ecosystems by facilitating the sustainable use of water, reducing pollution and mitigating the effects of drought and flooding. The *Directive* also states the need to implement a continuous and simultaneous monitoring of water availability and requirements for use in various territories. It defines the terms of use and the most appropriate economic instruments with which to influence the choices of consumers. The *Directive* calls for responsible policy to cover industrial and environmental costs, and the *opportunity costs* of water resources (Wateco, 2002). In Italy, Law 13 of 2009 requires the development of *water management plans* that contain these rules and tools.

It is important that a *management plan* is established to provide water services at reasonable prices. Water is essential for human life and ecosystems, but is also important for productivity in activities such as agriculture, in which large quantities are required at low prices to compete internationally. In particular, society has an interest in maintaining the low price of water services provided by irrigation consortia (Water User Associations, WUA), which is a key factor in irrigating vast areas of the Mediterranean Region. These services should be provided at prices that ensure a viable alternative to the use of groundwater and to prevent the indiscriminate exploitation of these resources (Dono *et al*., 2010). In contrast to the withdrawal of groundwater by individual farmers, the use of agricultural water based on WUA facilities is quantifiable and, above all, is conditioned by existing instruments regarding the governance of water use. Therefore, an increase in water prices, inducing farmers to reduce the use of WUA services to draw more groundwater, is disadvantageous, acting against the objectives of covering costs and ensuring environmental protection, as set by the *Directive* itself.

To design payment systems that resolve these contradictions, it is useful to study the formation process of the costs of WUA services. In this paper, we propose the use of a flexible functional form to estimate these *industrial* costs for an irrigation WUA at Oristano, Sardinia. An advantage of this approach is that the explanatory variables of the function that considers the supplied goods do not include the total volume of water; instead, the function considers the land served and the volume of water applied per hectare. These variables allow the development of water payment systems which, in decision-making businesses, place on different levels the costs of the WUA service and the costs of drawing groundwater. This approach can help to overcome the inconsistencies between a policy of cost recovery in public amenities and the protection of groundwater resources.

2. Water distribution in the Water User Association of Oristano

The studied WUA provides surface water to *Campidano d'Oristano* farms, in an area of 25,000 ha. Water is distributed to twenty six districts that can be classified into four types based on the technological characteristics of water plants and water systems. The first type, HP (high pressure), includes districts where water is distributed through pipelines and pumping equipment that transport water to tanks at high altitudes; the farms receive high-pressure water (> 3 atmospheres). The districts in the second category, LP (low pressure), use a similar system in which water is distributed under low pressure (0.5–3 atmospheres). In the third category, GL (lifted and gravity), pumping plants raise the water by several meters, and it is then distributed through ducts, without being under pressure. In the districts of the fourth category, GR (gravity), water is delivered to farms solely by gravity, as water outlets are located at elevations above the area to be served. Water is carried in channels, without being under pressure. Table 1 shows, for the years 1995 to 2005, the average primary operational costs of the WUA (labor and electricity), area of irrigated lands and amount of water delivered to the four types of districts. The data show the differences in average costs among the four types of district.

Table 1: variable costs, irrigated area and water supplied (1995–2005) in the Oristano WUA.

Macro-districts	Energy cost (€)	Labor cost (€)	Irrigated area (ha)	Water delivered (000 m^3)	€ / ha	€ / m^3
HP	545,705	304,049	3137	20,164	270.8	0.042
LP	315,915	324,121	1946	26,601	328.9	0.024
GL	11,860	31,501	195	1595	222.2	0.027
GR	0	183,605	1423	13,547	129.1	0.014
WUA	873,480	843,276	7,216	66,669	237.9	0.026

During the analysis period, the WUA restructured the network. In some cases, these interventions have modernized the system without changing the technology; in other cases, the network was transformed from channels to pipelines, both high and low pressure. Moreover, the number of permanent workers was reduced from 24 to 7, and the number of seasonal workers was increased from 36 to 38. These changes have simultaneously transformed the number of employees per hectare of irrigated land and the volume of water, and changed the labor cost per employee.

3. Estimated costs of water distribution

The way the WUA works is very similar to that of private companies. In fact, the WUA Board includes a significant representation of the farmers that use the provided irrigation services. The management model of this type of public companies refers to what Martone defines of ‘contracting out’, where the company management is entrusted to independent third parties who are responsible to carry out the directions given by policy makers and administrators (Martone, 2007). In fact, all structures and facilities of the WUA used for distribution of irrigation water are made with funds from the Government, while operational management is entrusted to the WUA Board. Short term and long term management are thus different. Through representation into the Board, the users of the irrigation service are the same farmers who also run private farms, using water delivered by the WUA, and then operate in competitive markets through their agricultural private business. Therefore, the behavior of individual entrepreneurs can be considered optimizing, with the aim to maximize profit. The cost for irrigation appears in the budgets of individual farms and the objective of minimizing production costs also involves minimizing irrigation costs. Farmers make production decisions that may require a certain amount of irrigation service. The WUA system therefore contains within it elements of competition that lead to the minimization of costs: the management of the WUA is comparable to that of a "rational" entrepreneur for what concerns the management of short-term, which aims to minimize the cost to produce an exogenous level of output, the irrigation service. Indeed, the cost for irrigation incurred by the consortium is then shared among farmers and thus becomes a private production cost for the use of an input, the irrigation. The introduction of these elements of competition promotes the efficient allocation of resources and thus minimize the costs of the irrigation in the short term. Short-run decisions of the WUA Board are guided by the minimization of costs for the irrigation of private companies, since these costs will still be covered by the farmers. Costs of irrigation water distribution can be reconstructed with an *engineering* approach that examines the relationships between inputs and outputs (production function), then identifies the optimal combinations of technical inputs for given production levels and, given the inputs' prices, obtains the cost (Koutsoyiannis, 1981). Unfortunately, it is not easy to establish these relationships when it is necessary to determine the cost of service provided by a consortium as a whole, which may operate various types of plants. Moreover, an engineering approach generally provides information related to the volume of water supplied and not to the size of serviced areas. As mentioned above, the objective of this analysis is to relate to the size of serviced areas the cost generation process. For this reason, for an econometric analysis, we adopt an approach that estimates the cost function using observed values rather than calculating costs from technological relations.

Many previous studies have performed econometric analyses of the water industry, generally focusing on the systems developed for residential supply. Among the more recent studies are those of Kim (1987), Kim and Clark (1988), Fabbri and Fraquelli (2000), Fraquelli and Moiso (2004), Mizutani and Urakami (2001), Antonioli and Filippini (2001) and Barabaschi (2007). Many of these studies used data from several companies, reported over several years, to estimate cost models whose explanatory variables include the technical characteristics of the network, or they considered water supply as a multiple service. These studies generally evaluated the effects of regulatory policies and charging for use, and to this end also studied the existence of economies of scale in water services, with the aim of identifying the optimal scale of operation. Among previous analyses of the Italian water sector, Fabbri and Fraquelli (2000) employed a total cost *Transolg* function to study the impact of the Galli Law on the cost of integrated water services management. Antonioli and Filippini (2001) used the *Cobb–Douglas* model to study the role of labor costs, energy and capital in providing a number of clients with a single output (i.e., water). Their analysis considered various specifications of the system, such as network length and extent of losses. Barabaschi (2007) used the *Translog* cost function to investigate the water industry, employing data collected since 2002 for 203 Italian providers of an aqueduct service. This work showed that the volume of water supplied, the number of users served, their location within the territory, and therefore the length of the network involved in distribution, are all outputs of joint water service. Therefore, this is a complex service that may be characterized differently depending on the relative weighting of these different outputs and that may be reductively assessed only according to the volume of water supplied. Consequently, the multi-function estimated by Barabaschi provides the elasticity of cost with respect to each of the outputs.

Relatively few studies have investigated the costs of irrigation water distribution in agriculture. Dono (2003) estimated a cost function whose shape is a cubic restriction imposed a priori. This functional form is consistent with the theoretical behavior of cost functions. However, the proposed model does not include input prices as explanatory variables in production costs. In fact, the function is merely the link between costs and a multi-output system in which the extent of irrigated area is considered in addition to the volume of water.

3.1 Main features of the *Translog* function

The present study uses a flexible functional form that eliminates prior restrictions on its first and second derivatives, as is preferred in empirical analysis. Specifically, the analysis uses a *Translog* function, that was used for the first time by Christensen, Jorgenson and Lau (1973) in an econometric estimation of production based on two inputs and two outputs. In 1971, the same authors had suggested the use of *Translog* to study costs through the principle of duality, as detailed later by McFadden (1978). *Translog* has been used to study multi-output dimensions, including by Panzar and Willig (1977), Chambers (1988) and Panzar (1989). The advantage offered by the *Translog*, with respect to other flexible forms, is to be more parsimonious in the number of parameters to be estimated. However, a limitation of this approach is that null values are not allowed because the variables are expressed in logarithmic form and the logarithm of zero is not a finite number. A solution to this problem was proposed by Weninger (2003), using the method of *small valuing.* The *Translog* functional form has the following structure:

$$\ln C(z) = \alpha_0 + \sum_i \alpha_i \ln(z_i) + 1/2 \sum_i \sum_j \alpha_{ij} \ln(z_i)\ln(z_j), \quad \alpha_{ij} = \alpha_{ji}, \tag{1}$$

For convenience of notation, we consider the case in which the first elements of *z* are the quantities of outputs *(y),* a second group *(w)* includes the prices of inputs, and a third *(λ)* is given by *instrumental* variables that represent structural or environmental characteristics that influence the performance of the system. The *Translog* is therefore a quadratic function of the logarithm of z. To comply with the principle of duality, the multi-output cost function must be homogeneous of degree one in input prices. This restriction has been imposed by the method suggested by Greene and Christensen (1976), sharing the prices of inputs and the total cost for the price of an input.

3.2 The Translog cost function for water supply for irrigation

A *Translog* model is estimated for each of the four systems used by the consortium to distribute water to the four types of districts. The estimation uses annual data (1995-2005) on costs, output supplied and input prices, and an environmental variable for individual districts of the four types defined above. In all four cases, the model represents a water service that provides two outputs: the size of irrigated area and the volume of water applied per irrigated hectare. Defining this set requires overcoming a common problem in studies of multi-output functional forms: the strong correlation between outputs. In the present case, there is a strong correlation between size of irrigated land and total volume of water supplied. The multicollinearity disappears as an alternative second output, watered intensity, is employed, calculated as the ratio between irrigated area and total water volume. Thus, the irrigated area and watering intensity are a transformation of water volume, and the estimated function enables such values to be derived. The inputs considered in the function are energy and three categories of labor: permanent, casual and technical staff.

The *Translog* model is based on an estimate of the *dual*, which according to Shephard’s lemma derives the cost function with respect to input prices and thus derives the demand functions of the inputs bound to the vector of outputs. In the *Translog*, the variables are in logarithmic form, so the derivative of the cost function with respect to the price of an input is equal to the share of expenditure for that input on the total cost expressed by the function. This allows the creation of a system of equations that includes the cost function and the share of spending on various inputs. In this way, an increase in efficiency of estimation is gained. This system is estimated using the method proposed by Zellner (1962), which considers the heteroskedasticity and the simultaneous correlation of errors between the equations (Seemingly Unrelated Regression).

4. Results of the econometric estimation of the four models

Table 2 shows the results of estimates of four models that reproduce the structure of costs incurred annually for water delivery in an average district for each of the four systems.This time reference has immediate practical utility, as the consortia calculate the payments required to cover their operating costs on an annual basis; therefore, the calibrated policy of pricing is compared with this time horizon.

The model that depicts the costs in *water delivery system under high pressure* (HP) explains 92.1% of the cost variability. Most of the variables are statistically significant. The model *pipeline and low pressure* (LP) explains 60.5% of the variability of the data. In the model for *channels by gravity* (GR), the inputs are solely the categories of labor: hard labor, casual workers and technicians. Unlike piped districts, the channels lose large amounts of water, up to 30% of the input volume. The water lost is therefore used as an *environmental variable* in the estimation of the model, explaining 44% of the variability. Finally, the results derived from the cost model in the network *channels and lifting* (GL) are unreliable, given the small number of observations. The estimates are shown in Table 2 for completeness.

Table 2. Estimates of the costs of water delivery via four different technologies

Ind. Variable	High Pressure		Low Pressure		Lifted Gravity		Gravity	
$\bar{C}$	11.89041	***	11.63566	***	10.44431	***	10.32848	***
PrFx	0.067946	***	0.198915	***	0.198504	***	0.343989	***
PrAv	0.290386	***	0.309351	***	0.435940	***	0.580723	***
PrEn	0.633720	***	0.469242	***	0.314343	***		
*PrFx * PrFx*	0.007534	***	-0.004657		1.333781		2.340915	***
*PrFx * PrAv*	-0.016169	***	-0.002017		-0.863446	***	-2.126350	***
*PrFx * PrEn*	0.008794	**	0.006670		-0.358713			
*PrAv * PrAv*	0.209019	**	0.201878	***	-0.105061		1.937992	***
*PrAv * PrEn*	-0.035478		-0.175069	***	0.765615	***		
*PrEn * PrEn*	0.064494		0.190112	***	-0.087053			
Ha	0.798441	***	0.825536	***	0.407304	***	0.592361	**
A/Ha	0.378109	***	-0.089591		0.455764	***	0.100589	
*Ha * Ha*	0.074323	**	0.166666	*	-0.701072	*	0.224397	
*Ha * A/Ha*	-0.059316		-0.027856		-0.245399		-0.540636	
*A/Ha * A/Ha*	0.250888		-0.523721	***	0.145460		-0.191245	
*Ha * PrFx*	0.003696		0.099084	***	-0.228624	***	-0.195839	***
*Ha * PrAv*	-0.048788	***	-0.175388	***	0.304961	***	0.256146	***
*Ha * PrEn*	0.054619	***	0.089920	***	-0.066023	*		
*A/Ha * PrFx*	0.000700		0.062706	***	-0.506583	***	-0.195839	***
*A/Ha * PrAv*	-0.087746	**	0.198915	***	0.511855	***	0.218365	***
*A/Ha * PrEn*	116630	***	0.309351	***	0.008125			
Perd					-0.135006	***	-0.372878	
*PrFx * Perd*					0.351925	***	0.266120	***
*Perd * PrAv*				***	-0.436163	***	-0.280922	***
*Perd * Perd*				***	-0.190741		-0.613597	
*Perd * Ha*					0.263130	*	0.184168	
*Perd * A/Ha*					0.285853		0.580907	
*Perd * PrEn*					0.070641	**		
K1	-0.167576	***	-0.334101	***	-0.761421	***	-0.509385	***
Bx	0.182456	*						
Adj. R2	0.906502		0.748512		0.988468		0.486726	
Observations	57 (228)		65 (260)		17 (68)		67 (201)	

*** The significance is <0.01%, ** <0.05 * <0.1. Numbers in parentheses indicate the total number estimated by the balanced system. R2 for the GL model is unreliable because of the small number of observations.

Variables - PrFx: hard workers price; Prav: casual workers price; PrEN: electricity price; Ha: irrigated area; A: distributed water per hectare; Perd: water lost from the network; K1: dummy for labor reorganization; BX: dummy for district changed from HP to LP.

In all cases, the estimated coefficients are highly significant for parameter K1, which captures the effects of the reorganization of staff and their tasks, as implemented by the consortium in 1999. The variable K1 is a dummy present in all models and is valued 1 in 1999–2005 years. The estimate of its coefficient is always negative, indicating that the reorganization of labor had the effect to reduce costs. The *environmental* variable for network losses has a negative sign, indicating that a reduction in losses would result in higher distribution costs. This result is consistent with the reality of network management in channels, for which a loss is technologically expected because to serve the needs of all users, the channel must be filled, which results in leakage of water that is unusable. The losses can be reduced, albeit partially, by a greater commitment to work; e.g., calibration of the network entries in hours of employment other than ordinary. This greater commitment increases the cost of water distribution. Thus, the result indicates the cost parameters associated with intervention to reduce losses to obtain an output, water savings, which has value for farmers and for society in general.

4.1 Elasticity with respect to cost

The Translog gives the direct point[1] elasticity of a variable differentiating the function with respect to the logarithm of the variable.

$$\varepsilon_{Cz_i} = \frac{\Delta C}{\Delta z_i}\frac{z_i}{C} = \frac{\partial \ln C(z)}{\partial \ln(z_i)} = \alpha_i + \sum_j \alpha_{ij} \ln(z_j) \tag{2}$$

The estimated elasticity of the cost to the outputs can be used to detect whether the production system can gain economies by an increase in activity level. As is well known, an elasticity less than one indicates that the increased activity results in an increase in cost that is less than proportional; a value greater than one indicates that costs grow more than proportionally. With reference to average costs (AC) and marginal costs (MC), as shown in Figure 1, the condition of elasticity less than one is to the left side of the minimum point of average cost, where MC < AC. The condition of elasticity greater than one is to the right of the minimum average cost, where MC > AC.

4.2 General results

Table 3 shows the elasticity of cost with respect to irrigation and the values of average and marginal cost, estimated by the function. The elasticity of cost with respect to both outputs is always positive and less than one. Therefore, the elasticity plots to the left of the minimum average cost and is not making any *specific* economies permitted by the structure. Under such conditions of the *under-utilization* of facilities, a water pricing that aims to cover the total costs of water delivery must set the payment at the level of AC, by applying an amount well above MC. Since MC indicates the *pricing* efficiency, under these operating conditions there exists a conflict between the objectives of covering costs and of efficiency in water service.

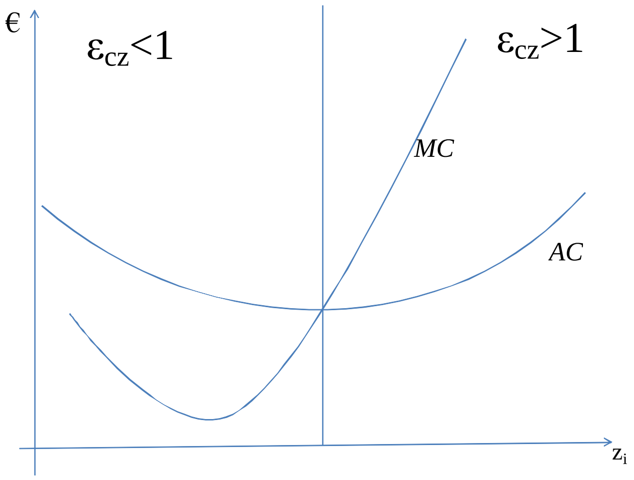

Figure 1: *Marginal cost (MC) and Average cost (AC)*

Table 3: Elasticity of cost w.r.t outputs.

Cost Elasticity	HP	LP	GL	GR
ε_{ha}	0,79844	0,82368	0, 554897	0, 896599
$\varepsilon_{w/ha}$	0,37811	-0,08392*	0, 509588	0, 497899*
R^2	0, 943233	0,830987	0,985403	0,631033

* the value of this parameter is not significantly different from zero.

There exists an environmental effect of the price required to cover costs. Indeed, a full coverage pricing applied within a volumetric scheme of payments influences the decision (i.e. assessment of the cost per cubic meter) between surface water (i.e. water supplied by the WUA) and groundwater. In this way, the WUA would increase the price disparity between the costs of the two water sources, thereby enhancing the exploitation of groundwater. This stimulus would be relevant in the analyzed

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[1] Since all variables have been indexed on the mean, Table 3gives elasticity at the mean point.

case. For instance, in 2001, which is close to the average situation of the entire analysis period, payments made by the water users covered 77% of the operational costs, thereby requiring an average increase of 23% in the water price. As indicated by other studies, this would induce farmers to replace the water supplied by the WUA with groundwater (privately drawn) (Dono et al., 2010). Any increase in the exploitation of groundwater would act against the objective of protecting environmental resources. Under these conditions, a reduction in the use of water delivered by the WUA, combined with the cost recovery, would lead to a gradual reduction in use of this public service. Indeed, under the current elasticity condition, a reduction in WUA water use would mean an increase in its average cost. In turn, this would result in price increase and thus a further disincentive to use the WUA water services and establishing a circular process that would worsen the conditions of the WUA and increase the pressure on groundwater. Instead, the results indicate that an increase in output would reduce the average cost of the water service, even bringing it closer to that of efficiency. Moreover, cost coverage would benefit from lower prices, which would avoid the replacement of surface water with groundwater.

Irrigated lands are influential in generating costs. It can therefore be inferred that irrigation water *pricing* based only on the volume of water used is incomplete and may be inadequate. As others have already warned (Barabaschi, 2007), description of the water service as a complex system that produces a set of outputs is required for services for irrigated agriculture, and is in line with the conclusions drawn in this study. The present results may be useful because they support the formulation of payment schemes unrelated directly to water volume, and thereby avoiding direct competition between WUA surface water and groundwater. In particular, the results can help in formulating plans that, as discussed extensively in the literature (e.g., Tsur *et al.,* 2004*),* apply fixed fees per irrigated hectare and that charge payments which vary with watering intensity; i.e., the type of crop and irrigation technique. The next section presents a proposal that takes account of these results in calculating contributions irrigation consortium.

5. Definition of the irrigation payment scheme

The use of the *Translog* model allows to show how operating cost vary with the level of output produced. The proposed payment system makes farmers pay only those costs that would occur under conditions of efficient use of the WUA facilities.

5.1 The relationship between water distribution cost and utilization of the WUA facilities

The estimates of the model can be used to compute the *estimated* cost, which permits to find the degree of cost recovery if compared to the water payments.

Table 4 provides some data on irrigated lands and *estimated* average cost for each macro-district. The first section of the table relates to the cost per hectare irrigated and provides maximum, medium and minimum of *estimated* average costs and the corresponding observed irrigated lands. For example, for high pressure (HP), in the examined period, the average irrigated area in the district have fluctuated between a maximum of 1902 hectares and a minimum of 34 hectares. For these two values, the model estimates an average cost of water distribution of 230 € and 640 € per hectare, respectively. The fourth row of the table is titled Optimum. This value is obtained through the function by extending the irrigated land to the level that generates the minimum average cost. Note that the model indicates *an* optimal value of 7900 hectares irrigated in the average HP district . As just seen, the highest value observed is much lower (1902) and the average is 520 hectares. Henceforth, this *optimal* value gives an idea about the condition of under-utilization of the WUA facilities.[2]

The second section of the table shows the variation of the cost referring to the change of water volume applied per hectare. It expresses the percentage change in volume per hectare and in

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[2] *Translog* is an approximation around a point of expansion; hence, it is better not to rely on simulations of values outside the range of observations that provided the estimates.

estimated average costs, and returns the corresponding levels of payment per hectare (*price*). For example, the table shows that in the average HP district, the *estimated* average cost is 230 € / ha when 1902 hectares are irrigated. Increasing the volume of water per hectare between 1 and 10%, increases the average cost of 1.7 %, which rises to 234 € / ha. Further, increasing the volume of water per hectare from 11 to 50%, increases the average cost by 11.3%, up to 256 € / ha. The table shows only estimated values for HP and GL, as only their estimates for these parameters are significantly different from zero (Table 2). The intervals of watering changes shown in Table 4 are defined arbitrarily and can be modified to meet specific needs. Instead, it should not be changed the reference period for computing the average water per hectare, that is from 1995 to 2005. In fact, the coefficient values of this study are obtained with an econometric estimation that refers to that range of data.

Table 4. Hectares Irrigated (HI) and respective *estemated* average cost for the four macro-districts.

	HP		*LP*		*GL*		*GR*	
Cost-component for Hectare Irrigated								
	HI	*Cost*	*HI*	*Cost*	*HI*	*Cost*	*HI*	*Cost*
Maximum	34	640	18	1453	13	83	79	341
Medium	520	328	480	340	270	189	151	347
Minimum	1902	230	1217	297	624	160	277	202
Optimum	***7900***	***213***	***1367***	***297***	***1674***	***104***	***1127***	***8***
Cost-component for Watering Intensity								
Δ% Watering	***Δ% Cost***	**Price**			***Δ% Cost***	**Price**		
-11-50	-13,5	199			-33,1	107		
-1-10	-4,3	220			-4,4	153		
average	**0,0**	**230**			**0,0**	**160**		
+1-10	+1,7	234			+3,1	165		
+11-50	+11,3	256			+16,3	186		
+51-100	+28,3	295			+29,4	207		
+101-150	+47,4	339			+31,9	211		

5.2 The proposed payment scheme

The results obtained with the estimates of the model can be considered useful because they support the formulation of payment schemes that are not linked solely to the total volume of water and thus reduce the competition between the consortium and the use of underground water source. In particular, these results may help to formulate plans which, as discussed extensively in the literature (Tsur et *al*., 2004), apply fixed fees per hectare irrigated and payments that vary with the intensity of irrigation intervals, ie the type of crop and of irrigation techniques.

The results obtained for the Oristano WUA can be used to define a system of cost sharing of similar type of irrigation service. This system, on the one hand, distributes the costs of distribution in proportion to those that determine them, on the other adopts a policy whereby the users of irrigation water are free of the inefficiencies that result from conditions external to their scope of action. This criterion can consider that the costs are more responsive to changes in the extent of irrigated area than the variation in water volumes, as shown by estimation results (Tables 2 and 3). The result is a payment scheme that sets a uniform payment per hectare irrigated and integrates it with another payment that varies according to water use per hectare. The contribution per hectare irrigated is chosen with a criterion that considers the recovery of operating costs and avoid including inefficiencies due to the underutilization of facilities. However, the results of the model (Table 1) indicate that in HP, GR and GL the theoretical condition of optimal utilization (where the average cost is minimum) is with an irrigated area not observed (7900 hectares in HP) and far away from the major extensions detected (1902 hectares in HP). Under these conditions, setting up a payment scheme applying the *Translog* results to the theoretical condition of optimal utilization, suffers of low statistical reliability. Therefore, here we chose to build the scheme on the average cost for the lowest observed in the territory during the period of analysis. In this case, the irrigation price in HP is based on the average cost per hectare irrigated estimated for the extension of 1902 hectares, equal to € 230 per hectare. This fee per irrigated hectare is then corrected according to actual consumption of water per hectare (Table 4, section 2), obtaining the irrigation price expressed per hectare. In this case, if the year has a consumption of water equal to the average observed over the period 1995-2005, then the contribution should not be changed and can be applied directly.

An example of implementation of this scheme is in Table 5, which shows the values of payments and budget, with the payment scheme that WUA implemented normally and those with the scheme proposed in this paper, applied to the case of 2007. Table 5 shows the percentage and the degree of cost recovery with both the *actual* and the proposed scheme. Initially, they are evaluated considering only the first cost-component, the hectare irrigated, and then by adjusting the fee by the irrigation intensity. In HP districts the hectares irrigated were 3378, with an average cost of 377 € / ha and an average *actual* price of 138 € / ha[3]. Instead, according to the *Translog* model, in this case the price should be € 230., There is a further difference due to the intensity of irrigation; in this case it was higher by 61% than the average of the period 1995-2005. Thus, the price should be corrected to 295 € / ha. In the HP districts coverage of the costs would rise from 37%, with the *actual* payment scheme, to 78% with the proposed scheme. In the other districts there are different values, in LP and GR the cost does not vary with the watering intensity, so the proposed scheme produces a unique price solution.

Table 5. Irrigate hectares, average costs of irrigation water distribution, requested and proposed payments.

2007	*HP*	*LP*	*GR*	*GL*	*WUA*
Irrigated Hectares	*3378*	*1409*	*92*	*921*	*5801*
AC observed (€/ha)	*377*	*395*	*379*	*216*	*356*
Actual Average price (€/ha)	*138*	*182*	*75*	*135*	*147*
Proposed per-irrigated-ha fee (€)	*230*	*297*	*160*	*202*	*241*
Irrigation intensity	*+ 61%*	*+ 159%*	*+ 24%*	*+ 11%*	*+76%*
Final price (€)	*295*	*297*	*186*	*202*	*279*
Actual cost coverage (%)	*37*	*46*	*20*	*62*	*41*
Simulated coverage – ha fee (%)	*61*	*75*	*42*	*94*	*68*
Simulated coverage – ha-and-irrigation fee (%)	*78*	*75*	*49*	*94*	*78*

The last column of Table 5 shows that the proposed scheme increases appreciably the degree of cost recovery for water delivery and does not transfer to farmers inefficiencies of the system that are not due to their choices. The rest of society is asked to support a relatively modest cost of about € 485,000. In fact, as can be calculated from the average costs and surfaces, the total costs of water distribution are approximately 2.1 million €, while the proposed system requires that water users pay € 1.6 million. This value is higher than the approximately 1.21 million € collected by the current scheme to support the use of collective facilities against drawing on groundwater.

6. Conclusions

Italian Law 13 of 2009 seeks to define water management plans that provide directions for use and the economic instruments capable of influencing the choices of those who use the water resource, as indicated in EC Directive 2000/60. To develop management plans to provide water services at reasonable cost, it is important to carefully consider the conditions that generate the use and cost at which water is delivered in various fields, including agriculture as a basic user. In particular, it should be carefully considered how to increase the coverage of delivery costs, given that there is a potential conflict with the objective of environmental protection. This study evaluated

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[3] This value is obtained by weighting the payments per hectare of individual crops, on their in irrigation reservations.

the cost of industrial water service provided by a consortium of irrigation. The distribution system of this consortium is representative of the technical characteristics and operating conditions of many of these facilities around the Mediterranean. For this reason a more general value is attributed to the conclusions reached on it.

The results show that water distribution can be usefully framed as a twofold problem of irrigating a certain extension of agricultural land, and of providing to this land a certain volume of water per hectare. Indeed, in many cases, the main cost elements are directly and exclusively related to the area served, suggesting that a pricing of irrigation water which considers only the volume delivered is incomplete and may even be inappropriate. The pricing should also take account of the distribution system, because the cost structure of pipeline systems varies with the pressure of the water delivered. In other words, management policy regarding irrigation water should consider the extent of the irrigated area and the particular technology rather than the volume delivered. This finding suggests that in many cases, it would not be beneficial to adopt volumetric payment systems by changing the criteria already used by the consortia, which link payments for water services to the extent of irrigated land.

However, the most important result of the elasticity analysis is that the system operates in conditions of under-utilization of facilities. In these conditions, it would be very dangerous any event which induces farmers to reduce the use of water delivered by the consortium (e.g., tariff increases, perhaps applied to increase the coverage of costs, or to attribute environmental costs to irrigation activities). A reduction in water supplies would, in fact, generate an increase in the average cost of the consortium irrigation service, thereby requiring an increase in prices for farmers who continue the practice of irrigation.. This, in turn, would trigger a vicious cycle that gradually reduces the use of consortium water services, while it increases the cost. Instead, the possibility of cost recovery would benefit from lower prices, as this would increase the use of consortium services and, progressively, would reduce its cost. Besides, this would also discourage the use of groundwater, which helps reaching the important water protection objective of the European Water Framework Directive.

In this regard the model identifies the parameters that help define a payment system which, being unrelated to used water volume, does not put in direct competition the recourse to the consortium source and the use of groundwater. This system would be based on two elements. On the one hand, would apply a fixed payment per hectare irrigated; on the other hand, would apply a charge that varies with the intensity of irrigation (ie, type of crop and irrigation technique). The fixed rate per irrigated hectare would be the prominent part of the payment and would only provide a little impact in stimulating the use of groundwater. Instead, the variable part would encourage farmers to use water resources efficiently.

7. References

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