ANALELE ŞTIINŢIFICE ALE UNIVERSITĂŢII „ALEXANDRU IOAN CUZA” DIN IAŞI
Tomul LV Ştiinţe Economice 2008

ROLE OF THE IRRIGATION CHARGES TO INDUCE THE ADOPTION OF WATER SAVING INNOVATION IN SEMI-ARID REGIONS

Giacomo GIANNOCCARO*, Maurizio PROSPERI**, Massimo MONTELEONE***,
Giuseppe GATTA****, Giacomo ZANNI*****

Abstract

The paper investigates about the effectiveness of water charges in inducing farmers to adopt the technical innovation aimed at water saving. It is claimed that by increasing water charge, the signal of the scarcity of the water resource is directly and effectively conveyed to farmers, who are supposed to promptly react by adopting a water saving technology. The analysis is referred to two types of innovation: an agronomic innovation, consisting on a crop mulching practice, and a management innovation, based on a voluntarily water pricing scheme with tariffs differentiated according to a peak and off-peak season. A theoretical model based on farms' profit maximization is proposed, to evaluate the trigger conditions for the innovation. The model is applied to a case study referred to a semi-arid region, located in the South of Italy, according to which there is no clear evidence that a generalized increase may induce farmers to adopt the innovation.

Key words: water pricing policy, water saving, adoption of innovation
JEL classification: Q12, Q15

---

* Giacomo GIANNOCCARO (giannoccarogiacomo@yahoo.it) is assistant researcher of Agricultural Economics, at the "Department of Economia, Sociología y Politica Agraria" University of Cordova. He received his PhD in: Management of the Innovation in Mediterranean Agro-Food Systems. His research interests include: water policy analysis, economics of the innovation, agricultural economics, natural resources economics.

** Maurizio PROSPERI (m.prosperi@unifg.it) is researcher of the Department PrIME, at University of Foggia, Faculty of Agriculture. He received his PhD in: Agricultural Sciences. His research interests include: water policy analysis, agricultural economics, natural resources economics. His teaching interests include: Land appraisal, Marketing Research, Food Safety and Nutrition Economics.

*** Massimo MONTELEONE (m.monteleone@unifg.it) is associated professor of the Department DiSACD, at University of Foggia, Faculty of Agriculture. He received his PhD in: Productivity of Crops. His research interests include: bio-mass crops, irrigation systems in semi-arid climate. His teaching interests include: Agricultural Ecology, Ecology of Landscape, Agronomy.

**** Giuseppe GATTA (g.gatta@unifg.it) is researcher of the Department DiSACD, at University of Foggia, Faculty of Agriculture. He received his PhD in: humankind and environment. His research interests include: biomass crops, irrigation systems in semi-arid climate. His teaching interests include: Irrigation in semi-arid climate.

***** Giacomo ZANNI (m.zanni@unife.it) is full professor of the Department of Engineering, at University of Ferrara, Faculty of Engineering. His research interests include: water policy analysis, agricultural economics, extension services in agriculture. His teaching interests include: Land appraisal, business and administration, environmental impact analysis.

1. Introduction

The awareness that the water resource is getting scarce has induced the European Union the enactment of the Water Framework Directive (Directive 2000/60/EC), aimed at the enforcement of a sustainable water policy across the EU member states. In order to improve the use efficiency, member states are recommended to adopt water pricing policies. In fact, the water charges are usually conceived as tool to recover the conveyance costs, but they do not consider the value of the resource due to its scarcity. According to the economic theory, the optimal allocation (first best) will occur when the water charge equals the marginal productivity of the water. On the contrary, since the water resource cannot be substituted by other goods or production input, it is commonly accepted that charges should follow either the economic efficiency, but also some relevant social objectives, such as equity, justice, income distribution, resource conservation, and public consensus [Boland and Whittington, 2000, 215-235; OECD, 1987].

Among several objectives mentioned in the WFD, the EU suggests the reform of the pricing policy, in order to enhance the efficiency of use and to promote the saving of the resource [WATECO, 2003]. This approach implies that the current amount of water, often distributed by public agencies at very low tariffs, may undergo to a sudden change in the distribution criteria among users and, in particular, in the agricultural sector. Consequently, farmers are supposed to adopt a water saving technology.

However, farmers and water agencies are very concerned about the effect likely expected due to a water tariff increase, and are reluctant to the full implementation of the directive, since they foresees that the possible benefits deriving from the introduction of the innovation in agriculture may not offset the higher burden consequent from the WFD enactment. Farmers may not be able to afford the higher cost of the irrigation service, while local irrigation agencies (e.g. consortium of farmers), in charge of the conveyance systems management, may also expect a dramatic reduction of water demand, with a decrease of their revenue and, being incapable of ensuring their service in the future [Dono and Severini, 2004, 167-187].

The aim of this study is to evaluate whether a water pricing policy based on the raise of water charges will exert a positive effect on the adoption of agricultural innovation aimed at the enhancement of water use efficiency. Some authors [Caswell and Zilberman, 1985, 224-234; Caswell et al., 1990, 883-890, Caswell, 1991, 295-312] discuss about the effect of higher water prices on the change of the technology.

The analysis discussed in this paper aims at evaluating the impact of the innovation on farmers' income (micro level) and on the wealth generated by the agricultural sector (macro level). Two sort of innovation are considered in this study: i) a process innovation, enabling farmers to enhance the water use efficiency, and ii) a management innovation, based on voluntary seasonal pricing scheme (peak and off-peak tariffs) adopted by the local irrigation agency, aimed at inducing farmers to modify their cropping patterns in favour of crops cultivated in periods with higher efficiency of use. The farm decision making process is modelled and simulated by means of a linear programming model. The analysis has been developed either theoretically and empirically, considering the case of study of the province of Foggia, in the South of Italy (Italy).

The structure of the paper is the following. In the next paragraph the state-of-the-art of water-saving innovation is reported. In the third paragraph, the economic methodology to evaluate the opportunity cost of benefits adopting the innovation is described, and formally specified. The fourth paragraph deals with the case of study of the South of Italy, while the results are discussed in the fifth paragraph. The last paragraph concludes with some concluding remarks and implications.

2. Water saving innovations in semi-arid regions

There are two basic, hypothetical approaches to improve irrigation water use: a) increasing the efficiency of the irrigation, trough the improvement of the distributive irrigation scheme, from the reservoir to the field, and the implementation of all the technical procedures to reduce irrigation water consumption without affecting the yield, and b) enhancing the crop productivity, in order to achieve a higher productivity for the water resource.

From an agronomic perspective, the overall productive water performance (or ‘water use efficiency’, WUE) with respect to these two different, but complementary, approaches, is described by the following equation:

$$WUE = \frac{Y}{W_{\mathrm{sup}}} = \frac{W_{abs}}{W_{\mathrm{sup}}} * \frac{Y}{W_{abs}} = \varepsilon * \rho \qquad (1)$$

This equation states that *WUE* is mathematically linked to two aspects: the water irrigation efficiency, defined as the ratio of the amount of water absorbed by the crop (W_{abs}) over the water totally supplied (W_{sup}), and the water irrigation effectiveness, defined as the ratio of the yield achieved (Y) over the amount of water actually absorbed by the crop (W_{abs}). Both these different terms are considered in agronomic models, and they are indicated as ε and ρ, respectively. Any technical innovation could be able to improve only one of the considered terms independently or both at the same times.

Among the most important advancement in the irrigation techniques achieved in the past, there is the substitution of the gravimetric irrigation methods with micro-irrigation systems, via the sprinkler irrigation method. This is one of the best examples in the upgrading in the irrigation efficiency.

Differently, the improvement in the timing of crop watering, according to several technical procedures in irrigation scheduling, can be considered as the uppermost example to achieve the highest irrigation effectiveness, because avoiding even the smallest crop water stress ensure the maximum crop yield.

In the present study, two kinds of water saving innovations are considered, and their consequences are directly compared with respect to increasing water pricing scenarios. The first is a process innovation on tomato cropping practices consisting based on the use of a bio-plastic soil cover as a mulching system. The second pertains to a management innovation carried out through a “shifting” of the irrigation season, escaping the period of maximum climatic crop water requirement (full summer) according to an alternative option on the species to crop.

The mulching technique is the partial, more or less extended soil covering, performed in strips along the rows of the plants. It is a very diffused cropping practice, particularly in small scale horticulture, but it is not diffused in large scale fields for industrial crops (e.g. tomato). At the present, plastic films are the more frequently used covering materials. There are several advantages and positive effects related to mulching, specifically in relation to crop water use and water savings, such as: the reduction of direct soil evaporation, the higher control of weeds along the plant rows, avoiding the use of herbicides and reduces soil water losses from weed evapo-transpiration, the improvement in soil structure, the enhancement of air and water circulation flow, and the preventing of the soil crusting.

Due to a general increase in the soil temperature regime, a most relevant effect of mulching is the shortening of the crop cycle; a further reduction in irrigation water supply is expected as a result of an earlier harvesting time. Another indirect effect of mulching on water use is related to a general increase in yield, implying a raise of the water productivity.

Several works have already confirmed these effects and the general suitability of mulching as an innovative cropping practice [La Mantia, 1990, 93-103; Candido et al., 2003, 379-386; Magnani et al., 2005, 59-68] on conditions that other important improvements were satisfied, such as micro-irrigation systems and, preferentially, fertirrigation.

In order to describe the second type of innovation, consisting on the shifting of the irrigation season, it is assumed that the distribution of the rainfall is not regular during the year, and it is asynchronous in respect to the crop cycle. For instance, the climatic conditions in the South of Italy are characterized by an irregular distribution of rains, both during the year and among the years, with frequently marked drought periods. In addition, the spring-summer period, during which most of horticultural crops are cultivated, the climate is similar to an arid or semi-arid region. For this reasons, irrigation is essential in order to promote agricultural productivity and to allow an economically viable farming.

Farming systems, notwithstanding a considerable variability from zone to zone, are mainly characterized by autumn-winter crops (such as wheat or sugar beet) in annual or biannual rotation with spring-summer crops. Wheat is usually a rainfed crop while sugar-beet benefits of supplemental irrigations; in areas where irrigation water availability is mostly reliable, tomato is the principal summer crop, widely diffused together with other horticultural crops; differently, under uncertain irrigation water availability conditions, sunflower or other drought tolerant crops prevail.

The period in which the highest irrigation volumes are requested (peak-period) is ordinarily placed between the last decade of June and the first decade of July, accordingly with the prevailing daily climatic condition (high temperature, great radiation load and a few or no rains at all). Any crop having a fast vegetative growth or a critical reproductive phase (flowering and fruit setting) during this period, will require frequent and massive irrigation volumes. At the whole district level, this situation leads to a great management difficulties, such as a drop in the hydraulic head and sometimes even a forced stop in water delivery due to a simultaneously massive request. In some cases, the total water availability is insufficient to supply farms' needs.

A significant reduction of irrigation water requirements may be obtained by substituting the summer horticultural crops with the other horticultural crops (e.g. broccoli, cabbage, spinach, lettuce), that implies a shift of the crop cycle from the peak to the off-peak irrigation period. These crops are characterized by lower seasonal irrigation volume with respect to summer crops, for two different reasons: the lower evapo-transpiration rate, due to different climatic conditions (lower temperature and radiation load), and the relatively higher amount of rain generally recorded in the autumn season, that represents a valuable source of water to sustain the plant up to the end of the cycle.

3. Economic modelling of the adoption of price-induced innovation

There is a considerable theoretical and empirical literature on the induced innovation hypothesis [Hicks, 1932; Thirtle and Ruttan, 1987]. The basic hypothesis underlying this approach relies on the assumption that changes in relative factor prices is sufficient to induce a firm operating in a purely competitive environment, to seek for improvements aimed at saving the more expensive factor [Fellner, 1967, 664-665].

As follows, a methodology to estimate the role of exogenous and endogenous affecting the adoption of a given innovation is proposed. The model is developed under the neoclassical paradigm of the firm theory, in order to model the decision making of a generic irrigation farm, involved in the choice whether adopting the innovation, or maintaining the current technology. The opportunity cost of the adoption of the innovation is evaluated by calculating the shadow price of the dichotomous variable linked to the switch between the two technologies. Farmers are assumed to maximize their profits, and the adoption of the innovation is assumed to occur without initial investments or transaction costs.

Two models are proposed to represent the opportunity to adopt the process innovation, or the management innovation.

Economic modelling of the decision to adopt a process innovation. Farmer's decision making process is modeled based on the profit achievement ($\pi = PY - C$), given by the difference between the revenue from the sell of the output (Y), at a given market price (P), and the production cost (C). The market price is an exogenous variable, while the output derives from the combination of the inputs, according to a Cobb-Douglas production function, that we assume to be concave and twice differentiable: $Y=a \cdot T^{t} \cdot L^{l} \cdot Z^{z} \cdot W^{(\varepsilon.\rho)}$. It is assumed that the output depends on a generic coefficient a, and the endowment of input, such as land (T), labour (L), other variable inputs (Z), and water (W). The productivity of irrigation water is represented by the water use efficiency (WUE), that is the product between the water irrigation effectiveness (ε) and the water irrigation efficiency (ρ). The production cost function is linear and depends on the purchase of all the variable inputs, multiplied by their market price (rent re, wage s, water tariff v, unit cost v for the remaining variable input) and the fixed costs (I), including those related to the irrigation system: $C=re \cdot T+s \cdot L+v \cdot Z \; \tau \cdot v_w \cdot W + I$, provided that τ is an exogenous policy variable, enforcing the full recovery cost principle and, therefore, inducing an increase of the basic water tariff.

In order to model the choice between two alternative technologies, two profit functions are considered ($\pi°$ for the current technology, and π' for the new technology), linked by the integer dichotomous variable α, such that its value may be equal to 0 or 1. Consequently, the objective function of the farmer becomes: MAX $\pi = (1- \alpha)\, \pi° + \alpha\, \pi'$, subject to the constraints of resources availability[1].

For the purpose of this study, the above function is solved, and the shadow price of the technology switch is evaluated (λ_α). In other words, the shadow price of α represents the marginal profitability of the farm, in terms of the objective function, consequent to the adoption of the innovation. After solving the equation through the Lagrange multiplier method, the result is the following equation:

$$\lambda_\alpha = \tau\,[(1+\lambda_k)(\sum_j x_j^{\circ} w_j^{\circ} - \sum_j x_j^{'} w_j^{'})] \cdot v_w + CONST' \qquad (2)$$

This equation demonstrates that the opportunity to adopt the innovation is linked to the water tariffs increase τ , but only if with the new technology there is an implicit reduction of the overall water demand (i.e. at a farm level). In addition, the equation reveals that the ef-

---

[1] The mathematical proof is available, on request to the authors

fect of τ also depends on the opportunity cost for the capital (λ_k), as well as on the current water tariff level (v_w).

Economic modelling of the decision to adopt a management innovation. A similar model is proposed to evaluate the opportunity of the farmer to adopt a different type of management for the water resource, in order to take advantage of the discounted water charge during the off-peak season. Therefore, the model considers two different periods in which they may be able to use the same amount of water (peak and off-peak), that follows two different charge regimes.

In this case, the Cobb-Douglas production function considers two different water source: $Y=a\cdot T^t\cdot L^l\cdot Z^z\cdot Ws_1^{(\varepsilon.\rho)}\cdot Ws_2^{(\varepsilon.\rho)}$, where Ws_1 and Ws_2 are, respectively, the water demand during the peak and off-peak season (s_1 and s_2). The seasonal water tariff of the peak season is assumed to be higher than those of the off-peak season, proportionally to a seasonal price discrimination index δ, given that $0 < \delta < 1$. Therefore, the resulting cost function becomes: $C=re\cdot T+s\cdot L+r\cdot Z+\tau\cdot\delta\cdot v_w\cdot Ws_1+\tau\cdot 1/\delta\cdot v_w\cdot Ws_2+I$

In this case, the new integer dichotomous variable β (ranging $0 < \beta < 1$) representing the technology switch, is introduced. The farmer's choice about changing its cropping pattern in favor of crops cultivated during the off-peak season depends on the solution of its profit maximization function: MAX $\pi = (1-\beta)\,\pi^\circ + \beta\,\pi''$, subject to the constraints of resources availability[2].

The solution of the profit maximization problem through the Lagrange multiplier method, the value of the β shadow price (λ_β), is analytically determined. In this case, λ_β represents the profitability of the farm, in terms of the objective function, of adopting the management innovation:

$$\lambda_\beta = \tau\, v_w (1+\lambda_K)\Big\{ \sum_j x_j^{''}\Big(1+\delta^2 \frac{w_{s1,j}}{w_{s2,j}}\Big) - \sum_j x_j^{\circ}(w_{s1,j}+w_{s2,j}) \Big\} + CONST'' \quad (3)$$

where $CONST''$ is a new constant, that does not have a direct relationship with τ.

The equation states the convenience for farmers to change their cropping patterns, in order to follow the seasonal water price differentiation, relies on τ , v_w , and λ_k . In addition, it should also be considered the relevant contribution of the overall water consumption for each season, for any crop (ratio w_{s1}/w_{s2}) that increases by factor of δ^2. This may be highly relevant in those situations where the water demand is unbalanced in favor of the peak season, and therefore δ may work effectively to achieve a more balanced seasonal water allocation.

4. Case study

The analysis is referred to a hypothetical, representative farm of the province of Foggia, South of Italy. The area is relatively homogeneous in terms of farming structure, soil quality, crop yields, and water availability. The area is characterised by a Mediterranean climate, with wet, mild winter and dry, hot summer. Rainfall varies from less than 400 mm/year to more than 700 mm/year, mostly distributed in autumn and winter.

The water district covers 143,000 ha, of which about on third is regularly irrigated. There are two types of sources of water, groundwater (wells) and water conveyed by a local

---

[2] The mathematical proof is available, on request to the authors

water agency, formed by a consortium of farmers (Consorzio per la Bonifica della Capitanata, or CBC). The water allocated by the CBC to farmers amounts to about 86 millions mc, while the overall consumption, including wells and other sources (pounds, recycled waters) is estimated to about 130 millions mc. At the present, the allocation of the water resource is determined according to the area served by the conveyance system. Farmers are allowed to consume a fixed amount of water, but they cannot transfer their use rights to other farmers. In general, since water is a constraint to the cultivation of the most profitable crops (e.g. horticultural crops, vineyards, orchards), every farmer consume the entire volume for which they have a right of use.

The water charges are applied by following a pricing scheme based on increasing block tariffs, with three levels: 0.09 Euro/mc (from 0 to 2.040 mc/ha), 0.18 Euro/mc (2.040-3.000 mc/ha), and 0.24 Euro/mc (over 3.000 mc/ha). Farmers usually draw groundwater from wells and they are able to cover about one third of the annual crop water needs, either during the peak season (July and August), or during the period in which the consortium is not operating (from November to March). The conveyance system managed by the CBC allows the distribution directly to the field, through a pressure pipes system. Farms irrigation systems have evolved from sprinklers or mobile rain guns, to micro-irrigation systems (like drip irrigation). Cropping patterns are mostly based on winter cereals (50%), and highly profitable crops, such as tomato (19%) and other vegetables (8%). Orchards, vineyards, and olive trees cover the remaining part of the farmland.

The case study is referred to a farm where the basic production factors are conferred by the farmer (10.21 ha of land, 1.5 labour units, and capital for 20,600 Euro). Additional labour is hired only during specific seasons, corresponding to the harvest of the fruits and vegetable crops. The plastic mulching technology is assumed to be feasible only for the tomato crop, with an increase of its variable costs for 857 Euro/ha, due to the purchase of plastic film, in comparison with the standard cultivation technique. In addition, an increase of the annual fix cost of 300 Euros, due to the depreciation of the investment in machineries necessary for the plastic film setting and its disposal before the harvest, is also considered. Conversely, it is assumed an increase of about 10% of yields, due to the higher water use efficiency, and about 10% of the market price, due to a higher quality of the harvest. The schedule of the cultural operations and irrigation is also has slightly different, since the crop cycle becomes 10 days shorter, in comparison with the current technique. Finally, 20% lower water consumption is assumed.

With respect to the seasonal water tariff differentiation, the irrigation season is divided into two critical periods, a first so-called ‘peak season’, corresponding to the period from April to July, and a second ‘off-peak season’, corresponding to the period from August to October. The overall increasing block water tariffs corresponding to the peak season have been increased uniformly (10%, 25%, 50%), while those of the off-peak season have been reduced by the same amount.

The simulations were performed through linear programming model, developed under the GAMS software (General Algebraic Modelling System), distributed by the GAMS Development Corporation, Washington, D.C.

5. Results and discussion

Water saving innovation based on plastic mulching. The optimal solution of the farmer’s decision making problem reveals that the mulching practice is always more convenient than the traditional practice, for any tariff charge. As it is shown on Table 1, the shadow price of α is positive and equal to 150 Euro/ha, according to the current scenario. This value remains constant also when tariffs increase up to 10 and 25 percent. This value is still below the water marginal productivity. However, in case of higher tariffs (+50%), the innovation is still profitable but, in relative terms, the profitability tends to be lower.

In order to explain this phenomenon, it is worth to refer to equation (2), that describes the relationship between the profitability of introducing the innovation (λ_α), the tariff increase rate (τ) and the difference on total water consumption. The model results prove that τ does not have any effect on λ_α until all the available water is completely consumed. However, τ exerts a negative effect with the introduction of the mulching technique because, since the latter is able to use water more efficiently, again the farmer utilizes all the available irrigation water. In particular, the profitability of the mulching technique starts to decline only if τ riches values equal or superior to an increase of 50%.These findings are consistent with the theoretical demonstration previously shown in this paper.

If the objective of the water tariffs increase was a reduction in water demand, the introduction of the technical innovation cancels this effect, but also significantly increases the consortium revenue.

Finally, the increase of the tomato cropping surface is explained by considering that the mulching technique, at the present time, is applied only to this crop.

Table no. 1 - Effects (expressed in relative terms with respect to the corresponding current condition) consequent to the introduction of the bio-plastic mulching innovation

	Current	**Changes due to water price increase**		
		+10%	**+25%**	**+50%**
α shadow price (Euro/ha)	150	150	150	144
Income	9%	9%	8%	26%
Added Value	-30%	-30%	-29%	-14%
Irrigated area	-19%	-13%	-11%	-8%
Water use application rate	23%	15%	12%	45%
- peak season	129%	111%	52%	271%
- off-peak season	-82%	-81%	-67%	-100%
Consortium revenue	0%	0%	0%	41%
Tomato crop area	106%	104%	102%	96%

Water saving innovation based on the shifting of the irrigation season. This innovation showed a positive relationship between the water tariffs increase (τ) and the profitability of introducing the innovation (λ_β) (Table 2). This observation is consistent with the theoretical demonstration of equation (3). The effect of τ also depends on the value of the tariffs differentiation rate (δ), but it varies according to the overall ratio between the water consumption of the first period (peak season) relatively to that of the second period (off-peak season). Therefore, if τ itself causes a relevant shift on water consumption from the peak to the off-peak season, then the effect of δ becomes lower, and there will be a certain reduction in the profitability of introducing the differentiated tariffs scheme.

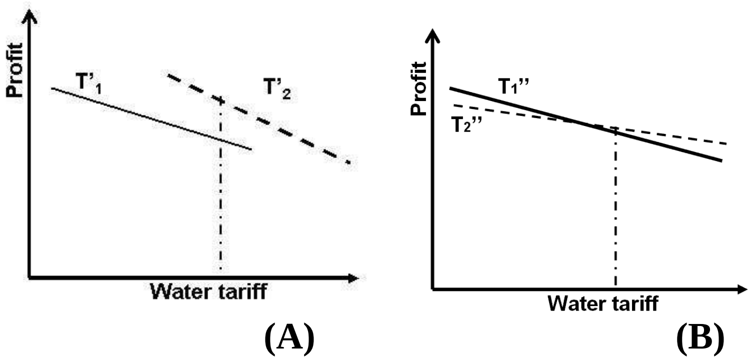
Table no.2 - Effects of the seasonal water tariffs discrimination

	Current	**Changes due to water price increase**		
		+10%	**+25%**	**+50%**
10% interseasonal tariff difference				
β shadow price (Euro/ha)	0.29	0.29	0.39	0.78
Income	3%	3%	3%	0%
Added Value	6%	6%	6%	0%
Irrigated area	-7%	0%	0%	0%
Water use application rate (mc/ha)	8%	0%	0%	0%
- peak season (Consortium)	-17%	-23%	-42%	0%
- off-peak season (Consortium)	33%	23%	83%	0%
Consortium revenue	-1%	-1%	-1%	-1%
Tomato	-17%	-17%	-17%	0%
25% interseasonal tariff difference				
β shadow price (Euro/ha)	2.25	2.15	2.74	2.94
Income	4%	4%	-1%	13%
Added Value	7%	7%	1%	19%
Irrigated area	-9%	-3%	-3%	-2%
Water use application rate	10%	3%	-8%	15%
- peak season (Consortium)	-19%	-24%	-65%	-27%
- off-peak season (Consortium)	39%	31%	99%	50%
Consortium revenue	-3%	-3%	-17%	12%
Tomato	-25%	-25%	-25%	-33%
50% interseasonal tariff difference				
β shadow price (Euro/ha)	10.87	10.77	11.75	9.21
Income	4%	4%	4%	22%
Added Value	7%	7%	8%	31%
Irrigated area	-18%	-13%	-18%	-15%
Water use application rate	22%	15%	14%	46%
- peak season (Consortium)	-58%	-61%	-73%	-41%
- off-peak season (Consortium)	102%	90%	182%	118%
Consortium revenue	-17%	-15%	-20%	15%
Tomato	-25%	-25%	-33%	-33%

Concerning with the specific empirical study, for low τ values a higher water consumption is get on the peak season, therefore the introduction of the innovation suitable to correct this phenomenon. However, for high values of τ (+50%), we got higher consumption for the off-peak season, then the profitability of introducing the innovation becomes relatively lower.

With respect to the economic performances, a higher levels of income and product added value is observed consequently to the introduction of the innovation. On the contrary, concerning the effectiveness of the innovation to reduce the water consumption, only two cases were actually detected (the combination τ = +25%; δ=+25%, and τ = +25%; δ=+50%).

A simple representation of the findings of the analysis is shown on Figure 1, in which the relationship between water tariffs and the farm profit is depicted. In the first case (A), there is a certain range of water tariffs in which both technologies may coexist. In the example of the second innovation, the increase of the water tariff exerts a positive role, although the magnitude of this effect might be too small to be perceived by farmers.



The technical innovation (T2) as compared to the conventional one (T1). Panel (A), represents the case of the mulching technique, while panel (B) represents the differentiation of seasonal tariffs.

Figure 1. Simplified scheme of the effect of water tariff on the adoption of the innovation

Concluding remarks

This research has developed an analytical framework to assess the role played by the water price on the adoption of an water saving innovation in the irrigated agriculture. Following this context, this study has analyzed the farmers' behaviour in different water charge options. In particular, the adoption of a process innovation, and a management innovation has been analyzed. According to our findings, although the increase of the water charges induces the adoption of water-saving technologies, it is also evident that there are other factors that may still play a relevant role, such as the capital, and the overall water consumption. On the one hand, the cost for implementing the new technologies has a great importance for the farmer' decision process. At the present, in most of family farms, the profit value is negative and this may hinder the innovation process. In addition, the crop diversification potential in a given area of cultivation and the magnitude of the available water (i.e., resource endowment) affect the farmer' decision process. On the other hand, the impact of the innovation on farmers' income, local water agency revenue, and agricultural added value are positive.

In the case of the shifting of the irrigation season, the water pricing policy may be a suitable tool to induce farmers to change their cropping patterns. The most important advantage, may be visible at the district level, since it may effective in redistributing the water demand during the peak-season. However, this effect may be controversial, since there are some negative effects related to the fact that changes in technology may induce new crops patterns and increase total water consumption. For instance, García Mollá [2002] shows that drip irrigation technologies have been adopted in the region of Valencia (Spain), but contrary to general belief irrigators have not reduced application rates. Similar behaviour has been observed in the Guadalquivir river basin (Spain), in the sense that the adoption of drip irrigation has encouraged the planting of new crops (orchards, vegetables, etc.) that are more water demanding than the preceding ones [Berbel 2005].

Whatever innovation aimed at improving the water use efficiency will not be effective to reduce the overall water demand (i.e. farm level), since the amount of water made available consequently to the water efficiency enhancement may be easily devoted to increase other production activities undertaken in the same farm. This may easily occur in arid areas (e.g. Mediterranean region), where water is a very limiting factor of intensive agriculture. The exception occurs when some other production factors will represent the most important constraint for the expansion of irrigated crops (e.g. land, labour, capital).

References

Boland, J.J. ,Whittington, D. (2000), The Political Economy of Water Tariff Design in Developing Countries: Increasing Block Tariffs versus Uniform Price with Rebate, in *The Political Econoy of Water Pricing Reforms*, Dinar A. (editor), Oxford University Press, New York, pp. 215-235.

Berbel, J. (2005), *Análisis económico del agua en la Directiva Marco. Su aplicación a la Cuenca del Guadalquivir*, Conferencia ISR, Córdoba, Spain, 28/abril/2005., at http://www.isrcer.org/jornadas.asp, accessed on November 11, 2008

Candido, V., Miccolis, V., Gatta, G., Margotta, S., Manera, C. (2003), Innovative films for melon mulching in protected cultivation, *Acta Horticulturae* 614, pp.379-386.

Caswell, M. (1991). Irrigation Technology Adoption Decisions: Empirical Evidence, in *The Economics and Management of Water and Drainage in Agriculture*, Dinar, A. and Zilberman, D. (eds.). Kluwer Academic, Boston, MA, pp. 295-312

Caswell, M., Zilberman, D. (1985), The Choice of Irrigation Technologies in California, *American Journal of Agricultural Economics*, 67(2), pp. 224-234.

Caswell, M., Lichtenberg, E., Zilberman, D. (1990), The effects of pricing policies on water conservation and drainage, *American Journal of Agricultural Economics*, 72, pp. 883-890.

Dono, G., Severini, S. (2004), Sistemi di contribuzione irrigua e costi di distribuzione dell’acqua: un’analisi su un Consorzio di Bonifica dell’Italia meridionale, *Nuovo Diritto Agrario n.1*, pp. 167-187.

Fellner, W. (1967), Comment on the Induced Bias, *Economic Journal*, 77, pp. 664-665.

García Mollá, M. (2002), Análisis de la influencia de los costes en el consumo de agua en la agricultura valenciana. Caracterización de las entidades asociativas para riego, Doctoral Thesis, Departamento de Economía y Ciencias Sociales. Universidad Politécnica de Valencia, Valencia

Hicks, J.R. (1932), *The Theory of Wages*, Macmillan, London.

La Mantia, F. (1990), Alternatives to polyethylene mulch film, a field assessment of transported materials in capsicum (Capsicum annuum L.), *Australian-Journal of Experimental Agriculture*, 41:1, pp 93-103.

OECD (1987), *Pricing of Water Services*, OECD, Paris

Magnani, G., Filippi, F., Grainfenberg, A., Bertolacci, M. (2005), Valutazione agronomica di film biodegradabioli per la pacciamatura, *Colture protette*, 1, pp 59-68.

Thirtle, C. G., Ruttan, V. W. (1987), The Role of Demand and Supply in the Generation and Diffusion of Technical Change. Harwood Academic Publishers, London.

WATECO (2003), Common implementation strategy for the Water Framework Directive (2000/60/EC). European Commission, Bruxelles.