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Modelling moral hazard for irrigated agriculture with fixed and variable transaction costs

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Abstract

The paper develops a water pricing strategy for irrigate agriculture under conditions of asymmetric information and explores a pricing strategy which tries to link water tariffs with the irrigation water supply costs on the bases of farms water use. While analysing this phenomenon the attention is given to the moral hazard problem and also examine how transaction costs affect the social benefit and the WA's pricing strategy. The analysis is based on a principal-agent model implemented as a mathematical non-linear programming model. In addition an empirical example is drawn which illustrated conditions of under what level of monitoring intensity monitoring technology is effective. The numerical example show that the WA's has a trade-off between setting the level of monitoring intensity and costs arising from monitoring. In addition for high water cost level (water supply cost and transaction costs) the WA's monitoring intensity increases. This result indicate that when water supply costs are large, the gain by increasing monitoring intensity in order to prevent any cheating action by farmers is greater than the loss due to cost of monitoring. The study concludes by showing that for increasing transaction costs level the pricing strategy shift to a more costly allocation mechanism showed by the decrease of the social benefit.

Keywords: moral hazard, water pricing, transaction costs, monitoring, principal agent model

1. Introduction

Incentive pricing mechanisms are vague in most countries, and current water pricing systems are often distorted leading to large cases of no incentives for water conservation [1]. The obstacles that WAs (Water Authorities) face while designing and developing water policies are: lack of water metering, the presence of asymmetric information between WAs and water users, high level of transaction costs and heterogeneous population of water users that complicate the implementation of incentive mechanisms. These limitations affecting the applicability of ideal pricing instruments oblige WAs to implement uniform tariffs disregarding any differences in water use and not incentivizing efficient use [2]. On the other hand, irrigated agriculture remains a critical sector for attaining efficiency of water use [3].

In order to make a significant improvement of using water in a more efficient way, the sector needs to apply tools and strategies that enable farmers to use the water resource in a more rational way [2]. Such strategies are expected to have a positive impact on the social benefit and enhance productivity. One of possible strategies of water management is via pricing [4,5] but its implementation and design requires to be built upon the establishment of incentive strategies and well-functioned schemes [6].

Most of WAs find difficult to apply incentive pricing schemes because of implications of transaction costs. While scholars have assessed the design of strategies regarding incentive schemes but have neglected the potential effect on the policy goal of transaction costs by not spending much effort to incorporate transaction costs in empirical analysis and to assess their impact [7]. Analysing these costs in a policy design is highly important for the governments or resource provision entities, and should be on the focus of the policy design, especially in the case of environmental and natural resource policy issue [6] because its existence fundamentally affects the efficiency of the policy implementation [8].

In several cases transaction costs are difficult to define, as they may include subjective attitudes towards particular tasks [9]. Among descriptions of transaction costs a more suitable definition for this study is the one defined in the paper of McCann et al. [6] The author defines transaction costs as the expenses of organizing and participating in a market or implementing a government policy.

Regarding the above definition, two types of transaction cost are considered: 1) transaction costs from money collection thought water tariffs; 2) transaction costs arising from money collection through the imposition of sanction due to asymmetry of information.

Transaction costs assumed from the money collection of the tariffs are considered to be fixed and non-differentiable among farm types. Whereas transaction costs related with money transfer from the sanction are assumed variable and arising from the farmers that are sanctioned. Specifically this costs turns to be variable because are connected to variable components (i.e. related to the farmers cheating action).

The distinction between these two types of transaction costs is very importin in a policy design due to its effect on the policy drives to the decision of accepting a policy of regulation or deregulation [2]. For example if transaction costs are distinguished and separated may be trade-offs between different types of transaction costs. In addition some policies with low transition costs of money transfer might have high transaction costs of monitoring and if distinction is not made a rejection of the policy might occur [6].

The objective of this study is to exmine the moral hazard problem in designing water-pricing policies in Emilia-Romagna (E-R) region and to analyse how transaction costs affect WAs' pricing strategies in the context of irrigated agriculture.

The model applies to a case of moral hazard problem of asymmetric information in irrigated agriculture with the focus of maximizing social benefits from the policy implementation and not minimizing transection costs per se. Moral hazard (hidden action) occurs if the regulator cannot monitor farm's compliance perfectly; in this case, the farmer has an incentive to cheat if the expected pay-offs from cheating is greater than the pay-offs from the alternative behaviour[10,1112,13]. In this research farms' cheating action is characterised by irrigating higher share than agreed with the contract. The relationship between the WA and the farmer is such that, the WA delivers and manages the water resource and the farmer irrigates the land in return for a payment. We assume that the irrigation network combines different farm types with variation of water productivity. In order to do so the WA offers to the farmer a contract that include specification on the tariff that the farmer has to pay upfront the irrigation of given a share of the farmland, (i.e. irrigated share is a proxy of water use). On the other hand the farmer may be compliant or not with the contract.

In this regard, the study contributes to literature in two ways. First we design an innovative model for regulating the water resource for irrigating agriculture by involving monitoring strategy to control farmers behaviour and second by modelling transaction costs in a policy design and analysing its effect with empirical simulates. In addition, the assumption of considering different types of transaction cost function allow us to determine more detailed and specific impact on the policy.

The paper is organised in four section: Section 2 describes the method used and the theoretical model by assuming that the WA is fully informed about farm types and their behaver and then extending the analysis under asymmetric information condition when the WA introduces monitoring strategy to prevent farms costly behaviour. This section end with a description of transaction cost function and its effect on the policy. Section 3 start by a brief description of the data used and then introduces the results achieved by running the mode under different transaction cost level and monitoring intensity. Finally, the paper ends with section four by drawing some discussion and presenting the main conclusion.

2. Material and Methods

The model is based in principal agent theory, the principal is the WA (who supplies irrigation water for farmers) and the agent is the farmer (who demand water from the WA). The application of principal agent model is intended to apply some economic criteria for water management in irrigated agriculture and it refers to the method applied in papers of [2,14]. In this setting is considered that the WA deals with many farm types. The relationship between WA and farmers is such that, the WA deliver and manages the water resource and the farmer irrigate the land in return for a payment in form of the tariff. The WA's aim is to maximize the social benefit by providing the offer to the farmer, it is supposed that the WA know farms profit and its water cost function but has no information if he complies with the offered contract or not. Therefore, the farmer is supposed that accepts the contract but he can be compliant or noncompliant.

In the following, we investigated two possible cases: Firs we analyse a case when the farmer and the WA share the same information in term of water use and its profitability, under such conditions the WA modulates water tariffs in function of irrigated share without involvement of transaction costs from sanction and monitoring. Second, we turn to a case where the WA operates under asymmetric information conditions, where may face a farmer or group of farmers that behave dishonestly (during the irrigation season farmers irrigates a greater share compared with what agreed before the irrigation season). Farmers behaviour may be costly for the WA because it fails to link the water tariffs with water supply costs and generating twofold impact on the WA's overall water supply costs: first by increasing costs for supplying the water resource to farmers (real costs are higher than expected costs) and second by increasing costs for revealing farm's private information (because of imposing monitoring technology or introducing a more restrictive criteria to incentivise farmer's compliance) to prevent such farmers behaviour.

By the needs of preventing any costly action by farmers during the irrigation season, the WA develops incentive strategies in a way of incentivising farmers to comply with the contract. The designed strategy is such that the WA monitor his irrigated area and cultivated crop in the way of detecting whether there are irregularities compare with what has been declared. However, the model setting under monitoring activity would allow the farmer to participate and give him the opportunity to avoid the extra costs in form of sanction if he would be found noncompliant with the rules of the contract.

The intention of the WA is to determine a water-pricing scheme that allow the farmer to pay the water tariff according to the amount of water consumed. We are aware that under surface irrigation network is not possible to measure in unites a delivered amount in the farm. To this concern, we consider farm's irrigated share as a proxy of farm's water use. This would allow us to link the water tariffs with farm's water consumption. The irrigated share is defined such that, the WA and the farmer agree before the irrigation season on farm's cultivated crop in a given area and the WA estimates the crop water requirement and determines the total amount of water that a farm needs during the entire irrigation season. This way, based in the overall cultivated area the WA easily can determine the share of irrigated area for each farm, similar to the paper of [15].

With the purpose of maximizing social benefit, the WA wants to determine farm's irrigated share at the level of what is optimal from the social point of view x_i. The letter i indicate the farm type which belong to $i = 1, \ldots, n$. Being aware that farm's behaviour is maximizing profits thus the farmer might choose to irrigate a share that is optimal from the private point of view x_i^{PR}. If the farmer choose to irrigated x_i^{PR} he applies unrestricted level of water use that would allow him to maximize profits $\pi_i(x_i^{PR})$. If the farmer choose to irrigate the share of what is optimal from social point of view he would be restricted on the share of irrigated area and receives a restricted level of profits $\pi_i(x_i)$ where $\pi_i(x_i^{PR}) \geq \pi_i(x_i)$. Hence, if the farmer chooses to irrigate x_i instead of x_i^{PR} he received a disutility, defined by the outcome of the difference between the profit received by irrigating from what is optimal from the social point of view and from what is optimal from private point of view.

$$\psi_i(x_i) = \pi_i(x_i^{PR}) - \pi_i(x_i) \qquad (1)$$

With regard to irrigated share x_i, the WA determines the level of water tariff t_i that the farmer must pay. If the WA is able to fully detect farm's action and find no irregularities in the irrigation network, the farmer would pay the tariff t_i. Otherwise, the WA sanction σ_i the farmer for being noncompliant with the statement. The sanction is in the form of extra payment and its role is to dis-incentivise farmers from cheating. If the farmer non complies with the rules and avoid to be caught by the WA, he would avoid the loss from the sanction and this loss is the utility that he would receive $u_i(\sigma_i) = \sigma_i$. The difference between the received utility and disutility defines that net utility

$$U = u_i(\sigma_i) - \psi_i(x_i) \qquad (2)$$

2.1. Model under full information

Let us now set up the mode under full information conditions where the WA is supposed is fully able to detect farm's action. In a taken assumption the social welfare maximizing objective function takes the following form:

$$\underset{x_i, t_i}{\text{Max}}\, Z = \sum_{i=1}^{n} [\pi_i(x_i) - c_i(x_i) - \delta t_i] \tag{3}$$

s.t.

$$\text{CRi: } t_i \geq c_i(x_i) + \delta t_i \tag{4}$$

Let Z denote the maximization of social benefits and the objective function involves farm's profit $\pi_i(x_i)$ which considered $\pi_i'(x_i) > 0$ and it means that the first derivative is decreasing in x_i and $\pi_i''(x_i) \leq 0$ with a constant sign as used in most of the literature (see the text book of Salanie, 2005). The second component $c_i(x_i)$ indicate the WA has some costs to supply water to the farmer and $c_i'(x_i) > 0, c_i''(x_i) \leq 0$.

The third term indicates the value of transaction costs in function of tariff and defined by symbol δ. Different typologies of transaction costs have been developed to facilitate measurement and allowing researchers to think about design more effectively [6]. In this research two type of transaction cost functions are analysed linear and nonlinear functions with the main purpose of achieving more close approximate of transaction costs from their distribution and examining its effect on the social benefit dimension. Despite the fact that here in the modelling are assumed to be proportional to water tariffs, its functions and effect is better described in the results sections.

In addition, the symbol δ denoting transaction costs, in this section indicates the cost arising from the collection of the money transfer only from water tariffs. Its estimation is assumed as the share of the overall transaction costs generated by all farmers involved in the irrigation district. Furthermore, the cost recovery constraint involved in the modelling guarantee that the water tariffs cover water supply costs and transaction costs.

Under full information we assume that CR binds in optimum. By solving the equation (4) with strict equality we determine the value of tariff:

$$t_i = \frac{c_i(x_i)}{1-\delta} \tag{5}$$

Equation (5) means that the optimal level of the tariff is in function of the irrigated share and weighted by the value of transaction cost.

By substituting in the objective function the equation (5) and taking the first order condition (FCO) with respect to x_i the solution yield:

$$\pi_i'(x_i) = \frac{c_i'(x_i)}{1-\delta} \tag{6}$$

By solving the equation (6) is determined the optimal level of irrigated share from the WA's point of view which is weighted by the level of transaction costs. By substitution the determined optimal x_i^* in equation (5) we determine the optimal value of tariff t_i^* (i.e. the star superscript indicate the optimality). As the derivative is different from $\pi_i'(x_i) \neq c_i'(x_i), \forall \delta \neq 0$ this result indicate that water tariffs are set at different level from $\pi_i'(x_i) = c_i'(x_i)$. The difference is subject of the value of the transaction cost.

2.2. Model under full information

In the previous section we have provided an analysis of how the WA determines water tariffs and irrigated share under full information condition. We now aim at assessing a case of how this method may be implemented under asymmetric information conditions. In this regard the WA will develop a monitoring strategy aiming at enforcing compliance and introduce a sanction if noncompliance is detected. Let us now consider a case when the WA's monitoring accuracy is not fully efficient but the WA has some probability of detecting farm's noncompliance The WA's level of monitoring intensity can be defined as a relative number of monitoring intensity, and higher monitoring intensity increase the probability of detecting the noncompliant farmer. We model the monitoring probability by $P(m)$ which depends on monitoring intensity m and indicate the probability of detecting the noncompliant farmer. Also we have considered $P'(m) > 0$, and $P''(m) = 0$. In addition, monitoring incurs a cost for the WA denoted by the letter k linear on monitoring intensity m.

In doing so the WA know that the farmer can participate in the scheme but does not know if farmers comply with rules or are noncompliant. Therefore, farmers participation is ensured but its compliance is contingent of his individual action. Under such circumstances the farmer is fully informed about his outcome contingent of his action, so by participation in the scheme receives a level of net profit up to the level of the difference between farmer's profit achieved with a restricted level of irrigated share (i.e. irrigated share up to social optimum) and the water tariff from irrigation $V_i(x_i) = \pi_i(x_i) - t_i$. If the farmer decides to take action of irrigating up to his private optimal irrigation share x_i^{PR}, his level of net profit it depends on whether or not he is caught by the WA (i.e. $V_i(x_i^{PR}) = P(m)[\pi_i(x_i^{PR}) - t_i - \sigma_i] - (1 - P(m))\ [\pi_i(x_i^{PR}) - t_i]$.

If the WA is unable to observe farm types directly but is obliged to engage monitoring technology, the social welfare objective function now take the following form:

$$\underset{x_i, t_i, P(m)}{\text{Max}}\ Z = \sum_{i=1}^{n} [\pi_i(x_i) - c_i(x_i) - \delta(t_i + \sigma_i) - km \qquad (7)$$

s.t.

$$\text{CRi: } t_i \geq\ c_i(x_i) + \delta\ t_i + km \qquad (8)$$

$$\text{ICi:} \pi_i(x_i) - t_i \geq P(m)\big[(\pi_i(x_i^{PR}) - t_i - \sigma_i\big] + \big(1 - P(m)\big)\big[(\pi_i(x_i^{PR}) - t_i\big] \qquad (9)$$

The element km entered in the objective function means that the WA in addition to transaction costs face some costs of monitoring farm's action. The CR_i constraint now means that the tariff paid by the farmer must include the cost of supplying water to the farmer, transaction costs and monitoring costs. Here transaction cost δ involve costs arising from money transfer from water tariffs and sanction. The incentive constraint IC_i ensures that farms' net profit by being compliant is at least as theirs net profit if being noncompliant. By solving the objective function under binding CR_i and IC_i constraints, the WA is able to determine the optimal irrigated share x_i, water tariffs t_i and probability of detection $P(m)$. By solving equation (8) with strict equality the value of water tariffs is estimated which is in function of irrigated share, monitoring costs and weighted by the level of transaction costs:

$$t_i = \frac{c_i(x_i) + km}{1 - \delta} \qquad (10)$$

Likewise from equation (9) the value of sanction is determined

$$\sigma_i = \frac{\pi_i(x_i^{PR}) - \pi_i(x_i)}{P(m)} \qquad (11)$$

The value of the sanction is determined from the outcome of the ration of the difference of the private profit with the profit determined from the WA's point of view with the probability of detecting the noncompliant farmer. Substituting equation (10) and (11) in the objective function and taking the FCO with respect to x_i and m we have:

$$\pi_i'(x_i) = \left(\frac{c_i'(x_i)}{\left(1 + \frac{\delta}{P(m)}\right)(1 - \delta)}\right) \qquad (12)$$

$$P(m) = \sqrt{\frac{k}{\left(\pi_i(x_i^{PR}) - \pi_i(x_i)\right)(1 - \delta)P\prime(m)}} \qquad (13)$$

By solving equation (12) we determine the optimal level of irrigated share from the WA's point of view with respect to the type and from equation (14) we determine the optimal level of monitoring. The solution of equation (12) has several implications. If $P(m) = 1$ indicate that monitoring intensity is maximizes and the WA can perfectly detect farms' action. In addition, the value of x_i determined from equation (12) is now depending on transaction costs and monitoring probability. The variable x_i impact on the value of sanction which is estimated from equation (11). In other circumstances, if the WA reduces the monitoring intensity eventually $P(m)$ decrease (i.e. with respect to low level of transaction costs) which in turn influence the increase of the ration of the denominator of equation (12) and the irrigated share at some point start increasing toward the x_i^{PR}. This result tell as that for increasing farms' irrigated share there is a twofold outcome on the equation (11) due to the difference of the nominator decreases but the general outcome of the sanction increases due to the $P(m)$ decreases.

In addition, from the equation (14) is determined the optimal level of monitoring probability that maximizes social benefits. From above analysis we know that monitoring probability depends on monitoring intensity which are function of monitoring costs. Now the WA has a trade-off between the loos from the costs arriving from supplying water for higher irrigation share compare with what is optimal from its point of view and the gain from maintaining low level of monitoring costs by decreasing the frequency of monitoring $(m < m^{\max})$ where $m^{\max}$ indicate the maximum level of monitoring intensity.

2.3. Linear vs nonlinear transaction costs

To illustrate the relationship between transaction costs and variables of the objective function we have first to identify transaction cost function. To simplify the interpretation, we will consider now that the overall value of transaction costs is generated from all farmers that participate in the scheme. Suppose there are $i = 1, \dots, n$ farm types. The overall value of transaction costs is in function of money transfer from payments and from enforcement of sanction when possible. Let's model the transaction costs as follows:

$$\delta = f(\delta) = f(\delta^{t}) + f(\delta^{\sigma})$$

Where $f(\delta^{t})$ indicate the transaction cost function with regard to transfer of money because of farms payment and $f(\delta^{\sigma})$ indicate the function from the transfer of money from the sanction. Suppose $f(\delta^{t})$ is fixed (i.e. equal over types because all farmers have to pay irrigation tariffs and generate transaction costs) and assuming that $f(\delta^{\sigma}) = -aq^2 + bq$ is considered variable and is in function of number of farmers that are caught q where $q \in n$ and which contribute with its particular share of transaction cost and this is different among types as theirs sanction is estimated in function of theirs fault.

Now to pave the way for the numerical illustration, we will consider that the farms share of transaction cost from the transfer of money of the sanction is depicted in Figure 1. The ABCD concave line indicate the depicted quadratic transaction cost function in function of number of farmers on the x axes. Without loss of generality from the assumption, the concave curve regresses a more close distribution of the value of transaction costs with regard to the farmers. This allow us to determine in a more accurate way the level of transaction costs for a relative number of farmers that are considered being caught and enforcement of sanctions would occur.

We can also regress a linear combination of transaction cost as shown with the AD line in figure but as it is indicated all linear points remain below the concave curve. In effect, this means that the original concave function ABCD shows a better approximate of a series of values of transaction costs (i.e. from money transfer from sanction). Clearly additional activities may be defined to reduce the length of black dashed segments, thereby providing a much higher degree of approximation of the original function.

In addition, figure shows that for the q number of farmers the linear combination correspond to point E on midline of the AD which is inferior with the point C obtained from the concave curve which indicate a more real combination of transaction costs. Be aware that this explanation arises from the assumption of the concave transaction cost function.

This result is important because it implies that the model will always seek solutions that lies on or close to the original function. Similar result hold for any other combination of nonadjacent activities. With regard to our problem, this illustration clarifies conditions where the WA is able to better approximate the level of transaction costs to be collected to farmers and as well as illustrated by figure the concave function is better approximate of the original function (i.e. bullet points).

In addition, not all nonlinear relations can be linearized in this way. For example if we consider convex functions this explanation will not hold and points achieved through linear combination will be superior than points lying one or close to the original convex function but this explanation goes beyond of our focus and so we leave it as a window for future research.

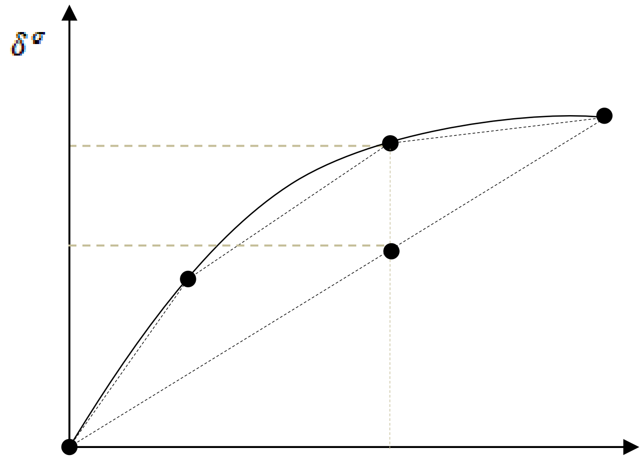

Figure 1. Linear vs nonlinear transaction cost function

3. Numerical example

In order to carry out this empirical analysis, the necessary data are taken from the paper of Viaggi et al. [14] which it refers the case study of the Irrigation Board of Romagna Occidentale (Northern Italy). In this regard we receive farms profit function and water use function as determined in the paper of Viaggi et al. [14]. Different from the reference case, the study considers three farm types (i.e. second, third and fourth as ranked in the Viaggis' et al. [14]). In addition the unitary cost of water provision is considered 0.1 €/m3 (i.e. this value was not showed in the model because it was already internalised in the water use function to estimate the water cost function). Also, to check the functionality of the model we here hypothetically determine the frequency of monitoring m which is assumt from 1 to 10 (i.e. monitoring technology is not defined) and its cost $k=0.7$ and transaction cost function approximated its valu as developed in section 2.3. This is for the purpose of empirically assessing the value of parameters theoretically modelled previously.

In this example, it is supposed that the WA offers to farmers a contract which combines water tariffs and determined level of irrigated share. As mentioned above it is supposed that under asymmetric information condition farmers are monitored in order to check if they comply with the rules of the contract. If farmers do not comply and are found noncompliant they face a sanction in from of additional payment. The value of sanction is determined upon farms' action (i.e. depended on the exceeded level of irrigated are with regard to the agreement). The expected result from the application of this methods is that the allocation of water resource to farmers would be at higher cost under asymmetric information compare with full information. Therefore, our focus now is to illustrate different scenarios under asymmetric information condition and analysing the WA's pricing strategy and its effect to the social benefit.

From the paper [2] we know that the implementability of incentive pricing scheme requires to maintain at low level the burden of transaction and monitoring costs. This means that depending on these values will be analysed trade-offs between benefits from the implementation of an incentive pricing mechanism and the loss from costs for the implementation of such mechanism because at some point the gain by implementing the incentive water-pricing scheme might not justify the loss, in term of social benefits, arising from the cost of pricing scheme implementation. In following, we assess and clarified in term of economic point of view the role and the relevance of transaction costs for the WA's decision-making process. Figure 2-7 illustrate the main results from model implementation.

Figure 2-3 displays the trend of farmers' irrigated share when the water supply costs is considered 0.1 €/m3 and two level of transaction costs 0.05 €/ha and 0.5 €/ha. The high degree of transaction costs is assumed to achieve more tractable results. Under the first scenario transaction costs 0.05 €/ha in Figure 2 farms irrigated share declines up to 14% for farm type 1 and up to 3 and 4% for the other two farm types. In addition it is achieved that the trend of the curve of irrigated share had a more pronounced decline in the second scenario (i.e. transaction costs 0.5 €/ha) as illustrated in Figure 3. In term of percentage the decline of irrigated share is up to 20% for the farm type 1 and 3 to 8% for farm type two and three.

As it turns out from figures farm type 1 is more affected from the increase of transaction costs. This result mostly occurs for two reasons: 1) farm type 1 has a greater demand for water and with increasing water costs (i.e. transaction cost) the overall water tariffs are increased. Therefore, farmers respond to water tariffs is by decreasing demand for irrigation and this is more flattened for other two farm types because the increase of water costs does not significantly influence the reduction of water demand; 2) by increasing monitoring intensity by the WA, farmers probability of being caught cheating is increased. Therefore, for greater monitoring probability farmers willingness toward costly action decreases because of sanction effect, in this way when monitoring probability maximizes farmers irrigated share declines toward the optimal level of irrigated share from the social point of view.

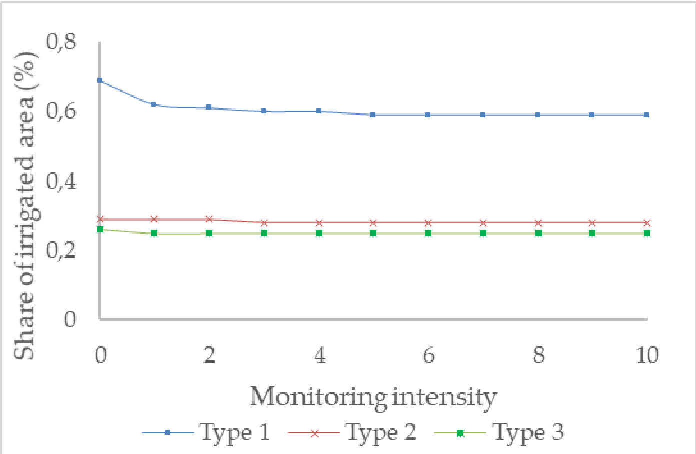

Figure 2. The trend of farmers irrigated share under different level of monitoring intensity and 0.05 €/ha level of transaction costs.

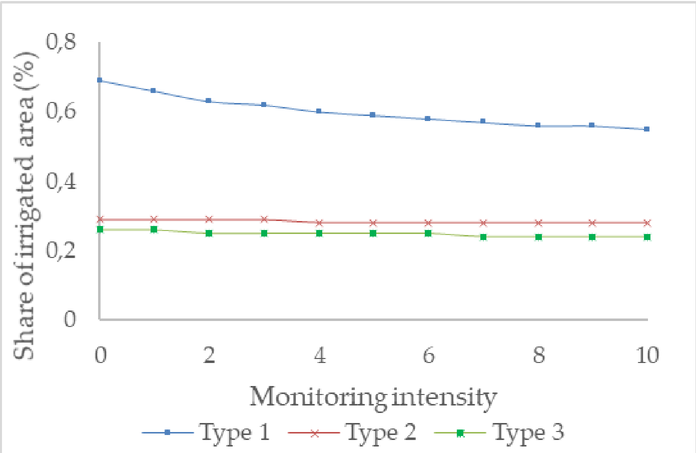

Figure 3. The trend of farmers irrigated share under different level of monitoring intensity and 0.5 €/ha level of transaction costs.

Figure 3-4 depict the value of sanction in function of monitoring intensity. From the fist view we see in Figure 2 that the farm type 1 (blue line) is mostly affected by sanction and this occurs because of the decline of the irrigated share. In addition we see that the blue curve (i.e. we refer to farm type 1 as the fluctuation of the curve is

more distinguishable) firs raises and then decline, while according to Figure 4 the tendency of the curve is more smooth when transaction costs are assumed greater.
This result is explaind for the fact that under low level of transaction costs there is no large decrease of farms irrigated share. Which eventually there is no large decrease of farms profit and farmers do not take cheating action unless the monitoring intensity is too low. This result happened because the additional increase of farms profit by cheating do not justify the loss arising from the additional payment by sanction if being caught. With other words farm's utility by respecting the rules of the contracts (avoiding being sanctioned) is greater than the disutility received by cheating.
In the second scenario when the transaction costs are fare greater than the first scenario, farms irrigated share decreases in greater size which in turn impacted by decreasing farms profit. Therefore, the farmer take the risk of cheating once the monitoring intensity is less then maximum. In turn even the irrigated share decreases but the intensity of monitoring remains high, this eventually from the equation (8) provides a level of sanction lower than the case when the monitoring intensity is low. That's why the blue curve in figure 5 is more smoothed than the one in Figure 4.

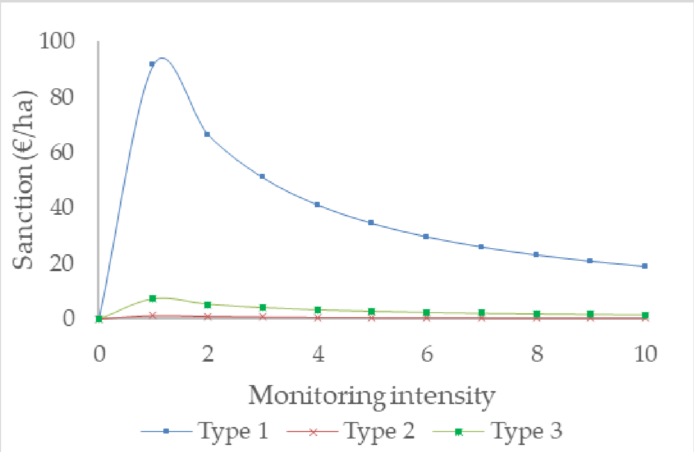

Figure 4. The trend of sanction under different level of monitoring intensity and 0.05 €/ha level of transaction costs.

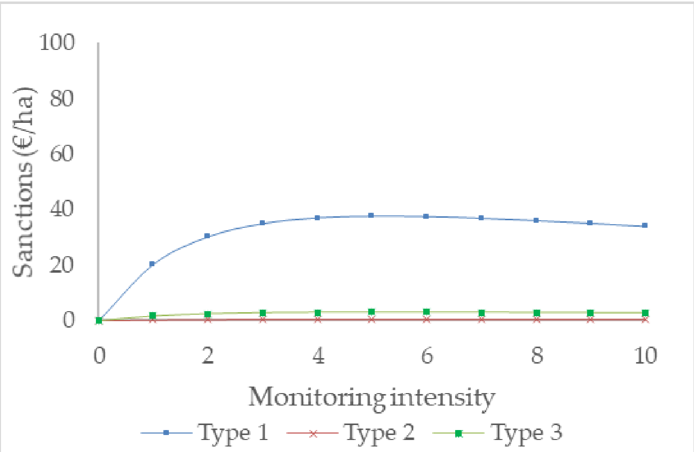

Figure 5. The trend of sanction under different level of monitoring intensity and 0.5 €/ha level of transaction costs.

Figure 6-7 show the variation of the social benefit in function of monitoring frequency. It can be seen from Figure 6 that the trend of the curve of the social benefit first increases and then decreases. This also show that the maximization of the social benefit is achieved when the monitoring intensity is relatively low. This result indicate that when the water supply costs are low (i.e. due to low transaction cost 0.05 €/ha) the WA employ low mentoring frequency because the gain by increasing monitoring intensity does not justify the cost arising from

monitoring. In the other hand in Figure 7 is illustrated that the maximization of the social benefit is achieved when the monitoring intensity is set relatively high (i.e. 0. 5 €/ha). This result indicate that when the water supply costs are increased (i.e. higher transaction costs 0.5 €/ha) the WA's monitoring intensity is increased because the save by bearing costs by monitoring farmers is greater than the loss from monitoring, even that monitoring intensity is not maximized due to the counterbalance arising by monitoring costs on the social benefits.
The main result from this analysis and with a policy meaning turns to be that the WA act strategically in a way of maximizing social benefits and in inducing monitoring intensity for detecting farms noncompliance. Hence, high monitoring cost might not be justified by the gain of inducing farm's compliance. In addition, the WA make a trade-off between the gain by improving levels of social benefits and the loss from incurring monitoring costs.

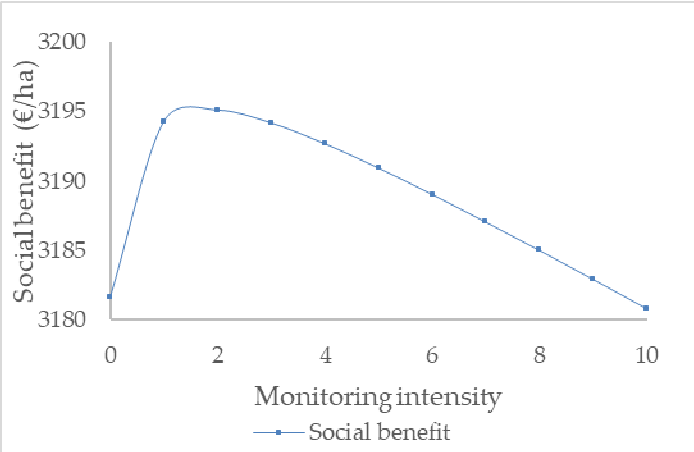

Figure 6. The trend of social benefits under different level of monitoring intensity and 0.05 €/ha level of transaction costs.

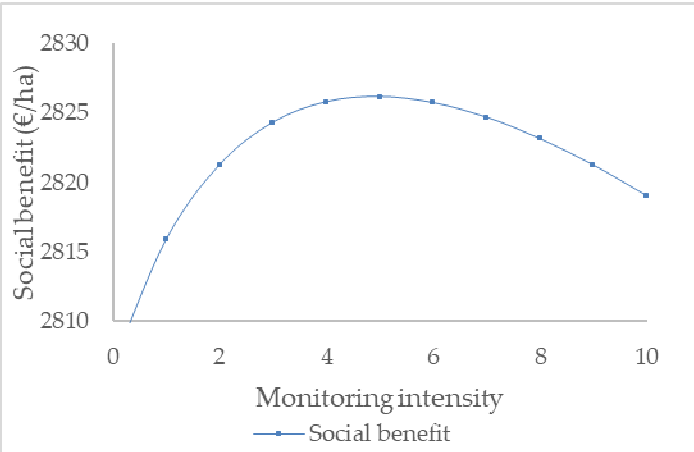

Figure 7. The trend sanction under different level of monitoring intensity and 0.5 €/ha level of transaction costs.

4. Discusion and conclusions

The paper presents a principle-agent model of water pricing for irrigated agriculture. The model aims at solving the moral hazard problem for irrigated agriculture and analysis the effect of transaction costs in the social benefit. In addition we show that under asymmetric information condition the WA is obliged to engage monitoring activity to prevent farms costly behaviour.

According to the mechanism design results suggest that the WA is able to keep higher level of social benefits even when the monitoring intensity is not maximized. Nevertheless, this result varies with level of monitoring costs.

The proposed incentive water pricing scheme can be considered as an efficient mechanism for sustainability of the use of water resource and might reach the WFD objective in term of integration of economic tools. We show that how promising is this method proposed by the WA for altering and distributing costs among farmers on the bases of their contribution on the overall costs.

In addition we show that involving sanction in the model is by means of not only discouraging farm's cheating action but also influencing the increase of effectiveness of irrigation network by incentivizing the farmer to irrigate rationally.

In term of policy implication can be stated that incomplete information and transaction costs are fundamental in a policy design and must not be overlooked while design and implementing a policy even that the implementation of a pricing strategy depends upon environment surrounding the irrigation network.

Nevertheless, the model introduced at a given form has several limitations. The main one stands with the fact that the determination of some functions relay in a hypothetic assumption, not allowing the achievement of results from real case study and realisation of its real implications. Another limitation of the model consist on the monitoring technology which is not defined in this study (i.e. but could generate different level of monitoring costs compare with the one introduced so fare) but monitoring is considered as one of possible options to deal with moral hazard problem for irrigated agriculture.

However, the research can be extended in exploring strategies to manage moral hazard problem by checking for strategies to optimize the problem by facing different level of monitoring costs arriving from different farm types. In addition, transaction costs have yet to be analysed addressing this issue and its implications in practice is important from the economists and policy makers.

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