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The impact of new regulations on water pricing in the agricultural sector: a case study from Northern Italy

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Abstract

The present study intends to investigate the expected impact of changes in pricing policies applied to the use of water resources recently experienced in an agricultural area located in Northern Italy. The study begins introducing the pricing criterion adopted by a water authority in different region supplied by its irrigation network. This pricing criterion is, then, analysed in light of the new regional mandatory requirement on water pricing and modified accordingly. A methodology is developed to evaluate the expected impact of the new pricing policy on the amount of water applied, land allocation and irrigation technology adoption. The methodology follows a two-step approach. In a first step we estimate the yield response to decreased water uses for the main crops cultivated in the area and for different irrigation techniques. In a second step, the estimated production function is integrated into an economic optimisation model to calculate relevant impacts. The results highlight that the change in pricing criteria would not cause substantial variations in water uses. This is mainly due to inelastic demand for water in agriculture. However, the new pricing criteria incentivize the adoption of water saving technologies. The study concludes by addressing that attention should be paid to synergies of water pricing with co-financing subsidies on investments for further promoting the adoption of water saving technologies.

Keywords: WFD, water pricing, irrigation, mathematical programming
JEL: Q5

1. Introduction

Global water resources are under pressure mainly because of two linked phenomena: world population growth and climate change impacts. The agriculture sector remains the single largest user of water (International Institute for Sustainable Development (IISD) 2013). Water pricing reforms are among various measures designed to encourage the efficient use of water resources (Renzetti 2000). Literature demonstrates that many countries have been engaged in such pricing reforms (Dinar 2015; Kahil et al. 2016). Since investments in new water technologies represent a high effort for both private and public funding, water pricing represents a key issue both for developing and developed countries (Duchin and López-Morales 2012). These features should be considered in modeling irrigation adoption decisions and the impacts of water pricing reforms.

Moreover, lessons learned from the extensive analysis of agricultural water use in middle and high-income countries can be transferred to low-income countries. For instance, the political economy of water price reform in Australia (Dinar 2015) confirms that successful reform requires the backing of an effective political coalition, and also it demonstrates the difficulty of costs identification, measurements, and sharing, particularly in the rural sector. Other works on water pricing in US (Read 2009) conclude that irrigation technology, crop choice, and land allocation are affected by the price of water as well, although elasticity is relatively small. However, the widespread absence of metering in this sector limit the possibility to set up incentive pricing mechanisms (Molle 2009).

The impact of new regulation on irrigated agriculture, including water pricing, has already widely discussed in literature (Johansson 2000). Nevertheless, conclusions from existing studies, comparing the performance of water pricing criteria among different countries, agree that there is no best practice that can be recommended to one country or sector (Kahil et al. 2016; TSUR et al. 2004). The reason is that optimal prices depend on the objectives of the water agency, as well as on the types of information available to it (Iglesias and Blanco 2008).

The Water Framework Directive 60/2000 (WFD from now on) is a cornerstone of the European Union’s view on water pricing, stressing the importance of treating water as an economic good and, in particular, of "setting the price right", to provide effective economic incentives to water users (Bank et al. 2002).

Specifically, the polluter’s pay and the full cost recovery principles introduced with the WFD call for using water pricing to incentivize efficient and sustainable uses of water resources both in the civil sector, the industrial sector and in agriculture. These principles have been hardly applied to incentivize efficient water uses in agriculture, at least in Italy (Massarutto, Antonioli, and Ermano 2013).

Nevertheless, the Emilia Romagna Region recently published guidelines on water pricing (Regione Emilia Romagna 2012) to homogenize the pricing citeria implemented by the water authorities operating in the region, also coherently with the WFD pricing principles.

Theoretically, by pricing water for irrigation on a volumetric basis it is possible to achieve a profit-maximizing equilibrium modulating the amount of water applied until marginal profits equal the unit price of water. Otherwise, if the tariff is not directly connected to water uses, i.e. the marginal cost of water is zero, the optimal level of water use is the same as the maximum level of production in the production function. Therefore, farmers still irrigate even when the marginal productivity of water falls below the real (social) marginal costs of water.

In fact, water metering is a prerequisite to put into practice such principles and this rarely occurs in the northern Italian agricultural regions. Here, water for agriculture is mainly supplied through surface irrigation network and the withdrawal of water by farmers is not monitored. But, even where it is possible to meter irrigation water consumption (e.g. farmlands served by pressure pipes), volumetric tariffs might not be applied, because for example, manometers to monitor water use may be exposed to sabotage (Cornish et al. 2004). Even in some circumstances, where users pay volumetric tariffs, the reduction of water uses are negligible, as irrigation water demand is often inelastic (Fragoso et al. 2011). Yet, some authors highlight that tariffs linked to the actual or alleged uses of water for irrigation may incentivize a wider adoption of water saving technologies, indirectly affecting demand for irrigation water (Moreno and Sunding 2005). Altogether, the possibility and the benefits of a shift towards volumetric pricing remain a rather empirical issue (Molinos-Senante, Hernandez-Sancho, and Sala-Garrido 2013).

In this context, the present paper compares the pricing criteria adopted by the Burana Reclamation Irrigation Board, (Burana RIB from now on), before and after the adoption of WFD pricing principles, as proposed by the new regional guidelines. Specifically, the study simulate the impact of the new pricing criteria with respect to the amount of water applied, land allocation and irrigation technology adoption by elaborating an economic optimization model.

The economic optimization model accounts of detailed techno-economic information about irrigation and about water pricing collected by the means of direct interviews and involving both farmers and water managers. A standard Positive Mathematical Programming method (PMP from now on) is used to reproduce initial conditions (Howitt 1995), Part of the inputs used for the economic optimization model are themselves output of a crop evapotranspiration estimation model (Guerra et al. 2014).

In the present study we adopted the standard PMP approach as we had the opportunity to exploit detailed techno-economic information about irrigation and other agricultural practices and about water pricing for all the agricultural districts served by the case study irrigation network.

Different pricing scenarios consistent with the regional guidelines on water pricing and with the characteristics of the irrigation water supply network where identified with the support of a representative of the RIB to simulate the relevant impacts.

This case study enriches the current debate around the effectiveness and practicality of new pricing criteria, able to incentivize a more rational use of water resources. Results provide practical policy recommendations to support local water authorities in the new regulation implementation process.

The paper is organized as follow: (i) the problem section, which starts with the description of the case study region, and then, explain the new pricing rules implemented by a local water authority to recover the costs faced to supply water for irrigation; (ii) the material and method section, describing a combined approach of crop growth models with economic optimisation models to estimate impacts of any variation in water pricing mechanisms, (iii) the results and discussion, addressing the impact of current and new pricing criteria on the amount of water applied, land allocation and irrigation technology adoption; (iv) discussion and conclusions, providing some water policy recommendations.

2. The problem

Characteristics of the case study region

The Burana RIB is a consortium administered by the same land owners under its jurisdiction and is responsible for reclamation and irrigation services. The area is located in Emilia-Romagna (Northern Italy). Its territory is enclosed by the Po River (in the North), the Secchia River (in the East), the Samoggia River (in the West), and the Tosco-Emiliano Apennines (in the South), and covers 140,000 hectares, of which 16,500 are irrigated. Open canals cover 90% of the plain area under the consortium's jurisdiction. These canals play the twofold functions of reclamation, mainly during the winter, and irrigation, mainly during the summer period. Pressure pipes cover the remaining 10% of the region where water is delivered to end-users on demand (Fig. 1).

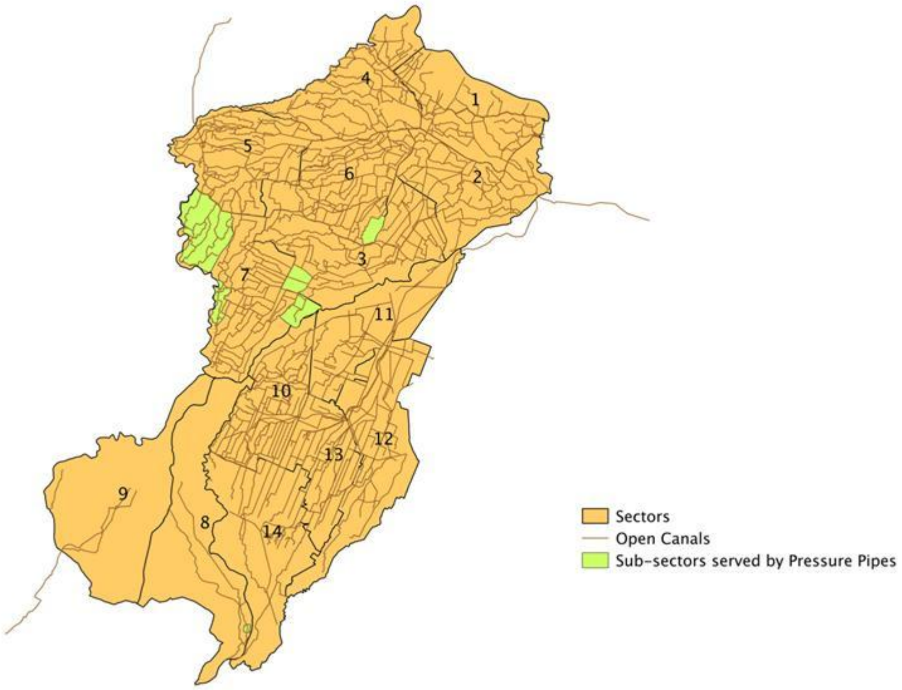

Fig. 1. - *Map of the area served by the Burana RIB irrigation services.*

Open canals serve four main sub regions, characterised by differences in altitude (low-plain and high-plain areas) and network infrastructures. Differences in infrastructure affect the possibility of setting rules for water use (imposition of turns), as well as imposing tariffs proportional to the amount of water used for irrigation. Water is priced on a per-area basis, in most of the sub-regions, and on a per hour basis for those farmers using furrow irrigation in two sub-regions. Arable crops account for more than a half of the total cultivated area in the region served by the RIB (56%) and are mainly concentrated in the low plain areas. Orchards and vineyards occupy 8% of the irrigated agricultural area, most of which are located between the low plain and high plain areas. Finally, vegetable crops account for 2% of the total UAA, most of which are located in the low plain region.

In the whole region, farmers integrate surface water sources with ground water sources to satisfy total crop water requirements, and there is no significant correlation between crop type and distance from water abduction sources. A higher implementation of water saving technologies is registered for sectors served by pressure pipes. Specifically, 25% of the irrigated crops are irrigated with drip irrigation systems for sectors served by PP and only 9% of the irrigated agricultural land is equipped with drip irrigation systems for sectors served by open canals.

Current and new water pricing policies

Under the current pricing system, the water authority applies different tariff strategies for the various sectors of the irrigation network. According to the characteristics of each sector, the tariffs are: (I) proportional to the total farmland; (II) differentiated with the distance from the main source of water; (III) differentiated with the type of crop and type of irrigation system; (IV) proportional to the duration of the irrigation interventions (for furrow irrigation technique).

The new regional guidelines on water pricing (Regione Emilia Romagna 2012) called water authorities to revise their pricing criteria consistently with EU regulation (WATECO 2000). These guidelines where published with the main intent to drive local water authorities to shift from pricing policies merely oriented to recover supply costs to pricing policies oriented to incentivize rational water uses.

According to the guidelines, supply costs for irrigation water should be recovered by the imposition of a two-parts tariff: a flat charge to recover fixed costs, and a variable charge to recover variable costs. The flat charge includes capital costs, full-time labour costs, ordinary operating and maintenance costs that the water authority faces independently from of the amount of water supplied. The variable charge includes mainly part-time labour costs, conveyance and pumping costs that the water authority sustains in relation to the water amount supplied.

The fixed component of the tariff must be applied to the total irrigable agricultural region covered by the irrigation network, independently of whether this is (or is not) irrigated. The payment of a minimum price is motivated by the need to guarantee the functionality of the irrigation network and by the fact that the potential usage of water for irrigation assured by the presence of the irrigation network is a value added of its own. In addition, the fixed component of the tariff must decrease with the distance of the field from the closest point of the irrigation network to assure that fields located in well equipped areas are priced more than fields located in region marginally covered by the network.

In addition, according to the regional guidelines, the variable component of the tariff must be tied to the amount of water applied in those region where it is possible to meter water uses, ensuring the conditions for the optimal use of water from an economic perspective. In the absence of water metering, regional guidelines mandate to differentiating tariffs according both to the type of crop grown and to the irrigation technology adopted.

The new mandatory Regional water pricing policy forced local water authorities, including the one operating in the case study region, to reformulate their pricing criterion accordingly. Up until the publication of these guidelines, local water authorities adopted arbitrary criteria to price water. These criteria were largely inconsistent with the ones deemed by the regional guidelines. Since the variable component was absent or kept to a minimum under the previous regulatory setting, it is expected that most of the water authorities operating in the region will experience a significant increase in the variable component. These new guidelines affect also the pricing policies of the Burana RIB who is called to increase the quota of supply costs to be recovered through a variable tariff and to homogenize the pricing criterion adopted in the different regions served by the irrigation network. Actually, the RIB recovers supply costs by imposing a flat rate for some of the sectors served by the irrigation network and a two-part tariff for others. Thus, the new regional water pricing reform is expected to impact differently the different region served by the network, with negligible effects in some region and evident effects in some others.

This condition motivates the purpose of the present study that is to carry out an ex-ante assessment to evaluate the possible impacts of the new pricing criteria addressed by the regional guidelines on the irrigated agriculture served by the RIB. In this respect we developed a methodology trying to answer to the following questions: how should the

Burana RIB allocate the water supply costs amongst users, to meet Emilia-Romagna regional guidelines? In addition, since new regulation requires a variable tariff, combined with a fixed tariff, does the variable tariff affect irrigation water demand? In the following section we provide a description of the methodology adopted to answer these questions.

3. Material and methods

The methodology is designed to simulate the impact of variations in pricing scenarios determined by the enforcement of the regional guidelines on water pricing in the case study region.

The methodology follows a two-step approach: 1) the estimation of the production function with respect to water uses for the main crops in the district and the main irrigation systems adopted; 2) a simulation through economic optimisation under different pricing conditions, through a PMP approach.

The first step made it possible to estimate the relation between crop production and the amount of water applied for the main crops cultivated in the district area and for different irrigation techniques, given the local meteorological conditions. In the second step, the estimated production function is used to set up the economic optimisation model, together with the inclusion of other techno-economic variables. The amount of water applied, land uses (allocation of land among crops) and irrigation technology choices appear as a decisional variable of the economic optimization model. Different water pricing conditions, after optimisation, entail different optimal values of the decision variables, affecting farmer's profits, water uses and land use allocation.

4. The production function estimation

This paragraph intends to explain how crop production function were developed from local meteorological data and information collected through farmers interviews.

Meteorological data (temperatures, precipitation amount, and wind speed) referring to the time period 1980-2013, and collected from a local meteorological station (Mirandola, Modena, Italy www.arpa.emr.it) were used as inputs to compute the monthly mean reference evapotranspiration (ETo) for the considered irrigation period, which goes from May to September. The monthly mean calculated ETo together with the monthly mean values for the same local climate variables were used as input in an ET model, named KcMod based on crop coefficient methods (Guerra et al. 2014) to determine crop evapotranspiration, ETCi,h, under well-watered conditions (absence of water stress) for a given crop, i, and for a given irrigation technology, h, as it follows:

$$Kc(tab)_{i,h} = \frac{Kc(obs)_{i,h} + 0.261(ET_0 - 7.3)}{1 - 0.261(ET_0 - 7.3)} \qquad (1)$$

where: Kc(obs)i,h is the tabular value of the crop coefficient for a given crop and for a given irrigation technology; 7.3 (mm) is the July ETo, which is the reference evapotranspiration, being July the month corresponding to the midseason period of the typical climate where Kc were developed, calculated using local meteorological data with the Penman-Monteith method (Allen et al. 1998). Therefore, Eq. (1) allows to calculate the base-climate Kctab values from research derived Kcobs in a "non-base climate", such as the Burana district climate. Then, ETCi,h is calculated as it follows:

$$ETc_{i,h} = Kc(tab)_{i,h} ET_0 \tag{2}$$

The cumulative crop evapotranspiration of the entire irrigation season (CETCi,h) was used in the program MAD6, to obtain the actual cumulated crop evapotranspiration CETAi,h as a result of crop water stress simulation, for a given crop, i, and for a given irrigation technology, h, under specific soil and climatic conditions (Raes et al. 2009; Smith and Steduto 2012). Specifically, CETAi,h data were assumed as optimum to simulate the effect on yields of a Variable Rate Irrigation (VRI) on main crop categories, according to the different irrigation technique adopted in the region of investigation. Yield responses to water stress were estimated in MAD6 by applying an algorithm, which is a variation of the methodology described in the FAO working paper 33 (Kaboosi and Kaveh 2011).

Then, yield responses for a given crop i and a given irrigation technique h to decreasing levels of actual evapotranspiration, ETAi,h, allowed to estimate the crop-water production functions with respect to water uses, as Eq. 3 shows:

$$y_{_{i,h}} = \mu_h Yc_i [1 - K_Y \left(1 - \frac{CET_{A_i}}{CET_{C_i}}\right)] \tag{3}$$

where: Ky is the reference yield crop coefficient (Smith and Steduto 2012), that is, the marginal productivity of water; Yci is the maximum yield (detected through interviews) obtained under base climate conditions (i.e. standard relative humidity and standard wind speed), for a given crop i; μh is a coefficient, which relates crop water requirement with the amount of water applied, and it varies with the type of irrigation technology, h.

Finally, we carried out a sensitivity analysis with respect to CETAi,h , varying from 0 to CETCi,h, to estimate the corresponding yield. The model simulates the water stress effect on crop yields, due to decreased irrigation amounts. In such a way, yield and CETAi,h value pairs allowed to estimate a non-linear concave crop yield function for the main crop cultivated in the case study region and for the main irrigation technologies, yi,h(wi,h), where wi,h is the amount of water applied, with y’i,h(wi,h) > 0 and y’’i,h(wi,h) < 0. Coefficients of water production function were used as input in the economic optimisation model to assess any impacts determined by variation on water pricing in the case study region.

By exploiting three existing evapotranspiration (ET) models: the first one was used to calculate the reference evapotranspiration (ETo); the second one allowed to compute the crop evapotraspiration (ETc); and the third model permit to simulate the effect of decreased irrigation amount on crop yields

5. The economic optimisation model

The following optimisation model estimates the impact of existing and theoretical pricing criteria with respect to the amount of water applied, land allocation and the irrigation technology adoption. A modified Positive Mathematical Programming method is adopted to obtain an exact representation of the reference situation. The method assumes a profit-maximising equilibrium in the baseline situation and uses the observed levels of production activities as a basis for estimating the coefficients of a non-linear objective function, in a way similar to what has been done in recent studies (Mérel and Howitt 2014; Solazzo et al. 2014).

Specifically, the method follows four stages: i) development of a background optimization model where the regulator set tariffs according to the actual pricing schemes enforced in each district of the irrigation network, including a constraint on land uses to calculate the relevant shadow prices; ii) removal of the constraint on land uses and inclusion of a quadratic cost function with respect to land use incorporating shadow prices in the objective function; iii) replacement of actual tariff schemes with the new pricing schemes suggested by the regional policy guidelines; iv) comparing the impacts of the changes in pricing rules on water uses, technological changes and variations in land use.

The district is the reference unit of investigation. We identify the district with the subscript a. The choice of this level of investigation is based on the fact that each district represents an independent management unit of the irrigation network, characterised by different supply infrastructures and by different operational and maintenance costs. The set of decisional variables considered in the model are: xa,z,i,h , the amount of cultivated land in district a, differentiated in sub-sectors varying with the distance of the field from the closest point of the irrigation network, z, for each crop type, i, and for each type of irrigation technology adopted by farmers, h; wi,h , the amount of water for irrigation, differentiated with the type crop, i, and with the type of irrigation system, h. Other variables are the tariffs implemented by the water provider to recover supply costs. Tariffs levels and characteristics differs with the sector of the irrigation network. These are: ta,z,i,h, tariffs not directly connected to the amount of water applied, which are differentiated among districts and sub-sectors of the irrigation network, differing also with the type of crop cultivated and the type of irrigation system used; va, tariffs proportional to the amount of water applied, differing with the district. Land use and tariffs are continuous variables, while the amount of water is a discrete variable, as farmers are able to modulate the application of irrigation water for fixed amounts, differing with the type of irrigation system adopted. Specifically, for drip irrigation the farmer is not subjected to any significant technical constraints, while for sprinkler and furrow irrigation each intervention is subjected to a timing constraint conditioned respectively by the workforce and by water flows. Thus, a mixed-integer non-linear positive mathematical programming model has been adopted to solve Equation 4, which represents the optimisation problem:

$$\max \prod_a = \sum_{z,i,h} [p_i y_{i,h}(w_{i,h}) - c_{z,i,h}(x_{a,z,i,h}, w_{i,h}) - (t_{z,i,h} + v_a w_{i,h})] x_{a,z,i,h} \forall a \tag{4}$$

s.t.:

$$\sum_{z,i,h} x_{a,z,i,h} w_{i,h} \le Land_a \forall a, z \tag{5}$$

$$\sum_{z,i,h} x_{a,z,i,h} w_{i,h} \le Wat_a \forall a \tag{6}$$

$$\sum_{z,i,h} [(t_{a,z,i,h} + t_a w_{i,h})] x_{a,z,i,h} \ge F_a^{sc} + \sum_{z,i,h} V_a^{sc} w_{i,h} x_{a,z,i,h} \tag{7}$$

$$w_{i,h} \ge 0; x_{a,z,i,h} \ge 0 \; with \; w_{i,t} \in Z^+ \; and \; x_{a,z,i,t} \in R^+$$

where: ∏a represents farm profits; pi represents the price of the crop, differentiated with the type of crop; cz,i,h(xa,z,i,h, wi,h) represents costs, differentiated with the distance from the main source of water, the type of crop and the type of irrigation system. Costs are both linear functions of the amount of water applied for irrigation, estimated through the information provided by the water provider, and quadratic functions of crop size, estimated through the cited PMP approach[1]. Equation 5 is the constraint for land availability, landa,z; Equation 6 is the constraint for water availability, Wata. Finally, Equation 7 is the cost recovery constraint. Tariffs are determined observing both cost recovery and pricing rules. Fasc and Vasc are respectively for fixed and variable supply costs. These are differentiated with the district served by the irrigation network. Vasc never exceeds a quarter of the total supply costs in each sector of the network. With respect to the pricing rules currently adopted by the water provider, fixed tariffs are sometimes differentiated with the distance of the field to the closest point of the irrigation network, while variable tariffs are sometimes differentiated with the type of crops and with the type of irrigation systems for sectors served by OC.

The new policy guidelines oblige the WA to apply a two-part tariff whatever are the characteristics of the network. In addition, the guidelines call WAs to reformulate the criterion they adopted for identifying the supply costs items to be recovered through the variable component of the tariff.

The new pricing scenarios differ from the current tariff scenario mainly by the way in which tariff options and levels are set up. The new tariff scenario introduces a two-parts tariff for all of the sectors served by the irrigation networks. For those sectors served by open canals, the variable component is linked to the alleged use and is differentiated with the type of crops and irrigation system. For those sectors served by pressure pipes, the variable component is linked to actual uses. In the current tariff scenario, only a few sectors of the irrigation network experienced the implementation of a two-parts tariff and none of the fields served by pressure pipes experienced the imposition of volumetric tariffs. With respect to tariff levels, the level of the variable component is very low when applied and the setting of tariff levels is arbitrary. This state of arbitrariness breaks down with the publication of the new regional guidelines that set the rules for the calculation of the type of costs to be recovered respectively through variable and fixed tariffs.

This new pricing condition poses the need to reformulate Equation 7 accordingly and to run again the optimization problem so far described. Moreover, for the new tariff scenario an iterative optimisation is carried out to obtain a sensitivity analysis with respect to the share of supply costs recovered through the variable and, respectively, the fixed component of the tariff.

The impact of the change from the old to the new tariff system may take different forms, such as a variation for applied water, land allocation, and irrigation technology adoption. Theoretically, variations for applied water occur only when water is charged on a volumetric basis, while variations in land allocation and irrigation technology adoption occur when tariffs differ with the type of crop and with the type of irrigation system adopted, respectively. Moreover, the amount of costs recovered through the variable part of the irrigation tariff influences the relevant impacts.

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[1] The quadratic component of the cost function of the above described optimization model was estimated by first including a constraint on land uses for each crop, irrigation system and district to calculate the relevant shadow prices, λ. Then the quadratic component was set as follows: $c(x) = \frac{1}{2}\frac{\lambda}{x_{obs}}x^2$, where x_{obs} is the observed level of land use. This way when the irrigated land reaches is observed values then the cost reaches its shadow price level. In addition, shadow prices were calculated including the effect of tariff schemes currently applied by the WA.

To carry out the assessment, information on prices and costs were retrieved by exploiting the regional farm accountancy data network (FADN, http://ec.europa.eu/agriculture/rica/). Information on land uses and irrigation technology adoption were collected from maps of the case study irrigation network. Crop management data were collected by interviewing farmers from the different sectors of the irrigation network. Finally, representatives of the RIB provided information on the pricing scheme currently implemented to recover supply costs.

6. Results

This section describes the results obtained from the two-steps methodology described above. They consist of: (i) a description of crop responses to water pricing; (ii) a comparison between the current and new tariff scenarios and the relative impact of the pricing scenario variation on water uses, land allocation and irrigation technology adoption; (iii) a sensitivity analysis of quotas of supply costs recovered through the variable component of the tariff and the relative impact on water uses, land allocation and irrigation technology adoption.

For example, Figure 2 shows yield responses to the amount of water applied (a) and the derived demand of water (b) for a crop (cherries) managed with two different irrigation systems: furrow and drip irrigation, under given climatic conditions.

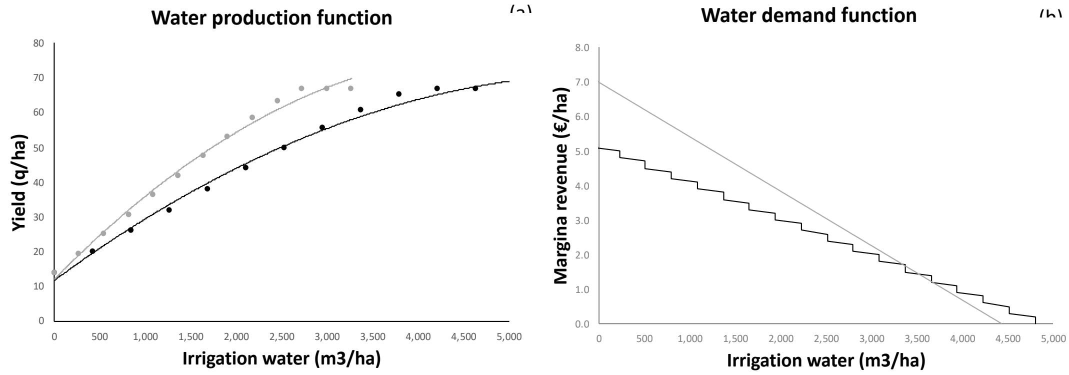

Fig. 2. *- Estimation of the production functions with respect to water uses (a) and estimation of the water demand function with a representation of the effects of pricing on water uses (b) for cherries managed with two different irrigation systems: furrow and drip irrigation, cultivated in the case study region.*

The figure depicts the relation between yield and the amount of water applied rather than the relation between yield and crop water requirements. Indeed, the amount of water applied may significantly differ from crop water requirements and is mainly conditioned by the efficiency of the irrigation system adopted by the farmer. As expected, Figure 2 (a) shows that for a given level of production, the amount of water applied is higher for furrow irrigation. The intercept with the y-axis indicates the production level for rain fed cultivation, whilst changes in the slope of the estimated functions express the transition from under-watered to over-irrigated crops. The amount of water needed to obtain the maximum yield corresponds to the projection of the peak of the curves on the x_axis. Here, the slope of the functions is equal to zero. Figure 2 (b) shows the characteristics of the water demand function derived from the estimated production function. The intercept of the functions with the x_axis indicates the amount of water needed to maximise the yield, which is higher for furrow irrigation. Functions differ also for the slope, which represent the demand elasticity. Demand elasticity decreases with the increasing slope of the curve. In general, both the amount of crop water requirements and demand elasticity decrease with the transition from furrow to drip irrigation systems. This condition implies that, with the imposition of a volumetric tariffs, drip irrigated crops may experience a lower reduction in the amount of water applied than furrow irrigated crops.

However, for furrow irrigation farmers are forced to use discrete amount of water with the consequence that, even with the implementation of a volumetric tariff, there are no significant changes in water use attitudes, until a given pricing threshold is reached (discontinuous slopes in Figure 2 (b) for furrow irrigation).

Tab. 1. *- Percentage variation of land uses and water applied for sectors served by pressure pipes (PP) and sectors served by open canals (OC) with the transition from the current to the new tariff scenario for the main crop categories cultivated in the case study area.*

GROWING CATEGORIES	LAND USE		WATER APPLIED	
	OC	PP	OC	PP
Non-irrigated crops	0%	1%	-	-
Vineyards	0%	-1%	-4%	-1%
Orchards	0%	0%	0%	-1%
Arable crops	0%	0%	0%	0%
Vegetables	0%	0%	0%	0%

Source: Authors' own elaboration

Tab. 2. *- Percentage variation on land uses and water applied for sectors served by pressure pipes (PP) and sectors served by open canals (OC) with the transition from the current to the new tariff scenario for the main irrigation systems adopted in the case study region.*

IRRIGATION SYSTEMS	LAND USE		WATER APPLIED	
	OC	PP	OC	PP
Furrow irrigation	-9%	-	-8%	-
Sprinkler irrigation	0%	0%	0%	-1%
Drip irrigation	1%	0%	0%	-1%
No irrigation	0%	1%	0%	0%

Source: Authors' own elaboration

Tables 1 and 2 show the estimated impact of the variation in tariff regimes on land allocation, the amount of water applied, and the irrigation technology adoption for both sectors served by pressure pipes (PP) and the sectors served by open canals (OC). Specifically, with respect to the main type of crops cultivated in the case study region (Table 1), the transition to the new tariff scenario does not show any appreciable impact for either land allocation or the amount of water applied. Table 1 shows a slight estimated variation in impacts between PP and OC. A variation in land uses is only registered for PP, where the transition to the new tariff scenario results in increased land coverage for non-irrigated crops. This is compensated by a land coverage reduction for vineyards. A reduction in the amount of water applied is registered for both OP and CC, but with a slight variation between the two groups of sectors in terms of intensity and the type of crops involved. With respect to the main type of irrigation systems adopted in the case study region (Table 2), the transition to the new tariff scenario results in a significant impact for furrow irrigation in OC. Here, furrow irrigation undergoes a significant reduction both in terms of land coverage and the amount of water applied. With respect to the other types of irrigation systems, Table 2 shows a slight increase in the presence of drip irrigation systems in OC and a reduction in the amount of water applied for both drip and sprinkler irrigation systems in PP.

The different impacts estimated for the two groups of sectors are due to the combined effect of the differences in pricing instruments and farming characteristics. With respect to farm characteristics, the main difference between the two groups of sectors is traceable to the type of irrigation systems implemented (see Table 2). Specifically, furrow irrigation is represented only in OC. Here, with the transition to the new tariff schemes, furrow irrigated crops experience a pricing variation from flat rates to volumetric tariffs. As a result, an appreciable reduction in furrow irrigation is registered both in terms of land coverage and the amount of water applied. This is particularly evident for vineyards; the main crop irrigated with furrow irrigation systems. With respect to the differences in pricing instruments between OC and PP, OC will experience mainly a transition from flat rates to tariffs partially differentiated by the type of crops with premium prices for drip-irrigated crops. As a consequence, a slight increase in land coverage is noted for drip irrigation systems. On the other hand, PP will experience a variation from flat rates to tariffs partially connected to water uses. As a result, irrigated crops tend to suffer a slight reduction in land coverage in favour of non-irrigated crops and a reduction in the amount of water applied.

Tab. 3. *- Percentage impact of the compared tariff scenarios on income, for sectors served by pressure pipes (PP) and open canals (OC).*

CROP CATEGORIES	CURRENT TARIFF SCENARIO		NEW TARIFF SCENARIO	
	OC	PP	OC	PP
Non-irrigated crops	5%	59%	0%	39%
Vineyards	1%	9%	1%	7%
Orchards	0%	2%	0%	3%
Arable crops	4%	4%	5%	5%
Vegetables	1%	5%	1%	4%

Source: Authors' own elaboration

Table 3 shows the differences in the per cent weight of tariffs on income for each crop category between the two tariff scenarios, for both OC and PP. With the transition to the new tariff scenario, this difference tends to decrease, particularly for PP, guaranteeing a more homogeneous allocation of costs among growing categories with respect to the alleged water uses. Indeed, Table 3 shows a significant reduction of the impact of tariffs on income for no irrigated crops and an increase for orchard and arable crops.

Figure 3 addresses the changes on land uses, irrigation technology adoption and the amount of water applied that may occur when increasing the amount of supply costs recovered through the variable component of the two-part tariff which is to be implemented under the new tariff scenario. With increasing quotas of supply costs recovered through the variable component of the tariff there is not much variability either in land uses or the amount of water applied in the whole region served by the RIB. This impact is particularly negligible for sectors served by OC. However, this is not the case when considering the types of irrigation systems.

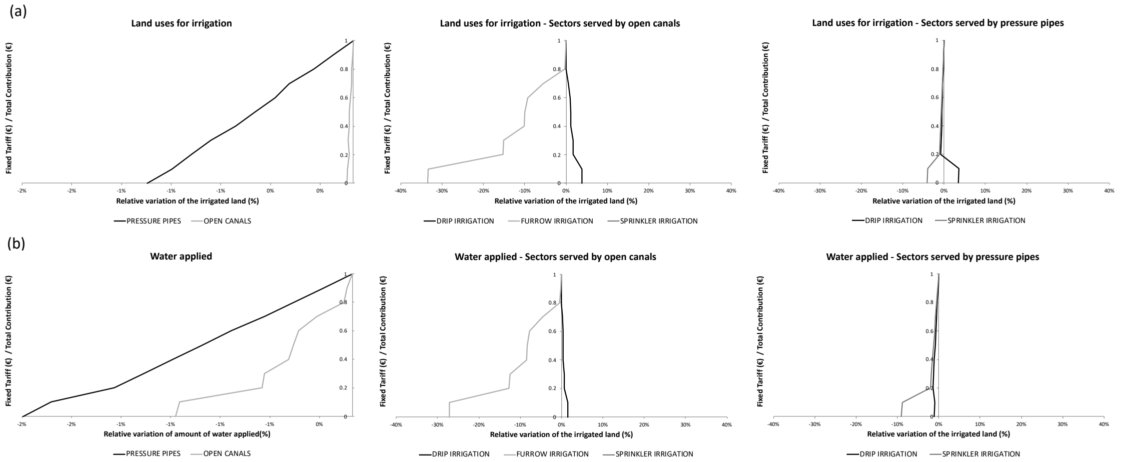

Fig. 3. - *Relative variation in land uses for irrigation (a) and in amount of applied water (b) with the variation of supply costs, recovered through the fixed and variable component of the tariff, assuming the implementation of the new tariff scenario.*

The transition to the new pricing criteria might result in an estimated 8% reduction in furrow irrigation systems compensated by a 1% increase in drip irrigation systems. This effect increases with increasing quotas of supply costs recovered through the variable component of the tariff until it reaches a 35% reduction in furrow irrigation systems and a 3% increase in drip irrigation systems. Here, with respect to OC, furrow irrigation suffers a consistent reduction in both land uses and the amount of water applied. This is compensated by an increasing representativeness of drip irrigation systems. Drip irrigation tends to increase in terms of land uses, including in the case of PP. This is compensated by a reduction in land use for sprinkler irrigation systems. In general, the representativeness of water saving technologies would increase when farmers undergo a transition from flat rates to tariffs tied to actual or alleged uses. However, tariffs tied to actual or alleged uses may result in different impacts on water uses. Indeed, despite the increasing representativeness of drip irrigation systems it is estimated an overall reduction in water uses for those sectors served by PP, where tariff are tied to actual uses. This is not the case for those sectors served by OC, where tariff are tied to the alleged uses, for which it is estimented an overall increase in water uses. Here, the reduction in water uses determined by the reduction in irrigated land equipped with furrow irrigation (we remind that only 1% of the irrigated land is equipped with furrow irrigation in sectors served by OC) is offset by an increase in water uses determined by the increase in land equipped with drip irrigation (we remind that about 10% of the irrigated land is equipped with drip irrigation in sectors served by OC).

In general, the implementation of the new tariff scenario in the two regions promote a reduction in water uses, but while for OC the pricing system favours the transition to water saving technologies without affecting the amount of water applied, for PP the pricing system affects both technology adoption and the amount of water applied.

Figure 4 Relative variation of farm profits with increasing quotas of supply costs recovered through the variable component of the tariff, assuming the implementation of the new tariff scenario.

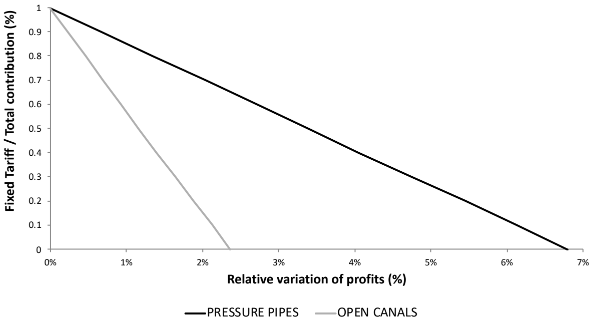

Fig. 4. *- Relative variation of farm profits with increasing quotas of supply costs recovered through the variable component of the tariff, assuming the implementation of the new tariff scenario.*

Finally, Figure 4 shows that with increasing quotas of supply costs recovered through the variable component of the tariff, farm profits increase across the entire region served by the RIB. This is particularly evident for PP and in those regions where the variable component of the tariff is proportional to the amount of water applied.

7. Discussion and conclusions

The present paper documented the changes in pricing rules recently experienced by a water provider in Northern Italy and analysed the relevant consequences. These changes were due to a regional regulation implementing the WFD pricing principles (full cost recovery and incentive pricing) in Emilia-Romagna. The analysis of pricing adaptation to new rules in the case study region reveals that, even assuming full compliance with the regional guidelines, changes in water uses are unlikely. This is mainly due to infrastructural constraints that limit the number of available pricing options and regulatory issues conditioning the quotas of supply costs recovered through the imposition of tariffs. Indeed, the imposition of tariffs only makes it possible to partially recover supply costs borne by water providers, as most of the costs are co-funded by the State. As a result, water is under-priced with respect to an ideal full cost. Under-pricing of irrigation water has been singled out as one of the crucial reasons for unabated use of water for irrigation by many water and development experts (Cosgrove and Rijsberman 2014).

Besides the financial and infrastructural constraints conditioning the efficacy of the new pricing criteria, the negligible impacts on water uses addressed in this study are also affected by the demand. That is, the water demand function for the main irrigated crops in the region is strongly inelastic, limiting the impact of pricing on water uses even in those sectors of the irrigation network where it is possible to implement volumetric tariffs. In the economic optimisation model presented in this study, demand elasticity is both conditioned by the slope of marginal profits with respect to water uses and by the fact that the amount of water applied appears as a discrete decisional variable, implicitly including technical constraints that limit the farmer's ability to modulate water uses. Other scholars (Fragoso et al. 2011) have also documented low demand elasticity for irrigation water.

Even though the estimated impact of pricing variation on water uses is negligible, the imposition of tariffs connected to actual or alleged water use may affect farmers' decisions regarding how to irrigate. Indeed, the transition to the new pricing criteria might result in a reduction in furrow irrigation systems compensated by a increase in drip irrigation systems. However, the variation in technology adoption does not necessarily imply that there will be a resulting reduction in water use, as increasing levels of water use efficiency may be compensated by increasing share of irrigated land. This compensating effect is called the Jevon Paradox. Such a paradox seems to be more evident when tariffs are not directly connected to water uses, since tariffs incentivize the adoption of more efficient irrigation technologies without conditioning the amount of water used. Similar results were addressed by other studies analysing changes in water pricing policies in other regions as, among the others, Mexico (Lopez-Morales and Duchin 2011), Spain (Berbel et al. 2014), and China (Song et al. 2018). These studies reveal that national and regional policies on water pricing are not primarily directed to use water pricing as an economic instrument to incentivize the adoption of water saving practices. In general, the results obtained by these studies indicate that water saving policies (with particular reference to water pricing) aimed at improving water productivity are not as effective as expected because of the partial rebound effect determined by an increase in the irrigated land.

Finally, the transition to the new tariff scenario causes an appreciable variation in supply cost allocations. Notably, with the new pricing criteria there is a reduction in tariffs paid for non-irrigated crops, compensated by an increase in tariffs paid for irrigated crops.

The methodology adopted in the present study reveal some important weaknesses that might limit the model capacity to correctly portray the possible impacts determined by changes in the pricing criteria used to recover supply costs. The first weakness is about the fact that the model relies on a profit-maximizing criterion under the assumption of perfect information. That is, the model neglect to consider that farmers' decisions on the type of irrigation system to be implemented and on the type of crop to be cultivated might be influenced by their technological knowhow, which might be limited (Zahedi and Zahedi 2012). In addition, it is assumed that the variable tariff is perfectly enforced and that it does not imply any additional cost. In reality, few scholars addressed the fact that changes in pricing criteria determine the occurrence of additional costs, especially when these changes concern the variation from fixed to variable tariffs (Galioto, Raggi, and Viaggi 2013; A Lika et al. 2016; Alban Lika, Galioto, and Viaggi 2017).

The second weakness is about the assumption that the variation in the tariff policy is lasting and that there is no foreseen variation in output and input prices and in water availability. This assumption condition hard decisions about changes in the irrigation technology and/or in the crop to be cultivated. A robust scenario analysis about future trends in prices and the availability of resources would provide more consistent results about the foreseen impacts.

The third and final weaknesses is about the methodology adopted. To estimate impacts the paper adopted a Positive Mathematical Programming method built following the seminal work of Howitt (Howitt 1995) in order to obtain an exact representation of the reference situation. This is a widely used approach for the specification of programming models designed for policy analysis (McCarthy, Hancock, and Raine 2014). The method assumes a profit-maximising equilibrium in the baseline situation and uses the observed levels of production activities as a basis for estimating the coefficients of a non-linear objective function. The PMP approach used in the present study neglect to consider few relevant last advances in PMP that helped improve so shortcoming of the original PMP approach.

Since the pioneering paper of Howitt (1995) it is worth to mention the PMP method with variant activities developed by Röhm and Dabbert (Rohm and Dabbert 2003), which is capable of capturing the factors that determine the elasticity of substitution between crops with similar characteristics, or different technologies seen as variants of the same crop. Few extensions of the PMP method with variant activities where offered by Cortignani and Severini (Cortignani and Severini 2009) to include activities that are not present in the reference year. Alternative methodologies to the PMP approach have been then suggested by Heckelei (Heckelei, Britz, and Zhang 2012). Scholars proposed variant to the standard PMP approach basically to compensate for the absence of information and to drive any changes from the reference condition caused by variation on prices and on the availability of resources.

Despite the methodological limitations above addressed, this study confirms that pricing is not a particularly efficient instrument in conditioning water uses as it is seldom applied to the amount of water used (Molle 2009), and also that pricing may incentivize the adoption of water saving technologies (Moreno and Sunding 2005) and condition the allocation of supply costs (Molinos-Senante, Hernandez-Sancho, and Sala-Garrido 2013), but that even in those rare circumstances where water pricing is capable to incentivize the adoption of water saving technologies the effect on water uses in ambiguous because of the rebound effect on the irrigated land uses (Berbel et al. 2014; Lopez-Morales and Duchin 2011; Song et al. 2018). In any case, water pricing, which is an instrument commonly adopted by local water authorities to recover supply costs, could also be considered as an appropriate instrument for co-financing subsidies on investments, further promoting the adoption of water saving technologies (Lopez-Morales and Duchin 2011). Cross-compliance between the WFD and the CAP-reform could make it possible to identify a set of complementary measures with the aim of favouring the diffusion of water saving technologies. The new CAP-reform explicitly addresses this aspect, by promoting both the development of advisory services and co-financing investments for the implementation of water saving technologies, especially for those regions where water bodies are compromised by both qualitative and quantitative pressures (European Court of Auditors 2014).

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