Water framework directive: exploring policy design issues for irrigated systems in Italy

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Abstract

Today the EU must deal with a new legal framework: the new water framework directive (WFD) (60/2000/EC). This directive sets up new criteria for water management and promotes the need for policy changes in sectors using water, such as agriculture. This paper deals with the problem of water regulation in agriculture by testing the results of innovative policy instruments, such as the joint regulation of water use and water pollution. The methodology—based on a simulation model that integrates a mathematical programming model and an optimal regulation model—makes it possible to quantify water demand and optimal regulation from the policy makers’ point of view. The results show that, to meet the increasing social value attributed to water resources and pollution, major changes are needed in crop mix and policy design. However, changes in the economic role of farming and in the (cultural) attitudes of local populations towards agricultural work may have an even greater weight than water policy in the use of this resource.

Keywords: Irrigation; Italy; Mathematical programming; Water; Water framework directive

1. Introduction

Water management requires knowledge of the impact water use has on ecosystems—and thus directly or indirectly on human well-being—and requires suitable policy tools able to meet social objectives and deal with private behaviour. Today the EU legal framework must deal with the new Water Framework Directive (WFD) (Directive 60/2000) which establishes new criteria for water management, regulation and pricing.

In particular, when setting water prices, regulators must take into account the principle of full cost recovery (FCR). FCR includes running costs, water opportunity costs and economic as well as...
environmental externalities. In order to meet such requirements, policy designers must strike a balance between the diverse economic and environmental effects of water usage in each economic sector.

As one of the main water-using sectors, consuming 40–80% of all water used in the main Mediterranean countries, agriculture will most likely be strongly affected by the WFD. Italian agriculture relies heavily on water availability and on relatively low water prices. For many areas of Italy, the principles introduced by Directive 60/2000 may be a significant change over the present payment criteria, based on traditional rights, political prices and a relatively low degree of cost recovery from farmers.

This paper uses a simulation model to analyse the water policy for irrigated agriculture. This model is the integration of a mathematical programming model and an optimal regulation model structured on a principal agent framework. The methodology makes it possible to identify optimal regulation from the policy makers’ point of view. The final aim is to create support for the economic evaluation of alternative policy instruments for the application of the WFD to irrigation.1

The paper has the following structure: Section 2 provides an overview of the situation of irrigated agriculture in Italy; Section 3 summarises the method used while Section 4 gives the results. The final section offers a discussion. Appendix 1 provides a more detailed mathematical presentation of the methodology.

2. The water problem and irrigated agriculture in Italy

In Italy, as in many countries, the issue of water scarcity is rapidly gaining attention. Agriculture plays a major role in this issue, as it is the sector with the highest water use (around 50% of the total water used) due mainly to irrigation. A large fraction of the water used in the farming sector is derived from rivers (around 66% of the total). Only 18% comes from wells and springs.

Economic and physical constraints make it impossible to exploit about 55% of the surface water reservoirs (110 billion m³ per year). Moreover, most of these reservoirs are located in the north, while the centre and the south, where recurrent droughts make a greater water supply necessary, are less endowed. This explains why water supply is still critical despite the reduction in water use in the last decade. Water scarcity is a phenomenon that affects several Italian regions. About 12% of the total Italian population suffers the effects of supply discontinuity, with the highest proportion of the phenomenon affecting the south and the Islands.

In 2000 approximately 25% of the total agricultural area was irrigated, a number which has grown significantly over the last decade (in 1993 it was around 18%). The irrigated areas account for very different shares of the total agricultural area in different regions, ranging from 8.2% in the Marche region to 66.2% in Lombardy (ISTAT, 2000). For some crops (e.g. orchards, vegetables, flowers) virtually 100% of the cultivated area is irrigated. Roughly 55% of agricultural production is obtained by irrigated systems and 60% of all Italian agricultural exports involve irrigated crops (ANBI, 1992; Lamoglie, 2001).

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1 The work presented in this paper builds on the data and basic work carried out within the project WADI (Sustainability of European Irrigated Agriculture under Water Directive and Agenda 2000), funded by the EU 5th framework programme. See Bebel & Gutierrez (2005) for the full results of the project.
The water distribution system in Italy is mainly managed by reclamation and irrigation boards (RIBs). Formally speaking, these are associations of farmers that control the management and distribution of water resources over a certain area. Regulation of water use is based on a complex system of rights, often evolved since ancient times. In Italy, irrigation water is mostly charged on a per area basis. Volumetric pricing methods are applied only in a few cases where the RIBs distribute water using pipes. Water markets (or organisations similar to water markets) are limited to small parts of Italy. Much of Italy’s water utility services are characterised by a large gap between actual rates and expected full cost, with investments over the next 15 years estimated at more than 30 billion Euros.

The introduction of WFD could bring major changes for irrigated farming. Although application should be strongly differentiated at the regional level, as managed by various river basin organisations, some major criteria are common for all countries. From an economic perspective, the main point concerns FCR. According to this principle, the user of water should bear all the costs for the water supply. The principle is strongly related to the polluter pays principle (PPP). According to the PPP, water users should bear the cost of pollution as well as the costs of the water resources and water supply. The deriving notion of FCR proposed by WFD, which is basically coherent with other general definitions of FCR, includes financial costs (running plus capital costs), opportunity costs and externalities (both economic and environmental) (Rogers et al., 1998; WATECO, 2003).

The WFD and accompanying documents emphasise the role that water pricing plays as an efficient instrument for reducing water use and water pollution. Taking into consideration both economic and environmental costs, after the WFD is implemented, the suggested pricing structure may be made up of three components (European Commission, 2000): a fixed amount per unit of irrigated land, a price per unit of water used and a price per unit of pollution. The final price should take into account both full cost recovery and incentives in order to achieve the best social use of water.

From a farm point of view, the main risks from the WFD are an increase in the price of water and/or greater restrictions on its use. One can justifiably expect increased prices since today, in Italy, only a part of the running costs for water supply are borne by the farmers. Considering externalities in setting the price may lead to different effects. On the one hand, it could make things worse for irrigated farms since irrigation is often associated with more intensive farming systems which also make greater use of pollutants. On the other hand, many typical landscapes may be associated with irrigated farming systems. Consequently, positive environmental externalities may be linked to farming or to the water distribution system itself.

Evaluation of the impact of higher water prices and a search for improved policy instruments that can simultaneously deal with both water use and water pollution are therefore two major issues for water policy as related to irrigated agriculture.

3. Methodology

A great deal of literature exists regarding the pricing of water resources for agriculture, both in terms of policy analysis and in terms of instruments to support decision making. The key to the methodology

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2 For a review of some of the main works related to water, see for example Dinar & Subramanian (1997), Dosi & Easter (2000), Garrido et al. (1999), Gomez-Limon & Riesgo (2002), Tsur et al. (2002).
used in this paper is an attempt to couple mathematical programming (MP) models with optimal regulation (OR) models (Figure 1).

The first part of the model (step A) is based on the use of mathematical programming. This instrument, frequently used in the literature for irrigation problems, permits a search for optimal crop mix or activity combinations for representative farms. The problem is cast as a constrained maximisation, where constraints include water availability and the objective function is farm profit or net income. The same model also makes it possible to generate a demand function for water.

This part of the model has been implemented in the form of a decision support system (DSS), which allows easy data entry and provides simulations. The model takes into account the production cycle activities thus making it possible to quantify analytically the utilisation of water, chemicals, labour and machinery and their costs for the different irrigation systems at the territorial and farm level. The programme, which operates as a Windows application, is highly user-friendly. At the farm level, it can be used as a decision support tool for technicians and farmers. At the public level, it allows one to study and define water rates and policy, as well as to evaluate the impact of a territorial transformation caused by an increase or shortage in the water supply.

While the DSS can be used as an independent tool, in the context of the present work its main role is to estimate valuable combinations of farm activities, useful in that they can be fed into the OR model. Each combination represents a crop mix and other possible activities, such as the choice of a particular irrigation system.

In principle, any possible crop mix could be used as an input for the model. Nevertheless, given a linear mathematical problem, the optimisation algorithm for linear programming would choose a solution among corner points. In order to use the same rationale here, the DSS includes an algorithm able to determine the set of possible corner points for the model. The algorithm is based on a gross margin parameterisation of the activities included in the model. The set of feasible crop mixes is produced together with income, water use and any other useful parameters and can be evaluated through the OR model.

It must be pointed out that the corner points identified in such a way may or may not be efficient from the private point of view, depending on the actual price combination. On the other hand, the preferred

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social hierarchy depends on the added value produced, on externalities and on the social cost of providing incentives to the farmer to produce at any desired point.

Here is where the OR model comes in (step B). The OR model is aimed at identifying the optimal incentive scheme from the public regulator’s point of view, given the opportunity cost of water, the social cost of environmental externalities and the social cost of public transfers. It is constructed on the basic structure of a principal–agent relationship (Kreps, 1990; Rasmusen, 1994; Laffont & Martimort, 2002). In our case, we assume the existence of a public or semi-public decision maker (a RIB) interested in maximising social welfare by regulating the irrigation activity of one or more agents (farmers). The problem is to find the best possible regulation that takes into account the constraints imposed by the WFD and the economic relationships between individual parties.

In order to do this, the model needs simultaneously to identify both the optimal crop mix (from a social point of view) and the best incentives to induce the farmer to choose that crop mix. Regulatory variables are surface charges for irrigated land, the volumetric price of water and charges per unit of polluting emissions.

The model has been developed assuming both risk-neutral farmers and risk-averse farmers. Risk aversion by the agent has been considered in order to provide an initial evaluation of its relevance and how it affects the results. According to the literature, we assume the “textbook” representation in which the expected utility is given by the sum, over the possible states of nature, of the square root of the income in each state of nature.

The OR model runs on Gams 2.50 (Brooke et al., 1998).4

For our purposes integration between the two models appears particularly useful, as the DSS makes it possible to identify only “relevant” solutions, instead of infinite possible solutions. Moreover, this avoids infeasibility problems in the following OR model. Finally, it makes it possible to verify the results of the OR by feeding them into the MP model.

4. Results

4.1. The case study

The model has been tested on a hypothetical farm that is considered to be representative of a very common agricultural system in the province of Bologna (Emilia-Romagna, in the southern Po River Valley), is based on cereal cultivation and is coupled with industrial cultivation of such vegetables as the potato and onion. In particular, this area provides a very good production environment for the potato, which is protected through a local trademark. It relies heavily on the availability of water in order to improve production and reduce yield variability.5

The farm has 15 hectares of arable land and specialises in a potato–cereal rotation. It is analysed using only one environmental indicator (nitrogen) and a constant social cost for water across irrigation periods during the year.

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4 See Appendix for additional details about the methodology. A deeper analysis of the problem with a risk-neutral farmer is presented in Bazzani et al. (2004).

5 We also assume (see Appendix) that $c = 0.2$ (drawn from the literature, see White & Ozanne, 1997), $K_d = 1600$ Euro/year and $K_c = 2500$ Euro/year (both estimated on the basis of local data).
Through parameterisation of the DSS, 81 alternative crop mixes have been identified as corner points (i.e. locally efficient solutions) of the MP tool. Such alternative crop mixes have been introduced into the OR model for different social cost levels for water use and different nitrogen emissions. In this way, the optimal crop mix (maximising social benefit) has been obtained for each combination of value of resources/externalities.

4.2. The optimal crop mix

Figures 2 and 3 map the optimal crop mix against different combinations of water and environmental externalities values for risk-neutral and risk-averse farmers, respectively. Table 1 presents the composition of the selected crop mix and the results at farm and social level for both risk-neutral and risk-averse farmers.

As would be expected, when the social cost of water increases, the optimal solution shifts towards a non-irrigated crop mix. Two things are worth noting. First, the shift from an irrigated to a non-irrigated crop mix occurs when the water value rises above 0.3 Euros, about 6–10 ten times higher than the current price. This is because the cost is generally offset by the high value of agricultural production obtained through irrigation. Secondly, above this level the crop mix changes dramatically, without relevant substitution between irrigated crops. This is due partly to the actual economic relationship between different crops. Potatoes and onions are the two main crops that use water. When the social value of water is so high that it is not worth using for such crops, it is most likely not worth using for any other crop combination. In the current decision-making process, this effect is made more important by rigidities and technical constraints by which adaptation is a discontinuous, rather than a smooth, process towards less water-consuming crops.

On the other hand, in this case, one must note that the shift towards non-irrigated crops is helped by CAP (Common Agricultural Policy) subsidies applicable to wheat and soy but not to potatoes, onions and sugar beets. Without such subsidies, the shift would surely be slower. Another consequence is that the shift towards dry farming would, in this case, mean an increase in total CAP payments to the farm.

Risk aversion appears to slow down the hypothetical change towards less water-consuming farming. This is due to the fact that non-irrigated agriculture—based at least partially on sugar beet, maize or soy (for rotation purposes)—also involves greater variability of yields. This means that greater incentives are needed to persuade the farmer to shift to such crop mix.

The fees charged to farmers account for about 14–16% of the gross margin. The total amount is mainly determined by the costs for water provision and monitoring. The shift towards a non-irrigated crop mix leads to a reduction in farm income (−37% in the extreme case). It is also associated with a dramatic change in labour organisation, owing to the move towards much less intensive crops.

The total social cost of intervention is almost the same in every case. Small variations (within the ±10% range) may be found both for different crop mix and between risk-neutral and risk-averse farmers. Therefore the results obtained in this specific case indicate that risk aversion does not significantly change the total cost of the incentive scheme.

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6 It is necessary to point out that the figures do not represent water demand, but socially optimal crop mixes depending on the value of water, the value of externalities and the best regulation mechanism identified.
4.3. The optimal regulation

The results are obtained assuming that the optimal regulation system is used for each crop mix, as illustrated for a risk-neutral farmer in Table 2.

Basically, the optimal solutions are a mix of per crop taxation and charges per unit of water used. In strictly economic terms, per crop taxes are the least expensive instrument for the public administration. In addition, they can be used when it proves impossible to measure water use (which is quite common in Italy). On the other hand, charges per unit of water use are more effective in inducing a change towards water saving technologies.

Fig. 2. Dominant solutions for different levels of social cost of water (Euro/m$^3$) and environmental damage by nitrogen (Euro/kg) – risk-neutral farmer.

Fig. 3. The dominant solutions for different levels of social cost of water (Euro/m$^3$) and environmental damage by nitrogen (Euro/kg) – risk-averse farmer.
Table 1. Dominant crop mix (ha).

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>OPSW</th>
<th>OPS(i)SW</th>
<th>OPSW</th>
<th>OPS(ni)SW</th>
<th>OSB(ni)SW</th>
<th>OS(i)SW</th>
<th>OS(ni)SW</th>
<th>SB(ni)SW</th>
<th>S(ni)SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onion (i)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato (i)</td>
<td>6</td>
<td>5</td>
<td>4.5</td>
<td>5</td>
<td>4.5</td>
<td>7.5</td>
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<tr>
<td>Sugar beet (ni)</td>
<td>4.5</td>
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<tr>
<td>Sugar beet (i)</td>
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<tr>
<td>Maize (ni)</td>
<td>2</td>
<td></td>
<td></td>
<td>4.5</td>
<td>4.5</td>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize (i)</td>
<td>2</td>
<td></td>
<td></td>
<td>4.5</td>
<td>4.5</td>
<td>7.5</td>
<td></td>
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<tr>
<td>Soy (ni)</td>
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<tr>
<td>Soy (i)</td>
<td>2</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Durum wheat (ni)</td>
<td>6</td>
<td>5</td>
<td>7.5</td>
<td>5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
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<tr>
<td>Soft wheat (ni)</td>
<td>6</td>
<td>5</td>
<td>7.5</td>
<td>5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
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<tr>
<td>Barley (ni)</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation Plant</td>
<td>4.5</td>
<td>5</td>
<td>3.75</td>
<td>4</td>
<td>1.5</td>
<td>3.75</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gross margin (without incentive) (Euro)</td>
<td>18,466</td>
<td>18,366</td>
<td>18,389</td>
<td>18,385</td>
<td>14,581</td>
<td>13,854</td>
<td>13,709</td>
<td>13,050</td>
<td>11,730</td>
</tr>
<tr>
<td>Transfer costs (RN)</td>
<td>443</td>
<td>615</td>
<td>626</td>
<td>624</td>
<td>443</td>
<td>443</td>
<td>443</td>
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</tr>
<tr>
<td>Monitoring costs (RN)</td>
<td>615</td>
<td>615</td>
<td>615</td>
<td>615</td>
<td>615</td>
<td>615</td>
<td>615</td>
<td>615</td>
<td>615</td>
</tr>
<tr>
<td>Water provision cost (RN)</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
</tr>
<tr>
<td>Total policy cost (RN)</td>
<td>2658</td>
<td>2830</td>
<td>2841</td>
<td>2840</td>
<td>2668</td>
<td>2658</td>
<td>2658</td>
<td>2658</td>
<td>2658</td>
</tr>
<tr>
<td>Gross margin (after incentives) (Euro)</td>
<td>16,250</td>
<td>15,292</td>
<td>15,207</td>
<td>15,263</td>
<td>12,365</td>
<td>11,573</td>
<td>11,581</td>
<td>10,843</td>
<td>9525</td>
</tr>
<tr>
<td>Transfer costs (RA)</td>
<td>432</td>
<td>440</td>
<td>428</td>
<td>436</td>
<td>429</td>
<td>442</td>
<td>441</td>
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<tr>
<td>Monitoring costs (RA)</td>
<td>550</td>
<td>539</td>
<td>578</td>
<td>547</td>
<td>608</td>
<td>607</td>
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<tr>
<td>Water provision cost (RN)</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
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<td>1600</td>
<td>1600</td>
<td>1600</td>
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<tr>
<td>Total policy cost (RA)</td>
<td>2691</td>
<td>2642</td>
<td>2507</td>
<td>2613</td>
<td>2576</td>
<td>2649</td>
<td>2649</td>
<td>2649</td>
<td>2646</td>
</tr>
<tr>
<td>Gross margin (after incentives) (RA) (Euro)</td>
<td>16,306</td>
<td>15,306</td>
<td>15,341</td>
<td>15,301</td>
<td>12,434</td>
<td>11,581</td>
<td>10,843</td>
<td>9525</td>
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</tr>
</tbody>
</table>

Note: i = irrigated; ni = non irrigated; RN = risk neutral farmer; RA = risk averse farmer.
When taxes are applied, they are very high compared to the present rates (as much as ten times higher). For the most part, taxes on nitrogen are unnecessary because there is a substantial correlation between water and nitrogen use. The degree of monitoring accuracy is equal for different crop mixes and tends toward the upper limit.

The regulation scheme appears quite different when the farmer is assumed to be risk averse (Table 3).

Some crops are no longer charged while others are charged more than previously. Generally speaking, per hectare charges appear lower than before and less distributed across different crops. Payments per unit of water used and payment per unit of nitrogen are generally higher. In particular, the most extreme (less privately profitable) crop mixes are obtained by applying very high rates for nitrogen use. Altogether, for risk averse farming, the optimal policy sees uncertainty shift from the farmer (risk averse) to the RIB (risk neutral), leading to a completely different outcome in the regulation scheme.

### 4.4. The effects of the context: changing labour opportunity costs

The results up to this point are heavily affected by the assumptions that set labour opportunity costs at zero. Although this is usually regarded as a reasonable assumption, the current behaviour of farmers shows that they often attribute some value to their own labour. Nevertheless, as the farm is family run, attributing a value to the labour employed is not straightforward.

Figure 4 shows the effects of labour costs on the crop mix for different levels of social cost of water and environmental damage by nitrogen (case of neutral farmer). In Figure 4, the borderlines depict the borders between irrigated crop mixes (above every border) and non-irrigated crop mixes (below every
This figure shows that when labour costs increase, irrigated solutions are less profitable and the mix suddenly shifts to rain-fed crops, even for relatively low levels of water social costs and environmental damage by nitrogen. The same type of result is observed in behaviour of the risk-averse farmer (Figure 5). If the cost of labour is zero, when the water values reach 0.6 Euro, the optimal crop mix

Table 3. Optimal regulation scheme for each crop mix – risk-averse farmer.

<table>
<thead>
<tr>
<th>Crop</th>
<th>OPSW</th>
<th>OPS(i)SW</th>
<th>OPSW</th>
<th>OPS(ni)SW</th>
<th>OSB(ni)SW</th>
<th>OS(ni)SW</th>
<th>SB(ni)SW</th>
<th>S(ni)SW</th>
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</thead>
<tbody>
<tr>
<td>Monitoring accuracy</td>
<td>0.22</td>
<td>0.24</td>
<td>0.22</td>
<td>0.23</td>
<td>0.22</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>Tax per crop (Euro £/ha)</td>
<td></td>
<td></td>
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<tr>
<td>Durum wheat (ni)</td>
<td>5.4</td>
<td>44.35</td>
<td>49.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sugar beet (ni)</td>
<td>60.7</td>
<td>52.95</td>
<td>131.2</td>
<td>59.7</td>
<td>188.9</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sugar beet (i)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Wheat tenero (ni)</td>
<td>35.4</td>
<td>91.58</td>
<td>94.4</td>
<td></td>
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<td>Barley (ni)</td>
<td>25.85</td>
<td>26.07</td>
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<td></td>
</tr>
<tr>
<td>Maize (ni)</td>
<td>53.2</td>
<td>41.66</td>
<td>123.09</td>
<td>47.9</td>
<td>178.4</td>
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<tr>
<td>Maize (i)</td>
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<td>Soy (ni)</td>
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<td>88.4</td>
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<td>Potato (i)</td>
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<td>Tax on water</td>
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<td>(Euro/m³)</td>
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<td>Environmental tax (Euro/kg N)</td>
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<td>4.53</td>
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Fig. 4. Borderlines between irrigated and non-irrigated plans for different levels of labour cost (Euro/hour) – risk-neutral farmer.
mix switches to non-irrigated crop mixes; on the other hand, if labour costs are 20 Euro/hour, the switch occurs at a water value of 0.05 Euro/m³.

While a labour cost of 20 Euro/hour may be considered quite a high opportunity cost even in non-farm activities, 10 Euro/hour is a reasonable cost for hired farm labour. Labour costs affect the most intensive crops, potato and onion, which, besides water, are also quite labour-intensive. Henceforth, increases in labour costs or, simply, a shift towards younger, more educated farmers who actually perceive the opportunity cost of non-farming activities, may play a major role in inducing a reduction in water use.

5. Discussion

The model described in this paper simulates water management as the interaction between a regulating body and a farmer, thus making it possible to quantify optimal regulation from the point of view of a policy maker who is simultaneously interested in farm income, water savings and environmental improvement. The results of the case study show that major changes in crop choice are needed to meet the increasing social value given to water resources and pollution. On the other hand, if such values translate into real policies, they are likely to have a major impact on farm income and organisation. Adopting a mix of pricing instruments can significantly improve the efficiency of water policy, even though the degree of such improvement depends on the technical relationship between water use and the other parameters considered (e.g. environmental indicators).

Risk aversion by farmers tends to slow down the adaptation to water prices: it does not change the total amount of incentive needed, but rather has relevant implications for the optimal combination of instruments.

The results of the model (see its sensitivity to the cost of labour) must be cast in the overall scenarios concerning agriculture in Italy. The shift of labour away from agriculture and the increasing share of
educated and young people working in the sector, have raised the income expectations from agriculture and this results in a reciprocal decrease in the acceptability of under-remuneration for the farmers’ own labour. Given the current trend in the farming population in Italy, it is likely that, at least in some areas, the problem of excessive water use for irrigation will be more affected by demographics and social trends than by policy instruments. This trend would be emphasised by the difficulty in finding a workforce (even extra-EU) for agriculture, but it could be attenuated by farm restructuring and a concentration on larger, more efficient farms.

This hypothesis highlights the need to change policy perspective with regard to public irrigation projects. Still today funding is provided for new schemes aimed at increasing irrigated land. Incentives in this sense derive from both the low prices farmers pay for water and from the interest RIBs have in getting public funds and strengthening their position as water distributors. Within the context of evolving towards a regulation which achieves full cost recovery and decreases land profitability, this may translate into an “investment trap” that forces the remaining irrigating farmers to bear excessive water costs, against any actual policy objective.

In this changing context, the WFD offers the opportunity needed for a major overhaul of water regulation throughout Europe. As in the present paper, some of such revision appears to be in contrast to the social and economic objectives of farmers as well as to the economic, social and environmental objectives of the CAP. Nevertheless it is best to interpret water regulation reform proactively as the opportunity to anticipate potentially growing conflicts and to make water use altogether more sustainable.

The complexity of the discussion confirms the relevance of the issue for farming management and policy and the need for suitable decision-making systems, like those presented in this paper, even at the micro level. From a methodological point of view, the approach used in this paper is able to provide a broad, analytical view of the problem. However, a number of improvements and extensions can be made to the model. Examples include increasing the number of crops, farms, technologies and policy options, taking into account asymmetric information about the type of farmers, and using a more reliable way of modelling risk aversion. One issue that calls for particular attention is the role of positive externalities produced by the use of water in agriculture, which will most likely add greater rationale for a lower price of water.

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References


Appendix

Let us suppose that there is only one principal and one agent. We assume that, for our purposes, the behaviour of the farmer may be represented by discrete actions $a_i = \{s_{ij}\}$, each one made up of a vector of values $s$ of the decision variables $j$ and $i$, where $i = (1, \ldots, I)$ represents a farm plan (crop mix) and $I$ a set of possible plans, while $j = (1, \ldots, J)$, represents a crop, with $J$ as a set of possible crops; $s_{ij}$ is the surface of crops $j$ in plan $i$. Assuming linear relationships, we can interpret $s_{ij}$ as the degree of activation of each farm activity (crop) and $a_i$ as a vector of such degrees of activation in a farm representation that uses a fixed coefficients technology. We assume further that the results (technical, economic and environmental) of each crop depend on some state of nature $\theta_p$, with $p = (1, \ldots, P)$ each with probability $\pi_p$. Consequently, according to standard technology representation under uncertainty, farm income, water use and environmental results may be represented as a function of the state of nature occurring.

We can assume that, with regard to regulation, the objective function of the public decision maker includes the following components: farm income; value of the water used; value of externalities (positive or negative) produced; costs for water abstraction and delivery, including administrative and transaction costs; distortion effects due to social transfers (taxes or subsidies); monitoring and control costs.

Assuming that the problem of the principal is to maximise social welfare, it is possible to find the solution using a two-step procedure (Kreps, 1990; Rasmusen, 1994). The first step involves finding the least cost solution able to guarantee that each possible action is carried out by the agent. The aim of the second step to choose the action $a_i$ that maximises social welfare. While the second step is quite simple, the first is more complex.

Assuming that both the principal and the agent risk are neutral, the problem of cost minimisation representing our first step may be set as:

$$\min K_i = e \left[ \sum_j s_{ij} \sum_p \pi_p \left( F_j + \sum_h w_h \cdot Q_{jph} + \sum_k b_k \cdot Y_{jpk} \right) \right] + |T| + Kd + Kc \cdot f$$

subject to the following constraints:

IC1:

$$\sum_j s_{ij} \sum_p \pi_p \left[ ML_{jip} - \left( F_j + \sum_h w_h \cdot Q_{jph} + \sum_k b_k \cdot Y_{jpk} \right) \right]$$

$$\geq \sum_j s_{ij} \sum_p \pi_p \left[ ML_{jip} - \left( F_j + \sum_h w_h \cdot Q_{jph} + \sum_k b_k \cdot Y_{jpk} \right) \right]$$

for any $i'$ different from $i$.

IC2:

$$\sum_j s_{ij} \sum_p \pi_p \left[ ML_{jip} - \left( F_j + \sum_h w_h \cdot Q_{jph} + \sum_k b_k \cdot Y_{jpk} \right) \right] \geq \sum_j s_{ij} \sum_p \pi_p (ML_{jip} - f \cdot S)$$
BC:

\[ \sum_j s_{ij} \sum_p p_{ip} \left( F_j + \sum_h w_h Q_{jhp} + \sum_k b_k Y_{jpk} \right) + T \geq Kd + Kc f \]

where: \( K_i \) = social cost of action \( i \), \( ML_{jip} \) = gross margin of the activity \( j \), \( e \) = distortionary effect caused by taxation, \( Q_{jph} \) = quantity of water consumed by each activity \( j \), \( Y_{jpk} \) = quantity of pollutant produced by each activity \( j \), \( vh \) = unit social value of water (opportunity cost) by period \( h \), \( zk \) = unit social value (positive or negative) of each environmental parameter \( k \), \( Kd \) = abstraction and distribution costs of the RIB, \( Kc \) = monitoring costs able to guarantee 100% compliance and sure information transfer (\( f = 1 \)), \( T \) = public (state) transfers obtained by the RIB, \( S \) = sanction in case of non-compliance.

In this problem, the decision variables are the following: \( F_j \) = fixed charge per unit of activation (land) of each activity (crop); it may be positive or negative (subsidy), \( w_h \) = charge per unit of water used in each period \( h \), \( b_k \) = charge per unit of environmental parameter \( k \), \( f \) = level of monitoring accuracy (0–1).

The result of this constrained optimisation is a bundle of regulation parameters. This bundle represents the least cost solution able to persuade the farmer to accept each of the different actions considered in the evaluation. The social cost is the sum of the social cost of public transfers, the cost of water provision and monitoring cost. Monitoring costs are the result of the cost of total control multiplied by the level of monitoring accuracy, following a modified version of the linear monitoring cost used by Choe & Fraser (1999). Transfers account only for a fraction, determined by the distortion effect of taxation \( e \), i.e. the inefficiency caused by the subtraction of money from the private sector (White & Ozanne, 1997).

The second step is simply carried out by choosing the action that maximises social benefit \( B \):

\[ B_i = \sum_p p_{ip} \sum_j s_{ij} \left[ ML_{jip} - \left( \sum_h v_h Q_{jhp} + \sum_k z_k Y_{jpk} \right) \right] - K_i \]

In this case the social benefit is the farmer’s gross margin, minus the value of the externalities produced, minus the social cost of the regulation determined in the previous step.

When we introduce risk aversion by the agent, we have to revise the constraints IC1 and IC2. We denote \( F_j^+ \) as the positive charge per hectare of each activity (crop), \( w_h^+ \) as the positive charge per unit of water used in each period \( h \) and \( b_k^+ \) the positive charge per unit of environmental parameter \( k \). Instead we denote the decision variables as \( F_j^- \), \( w_h^- \), \( b_k^- \) when they are negative charges (i.e. subsidies). In addition, with \( E_{jp}^+ \) we denote the sum of positive charges per unit of activity and state of nature, as:

\[ E_{jp}^+ = \left( F_j^+ + \sum_h w_h^+ Q_{jhp} + \sum_k b_k^+ Y_{jkp} \right) \]

and respectively \( E_{jp}^- \) as the sum of negative charges.

Therefore we can rewrite our constraints as:
IC1: $$\sum_p \pi_p \left\{ \left[ \sum_j s_{ij} (ML_{jp} - E_{jp}^-) \right]^{1/2} - \left( \sum_j s_{ij} E_{jp}^+ \right)^{1/2} \right\}$$
$$\cong \sum_p \pi_p \left\{ \left[ \sum_j s_{ij} (ML_{jp} - E_{jp}^-) \right]^{1/2} - \left( \sum_j s_{ij} E_{jp}^+ \right)^{1/2} \right\}$$
for any \( i' \) different from \( i \).

IC2: $$\sum_p \pi_p \left\{ \left[ \sum_j s_{ij} (ML_{jp} - E_{jp}^-) \right]^{1/2} - \left( \sum_j s_{ij} E_{jp}^+ \right)^{1/2} \right\} \cong \sum_p \pi_p \left\{ \sum_j s_{ij} (ML_{jp} - f \cdot S) \right\}^{1/2}$$

This solution, though not completely satisfying from the theoretical point of view,\(^7\) may be sufficient to provide hints about the effect of risk aversion on the results.

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\(^7\) See Saxowsky & Wachenheim (2001) and Pennings & Garcia (2001) for some examples regarding the debate on the representation of risk aversion.