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The potential impact of markets for irrigation water in Italy and Spain: a comparison of two study areas*

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The viability of irrigated systems in Southern Europe is closely linked to efficient institutional settings and water-allocation mechanisms. A significant, although not widely used, mechanism for water allocation is an intra-sectorial water market. The objective of this paper is to evaluate to what extent water markets may contribute to the improvement of the efficiency of water allocation and to the profitability of irrigated agriculture. The related issues of water allocation among farm types and farm specialisation are also addressed. The analysis is based on a basin-level linear programming model, comparing the situation with and without a market. It includes both fixed and variable transaction costs and estimates their combined effects on market performances. The model is applied in two areas in Southern Italy and Spain, and simulates the behaviour of different farm types, derived from cluster analysis on a sample of farms in each area. The paper confirms that water markets could potentially improve the economic efficiency of water use, in terms of higher profit per hectare, given limited water availability. The potential improvements are associated with a more intense specialisation of farms and are strongly differentiated among farmers, particularly where significant restrictions to water availability occur. This corroborates the expectations of institutional difficulties in implementing water markets. However, the exchanges, and consequently the potential effects of water markets, are heavily affected by the actual level of water availability, as well as the size and the structure (fixed vs. proportional) of transaction costs. The paper calls for a more in-depth analysis of the connections between market performances and institutional settings, as related to the issue of water-agriculture policy design and coordination.

Key words: water trading, natural resource management, simulation, water management and policy, linear programming, irrigation.

1. Introduction

The viability of irrigated systems in Southern Europe is closely tied to water policy and institutions, particularly to mechanisms for the allocation of rights

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on the use of water. Water regulation is undergoing considerable changes due to the increasing perception of the issue of water scarcity. Recent legislation has sought innovative institutional solutions for reducing water use or increasing its economic efficiency. In particular, the legal framework in the European Union (EU) is today faced with the application of the Water Framework Directive (WFD) (The European Parliament and the Council of the European Union 2000). The WFD sets a framework for comprehensive management of water resources in the European Community, within a common approach and with common objectives, principles and basic measures. It addresses inland surface waters, estuarine and coastal waters, and groundwater. The fundamental objective of the WFD aims at maintaining high status of waters where it exists, preventing any deterioration in the existing status of waters and achieving at least good status in relation to all waters by 2015. The WFD introduces the principle of Full Cost Recovery (FCR) and the Polluter Pays Principles (PPP). It also proposes economic instruments as recommended tools for the regulation of water use and pollution (WATECO 2003). Even if not explicitly mentioned by the directive, water markets can be seen as a kind of instrument responding to the view that water may be considered as an economic good, use of which should be guided (in part) by efficiency principles.

The issue of pricing policy and water markets is very much debated in the water economics literature and particularly in the agricultural water literature (Schiffler 1997; Lee 1999; Easter *et al.* 2004).

The objective of this paper is to evaluate to what extent water markets may contribute to the improvement of the economic efficiency of water use and to the profitability of irrigated agriculture. It also addresses the complementary issue of different participation of farmers in the market (amount of water bought/sold) and the consequent impact on farm specialisation.

The analysis is based on a linear programming model at basin level. The model is applied in two areas in Italy and Spain.

The paper has the following structure. Section 2 briefly describes the theoretical background for water markets. Section 3 describes the methodology adopted. Section 4 illustrates the characteristics of the study areas and the data sources. Section 5 summarises the main results for the two study areas, and is followed by a brief discussion in Section 6.

2. Theoretical and policy background for water markets

Water markets refer to a mechanism of water allocation based on the exchange of rights on water use. Water markets are proposed and supported by economic theory on the ground that they lead to the efficient allocation of water resources (Milliman 1956; Schiffler 1997; Lee 1999; OECD 2003; Easter *et al.* 2004). However, water markets are not particularly common as water allocation mechanisms, particularly in agriculture. The acceptability of water markets and their ability to express their potential contribution to efficiency in water allocation may depend on different issues.

Existing experiences around the world (USA, South Africa and Australia) show that water markets are more acceptable in a mature legal system, with well-defined property rights on water use, and in communities with a high degree of trust. This is made necessary by the fact that the sale of water rights may be associated with a fear of losing those rights. In addition, water exchanges need to be supported by trustworthy contract enforcement systems. A clear result is that the existence of water markets is conditional upon adequate institutions and their introduction may only be accepted if accompanied by adequate measures, in order to guarantee, for example, adequate compensation to losers or the conservation of property rights on water (Easter and Smith 2002). The details about (initial) distribution of property rights and the bargaining mechanism adopted may also strongly affect the outcome of water markets (see, for example, DiSegni Eshel 2002).

Willingness to participate in a market may vary according to the length of the right being exchanged. For example, one-time, seasonal or annual exchanges may be viewed as a temporary transfer without major implications. Longer-term contracts may be perceived as encouraging a permanent transfer of rights or as creating a lock-in situation.

The use of market mechanisms may also be limited by higher transaction costs compared to those produced by other mechanisms of water allocation. Transaction costs include all costs involved in carrying out a transaction; they may emerge *ex ante* (for the collection of information, negotiation, contract writing, etc.) or *ex post* (for contract enforcement, etc.) (Williamson 1985).

McCann and Easter (2004) examine the issue of transaction costs in connection to different mechanisms of water allocation. The authors point out how relevant transaction costs should include both those related to water exchange once the market is established, and those required to set the market itself. Figures reported by McCann and Easter (2004) show that transaction costs in water markets account for between 6 and 23 per cent of the transaction price. A recent literature review about transaction costs in agricultural policy shows that such costs account for between 0.25 per cent and 110 per cent of policy transfers, with an average of between 15 per cent and 20 per cent (Cahill and Moreddu 2005). However, in most cases, the present system of water distribution already causes high transaction costs (e.g., irrigation boards' costs for water management, definition, and enforcement of property rights). It is not often clear to what extent water markets would actually increase such costs. At the moment, data available are very limited and transaction costs would, in any case, change very much from case to case and over time.

One major issue may be the cost of water transport, necessary for a market to exist, where possible traders are not already connected by water infrastructures (canals, pipes). However, in the case of local water markets with all users connected to the same supply system, this problem does not exist.

An important expected outcome of water markets in agriculture is to produce a concentration of water use on the more efficient farms. This is likely to produce a stronger specialisation in high added-value crops by water buyers, whereas the others would retain less-intensive crops. This effect has been observed in Australia, Chile, and the USA. Although this may contribute to an increase in the total agricultural production and the number of agricultural jobs (Sumpsi *et al.* 1998), it also implies an increase in heterogeneity of opportunities across farms, which could raise equity concerns. Chan (1989) highlights this problem and emphasises that it could become more significant as the variety (difference in productivity of water) of participants in the market increases.

Additional problems may arise from the existence of negative externalities or third-party effects. Howe *et al.* (1986) identify the changes in the amount and quality of return water volumes as market deficiencies, although they also propose solutions to mitigate these effects.

The potentialities of water markets are of some interest for European irrigated agriculture. European agriculture is undergoing major changes with abandonment by some farmers and an attempt by others to recover competitiveness in the global market. The contribution of water institutions to the efficiency of agricultural production processes is a significant issue for today's farming sector in Mediterranean areas. Water markets may in principle help respond to this need. However, they are almost absent in the EU. Only recently have Spanish regulations allowed for the exchange of water rights, although some traditional markets have been ages ago in Southern Spain (Maass and Anderson 1978). In Italy, the legal basis for proper water markets does not exist. However, there is evidence of formal or informal water markets in Southern Italy and, to a lesser extent, in the North, although their size is almost impossible to assess. Given the present situation, an important step is to check if potential gains from water trading justify a stronger political commitment towards the introduction of water markets.

3. Methodology and model

The rationale behind the methodology adopted in this paper is to represent water markets through the simulation of optimal water allocation among competing farm types assuming private profit maximisation. Figure 1 represents the simplest case, with two farm types. Curves D_A and D_B represent the demand curves respectively of farm type A and farm type B, competing for the allocation of a fixed amount of water.

The optimal solution is one maximising the aggregated profit function. This condition would be reached when the marginal productivity of water is the same in all farms and the resulting allocation would correspond to the private optimum of each single farm type if water exchange was allowed (e.g., in q^*). If the initial water allocation is different (e.g., q^e), trading may in principle produce mutual benefits. Shifting from q^e to q^* means that farm B buys water from farm A. The gain from trade is given by the triangle *ade*.

A key factor in determining the profitability of water markets is both the amount and the structure of market costs (transaction plus transport costs).

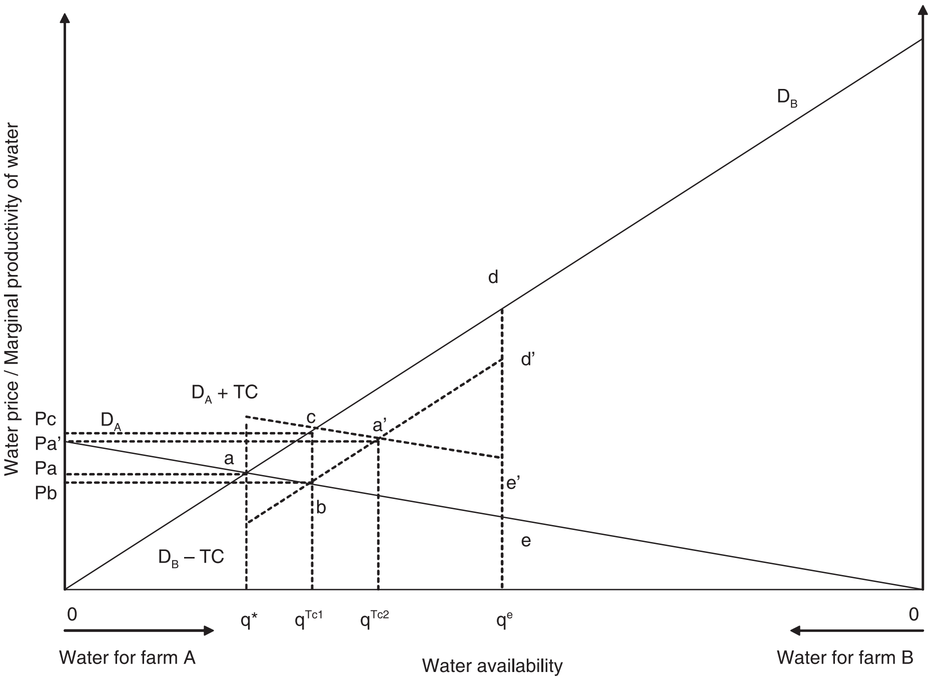

Figure 1 The theoretical framework for water markets with transaction costs.

In principle, they may be fixed or proportional to water exchange. They may be incurred differentially by buyers and sellers, and be dependent on the farm size and location.

This paper adopts an approach based on the combined modelling of fixed and proportional transaction costs. The impact of transaction costs (TC) may be seen in Figure 1 as the shift of the supply curve from D_A to D_A + TC if transaction costs affect the seller, and from D_B to D_B – TC if the transaction costs affect the buyer. The inclusion of transaction costs changes the optimal water allocation to the points, respectively c, b, or a' if transaction costs affect the seller, the buyer, or both. The gain from trade would be the triangles *cde'*, *bd'e* and *a'd'e'*, respectively. It is clear from Figure 1 that the distribution of transaction costs affects the price in different ways. If the transaction costs pertain to the buyer the price tends to be lower than if transaction costs affect the seller, given the same optimal amount of water traded. The assumption of proportional transaction costs only is the choice more commonly found in the literature (e.g., Gómez-Limón and Riesgo 2004). The main implication of this choice is that the profitability of trading depends only on the marginal value of water on the farm. Conversely, the main effects of fixed transaction costs would be to exclude exchanges of water, which total gain is too small to justify the cost of the transaction. However, fixed transaction costs would not affect the optimal level of water trading, once it is profitable to enter the market. In Figure 1, without proportional transaction cost, if fixed transaction costs are higher than the area *ade*, the transaction does not occur. As a result, by assuming only proportional transaction costs, the model tends to overestimate the willingness to trade water.

Proportional and fixed transaction costs interact. For example, if both sellers and buyers incur proportional transaction costs, the remaining gain from trade is limited to the triangle *a'd'e'* in Figure 1, which reduces the maximum fixed costs acceptable for entry into the market.

Operationally, the methodology adopted in this paper is based on the use of a mixed-integer linear programming model at basin level and may be seen as the transposition at basin level of farm-level linear programming models widely used for the analysis of irrigation issues (see, for example, Berbel and Gomez-Limon 2000; Gómez-Limón *et al.* 2002; Bazzani *et al.* 2005; Berbel and Gutierrez 2005). Similar models have already been used in seminal analysis of water markets in Italy and Spain (Arriaza *et al.* 2002; Bazzani 2004). The models presented in Arriaza *et al.* (2002) and Berbel and Gutierrez (2005) try to refine the interpretation of farmers' objectives through a multicriteria objective function.

The model adopted in this paper, modified from Tisdell (2001), is based on the maximisation of the aggregated gross margin function of the different farm types identified in a given area. The market is represented by allowing the exchange of water across farm types. The model utilises a mono-objective function for farmers. The assumption of profit maximisation is maintained in order to simplify the analysis and to allow a straightforward interpretation of marginal values of water constraints in monetary terms. It also means that the choice to enter the market is interpreted as a purely economical, profit-seeking decision, without considering other variables affecting utility, such as risk considerations. Wherever relevant, limits to profit-maximising behaviour due to farmer (or household) attitudes have been added as constraints in the model. The main extension in this study relative to existing model is explicitly taking into account transaction costs.

The model has the following structure:

$$Max \sum_j \lambda_j \left[\left(\sum_i GM_{ij} x_{ij} \right) - (t^p w_j^p + t^s w_j^s) - (T^p p_j^p + T^s p_j^s) \right] \tag{1}$$

s.t.

$$\sum_i x_{ij} c_{iz} \leq v_{zj}$$

$$\sum_i x_{ij} w_i \leq a_j + p_j^p w_j^p - p_j^s w_j^s$$

$$\sum_j \lambda_j w_j^p = \sum_j \lambda_j w_j^s$$

$$x_{ij}, w_j^p, w_j^s \geq 0$$

$$p_j^s, p_j^s = \{0,1\}$$

where:

λ_j = weight of the jth farm typology expressed as the proportion of the watershed area that is of farm type j;
GM_{ij} = gross margin for crop i on farm j;
x_{ij} = crop area for crop i on farm j;
c_{iz} = technical coefficient for crop i, for constraint z;
v_{jz} = availability of other resources on farm j, for constraint z;
w_i = water use for crop i (m^3/ha);
a_j = water availability on farm j.
w_j^p, w_j^s = water purchased (respectively sold) by farm j;
t^p, t^s = proportional transaction cost of purchasing (respectively selling) water;
T^p, T^s = fixed transaction cost of purchasing (respectively selling) water;
p_j^p, p_j^s = binary variable representing the participation in the market as buyer (respectively seller) of water.

The farming area is divided according to different farm types. Each farm type has a relevance on the average results based on the proportion of farming area occupied by that farm type (weight).

Where water trading is allowed, the water exchanges may be represented implicitly through the water allocation or explicitly through water purchase and selling variables. We adopted the second approach. As a consequence, water allocation to each farm is given by the initial availability, plus the water purchased, minus the water sold. This then needs to be linked to an additional complementary constraint stating that total water purchased must be equal to total water sold.

The gross margin and the amount of water used are derived variables and key indicators of the system's performance. The gross margin accounts for gross revenues minus all variable costs, including costs related to the acquisition of water. If the water market exists, the gross margin must include the revenues or payments due, respectively, to water selling or purchasing.

The decision variables in the model consist of the area dedicated to each activity (x_{ij}), the decision to enter the market as a buyer or seller (p_j^p, p_j^s), and the amount of water traded w_j^p, w_j^s. The proportion of surface area of key crops may be used as a simple indicator of farm specialisation. In all cases, results may be calculated by farm type in order to assess the differential impacts on different groups of farmers. The farm area of each farm type is normalised to 1, so that the land used for each crop is expressed as a fraction of 1. This is consistent with the decision to use the share of each type's farm area in proportion to the total area as a weighting factor for calculating the average per-hectare results of the model.

Some of the model's main assumptions need to be clarified. First of all, the programming model is disaggregated by farm type, each representing the average behaviour of a group of homogeneous farms. All the farmers who have water use rights can trade. Exchange is possible between all the farm types within each region.

The initial 'water availability' is determined by the pre-determined right of each farm to get acess to some share of water available at the reservoir or in the water bodies. As a consequence, it is determined by the combination of past weather conditions (that affect total water physically available) and property rights on water before the market exchange takes place.

The contract involves a commitment from a farmer not to use a part of his or her water rights (seller), and thus the possibility for the counterpart (buyer) to use the same amount of water in addition to the buyer's own rights. A system of water distribution reaching all farmers is supposed already to exist, so water distribution does not have any implication in terms of transport costs.

Water rights traded are temporary only and are assumed to last 1 year. The sequence of actions is the following: at the beginning of the year the farmer finds out his or her water availability (the forecast of the water authorities), then decides about water rights exchange, and makes all farming decisions after finding out about water availability. All farmers act in a context of perfect information about the technical possibilities (cost, production) given by the total water available after exchange, but are not fully informed free of charge about other farmers' actions and willingness to pay/accept. This gives rise to the possibility of transaction costs, both *ex ante* and *ex post.*

Farms cannot change the type they belong to. There are structural constraints that limit this change, for example in the case of livestock or fruit. Market constraints and CAP constraints may also limit changes in type. However, the technical economic orientation of farms may in fact change if major crop mix changes occur. The model is a comparative static one, in which intertemporal and dynamic issues are not considered.

The data refer to means in each zone for each crop. No weather uncertainty has been considered. The model takes weather behaviour into account only in so far as it affects water reserves. If the level of reserves is low, there will be water restrictions in the area, which are simulated by the model through constraints to water availability.

4. Study areas and data collection

The model was constructed for two study areas. The main features of the two case studies are illustrated in Table 1.

The first one is the Low Ter in Catalonia (in the northeast of Spain). In this area, there are two water users associations (named in Spanish Communities of Irrigators): Presa de Colomers and Sèquia del Molí de Pals. A Community of Irrigators is a group comprising all the owners of a single irrigable zone, who are united by law for the independent and common administration of irrigation water. These two water users associations have very similar characteristics, and in the study they are considered as one unit. The area is characterised by the cultivation of corn, fruit trees (crops with high costs and

Table 1 Main features of the two areas

	Low Ter	Foggia
Water supply	Dams, Ter river, private wells	Dams, Ofanto river, private wells
Water distribution system	Canals, pipes, and drains (not pressure)	Pressure pipes
Irrigation system	Surface irrigation	Drip irrigation
Water price	Variable from 6.18 to 59.77 EUR/hectare	0.09 EUR/m^3
Prevailing tariff system	Area payment based on irrigated area	Volumetric
Total agricultural area (ha)	7100	143000
Area in the sample (ha)	1373.4	1258.6
Number of farms sampled	60	131
Average farm size in the sample (ha)	22.89	9.6
Methodology for the identification of farm types	Cluster analysis	Cluster analysis
Number of typologies modelled	4	3

high income), alfalfa, and other minor crops. In addition, in the zone there are beef cattle operations with feed crops. Water availability is dependent upon the precipitation and storage capacity of the Susqueda and Sau dams, in the Higher Ter. Shortages of water have been a regular issue in recent years. With the objective of avoiding conflicts, the criteria of equally (in proportion to farmland) distributing water across farms has been used up to now, but with some privileges for the producers of fruit trees. Water regulation is based on payment by irrigated area.

The second case study is located in the South of Italy (Puglia), in the Reclamation and Irrigation Board (RIB) area of Capitanata (Province of Foggia)[1]. The RIBs (Consorzi di Bonifica e Irrigazione) are public bodies managed as associations of landowners, which control land reclamation and the distribution of water over a certain area. Agriculture in the study area is based on the combination of high-income industrial tomato crops and highly subsidised local traditional crops such as rain-fed durum wheat. The development of high value-added crops, such as tomatoes and other vegetables is counterbalanced by a high impact on the environment (mainly due to the use of pesticides and nitrogen fertilisers) and is dependent upon sufficient water availability. Water regulation is based on volumetric pricing. However, the aim of the board is not that of reducing water use. Instead, it focuses mainly on the best allocation of available water. Water availability depends on the storage capacity of the neighbouring area of Basilicata, from where most of the water comes. Shortages of water are a frequent problem in the area, even

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[1] The models used in the case of Foggia were based on data collection and validation carried out during the project WADI ‘Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000’ (EVK1-2000-00057) (Berbel and Gutierrez, 2005).

affecting human consumption. Water is normally distributed in proportion to farmland, with the objective of avoiding conflicts and guaranteeing equal opportunities across farms.

In both areas, water markets are absent. In Low Ter this is due to the fact that, even though the Spanish law allows them, their legal framework is not entirely developed. In Italy, water markets are absent due to the lack of a suitable legal framework and to the fact that water exchanges are possibly viewed as a way of eluding the current increasing block tariff system. The possibility that water may concentrate into the hands of few farmers is also viewed as conflicting with the basic rationale of the irrigation board based on the equity-driven idea of irrigation as a support to the development of small farms.

Altogether, the limited consideration of water markets in the two areas may be seen as a mix of late adjustment of the local legal system and institutional inertia in adapting to new needs. In fact, the directive 60/2000 does not explicitly promote water markets, but proposes more generically economic instruments, usually identified with volumetric pricing. However, even the approach based on volumetric pricing (or proxes such as irrigated area pricing) is not considered as acceptable by most Italian agriculture. However, the opportunities associated with improved water allocation systems are becoming a major issue in view of the economic difficulties in the farming sector and the need to increase the efficiency of water allocation for productive purposes.

Farm typologies in each study area were selected by means of a Cluster Analysis on a dataset derived from a representative sample of farms. In the Low Ter, the sample of 60 farms was obtained by quota sampling. In each zone, all the existing farms are classified by their size in different classes. The number of farms of each class is the variable used to define the quota used in the sampling. In Foggia, the Cluster Analysis was applied to secondary data derived from an available dataset (land registers held by irrigation boards) that includes all the farms located in the sub-area considered (131 farms).

Both the samples were clusterised by a hierarchical algorithm. The Ward method (Ward 1963) was applied to standardised variables (surface, crop area, irrigation distribution, etc.) and the number of clusters was derived by the study of the dendrogram. To validate the analysis, we used an analysis of variance (ANOVA) to test the significance of each discriminant variable (crop mix and farm size).

Four clusters were identified for Low Ter and three for Foggia. A description of farm types and related modelling features is provided in Table 2.

The four clusters in the Low Ter were characterised as being specialised in fruit growing, livestock production, or corn. An additional cluster is based on mixed crops. In the area of Foggia, three clusters were identified, on the basis of a combination of farm dimensions and crop specialisation. Large farms are basically characterised by cereal–tomato cultivation, whereas small farms may be specialised in either cereal–tomato cultivation or vegetable

Table 2 Types of productive orientation of the farms identified by means of the cluster analysis and main features of the models

	Low Ter				Foggia		
Model	LT.1	LT.2	LT.3	LT.4	Fg.1	Fg.2	Fg.3
Description	Extensive – mixed crops	Fruit	Livestock	Extensive – corn	Small farm – cereals–tomato	Small farm – vegetables	Large farm – cereals–tomato
Average farm size (ha)	18.31	20.51	29.62	33.91	7.52	7.71	31.36
Constraints:							
– Land	X	X	X	X	X	X	X
– Water	X	X	X	X	X	X	X
– Labour					X	X	X
– CAP (set-aside)	X	X	X	X			
– Market		X					
– Rotations	X	X	X	X	X	X	X
– Specific type of soil	X			X			
– Cattle feeding			X				
Cluster weight (λ_j)	0.34	0.19	0.12	0.35	0.365	0.361	0.274
Validation: sum of percent deviations from real crop mix	19.91	10.49	3.54	5.11	13.39	19.29	4.45

Note: X indicates that a constraint is used in a specific model.

production. Even though many farms in the Fg. 1 cluster reveal that many farmers employ multiple land uses, no separate cluster was defined based on mixed farming. In analogy, non-farm activities have not been considered in defining the clusters, so that hobby farming or pluriactive farming are not detected by the clusters.

Models were calibrated using primary data collected from the surveyed farms, concerning technical coefficients, economic parameters, resource availability, and constraints. Constraints include standard constraints such as land, labour, commercial constraints, and rotations. Land and labour constraints are given by resource availability, whereas commercial constraints and rotation mainly affect minimal/maximal proportion among crops. Land, water, and rotation constraints are included for all farm types. Labour constraints are the main determinant of the crop mix in the Foggia area. Market, soil, and cattle feeding constraints are binding in the Low Ter models. Market constraints are the main limiting factor for fruit expansion. In spite of their potential usefulness, market constraints are not used in the Italian vegetable and tomato farms, as in this case either water, rotation, or labour availability is the real limiting factor, depending on the farm. Labour constraints have been constructed by period. Five periods were specified. Models were validated against the actual crop mix, using as a simple validation parameter the sum of per cent deviations between the actual and the estimated crop mix. This validation parameter was selected on the rationale that the crop mix is the main indicator of actual choices taken by the farm. The validation parameter is mostly below 10 per cent, which was judged to be good performance, with only two cases (LT.1 and Fg.2) approaching 20 per cent.

An estimation of true transaction costs arising from water markets was not possible due to the absence of such a form of water allocation mechanism in the two areas. From a preliminary discussion carried out with local representatives and technical analysis of the water distribution system, however, it emerged that exchanges of water rights in the areas may be devised without additional water losses (leakages) or requirements for water transport infrastructure. As a consequence, transaction costs are most likely to be identified in search, negotiation, implementation, and enforcement costs. Given existing water-metering systems, it is likely that most transaction costs could be due to general negotiation about water prices. Such costs would be fairly low thanks to the role of the RIB in Foggia and of the water users associations in Low Ter. Given this situation, transaction costs would most probably be around the lower figures discussed in Section 2. However, in the absence of clear data, results are presented by performing a sensitivity analysis on transaction cost, distinguishing fixed and variable transaction costs. The levels of transaction costs used are the same for the two areas, even if this is not necessarily the case in practice. Variable transaction costs were allowed to vary in a range of the same magnitude of water prices in the two areas. The selected levels of transaction cost for sensitivity analysis were 0.00, 0.05 and 0.10 euro/m^3. Note that the transaction costs are defined as sum per cubic metre, and not as a percentage of prices. Fixed transaction costs are allowed to vary within a range that considers the probable value of a few working days for the farmer, plus some travel and administrative costs (0, 500, and 1000 euro/farm).

5. Results and discussion

Gains from introducing water markets for different levels of transaction costs and water availability in the two areas are reported in Tables 3 and 4.

The maximum increase in gross margin with zero transaction costs is about 156 euro/ha in Low Ter and 95 euro/ha in Foggia. This result does not say anything about the distribution of this gross margin. However, given the economic orientation of the farms and the changes caused by the modified availability of water, the increase in gross margin would mainly consist of increased remuneration for family labour. In the case of Low Ter, the increase of benefits generated by the water market may be as high as 30 per cent, whereas the highest increase in Foggia is less than 10 per cent. Altogether, although the effect of the market appears rather significant in Low Ter, it seems less important in Foggia.

In both cases, the highest level of variable transaction costs result in zero gain from the introduction of a water market (except in the case of zero fixed transaction costs for Foggia). For Low Ter, the gains are broadly similar for the three levels of water availability, whereas for Foggia, there are distinct differences between the levels, with the highest availability resulting in no gain from market introduction unless total transaction costs are zero. This is because the demand curves (marginal value of water) and the distance between demand curves of different clusters fall much more sharply for Foggia than for Low Ter. In other words, 1000 m^3/ha is a relatively smaller amount of water in Low Ter than in Foggia.

Assuming that the most likely results will be those related to the lower levels of proportional transaction costs and moderate fixed transaction costs, the introduction of a water market would generate modest benefits in Low Ter (4.5–6.1 per cent increase in GM) and at most, modest benefits in Foggia (0.0–3.4 per cent increase in GM).

In other results not shown in Table 3, we calculated that, given zero proportional transaction costs, the water market would generate no gains for fixed transaction costs greater than around 1500–2000 euro/farm in Foggia and around 4500–5000 euro/farm in Low Ter.

The water availability corresponding to the highest increases in gross margin is around respectively 2000 m^3/ha for Low Ter and 1000 m^3/ha for Foggia, which is about half of the water availability for each area in a normal year. This result is determined by the difference in the marginal value of water among clusters of the same area (and not by the marginal value of water in itself). The difference in marginal value of water tends to be low for small amounts of water, then to increase, then to decrease sharply. The 2000 m^3/ha for Low

Table 3 Gain from markets for different levels of transaction costs – Low Ter (Spain)

Transaction cost		Increase GM (euro/ha and %)			Marginal value of water (price) (euro/m^3)		
		Availability =			Availability =		
Fixed (euro/farm)	Proportional (euro/m^3)	1000 m^3/ha	2000 m^3/ha	3000 m^3/ha	1000 m^3/ha	2000 m^3/ha	3000 m^3/ha
0	0.0	120.0 (30.0%)	156.9 (31.8%)	130.1 (22.2%)	0.042	0.022	0.018
	0.05	39.1 (9.8%)	58.7 (11.9%)	48.8 (8.3%)	0.032	0.021	0.020
	0.1	0.0 (0%)	0.0 (0%)	0.0 (0%)	–	–	–
500	0.0	98.2 (24.7%)	136.6 (27.6%)	113.5 (19.4%)	0.042	0.012	0.014
	0.05	17.9 (4.5%)	39.7 (8.0%)	35.6 (6.1%)	0.032	0.021	0.023
	0.1	0.0 (0%)	0.0 (0%)	0.0 (0%)	–	–	–
1000	0.0	77.8 (19.4%)	117.5 (23.8%)	103.7 (17.7%)	0.042	0.012	0.011
	0.05	0.0 (0%)	20.6 (4.2%)	25.8 (4.4%)	–	0.023	0.023
	0.1	0.0 (0%)	0.0 (0%)	0.0 (0%)	–	–	–

Note: – indicates that there is no water price, as there are no water exchanges.

Table 4 Gain from markets for different levels of transaction costs – Foggia (Italy)

Transaction cost		Increase GM (euro/ha and %)			Marginal value of water (price) (euro/m^3)		
		Availability =			Availability =		
Fixed (euro/farm)	Proportional (euro/m^3)	1000 m^3/ha	2000 m^3/ha	3000 m^3/ha	1000 m^3/ha	2000 m^3/ha	3000 m^3/ha
0	0.0	95.0 (8.3%)	69.4 (5.3%)	11.3 (0.83%)	0.208	0.032	0.032
	0.05	68.2 (5.9%)	35.5 (2.7%)	0.0 (0%)	0.190	0.051	–
	0.1	49.3 (4.3%)	1.7 (0.1%)	0.0 (0%)	0.172	0.169	–
500	0.0	58.9 (5.1%)	41.6 (3.2%)	0.0 (0%)	0.208	0.032	–
	0.05	38.6 (3.4%)	7.8 (0.6%)	0.0 (0%)	0.190	0.051	–
	0.1	0.0 (0%)	0.0 (0%)	0.0 (0%)	–	–	–
1000	0.0	31.1 (2.7%)	13.8 (1.0%)	0.0 (0%)	0.208	0.032	–
	0.05	10.8 (0.9%)	0.0 (0%)	0.0 (0%)	0.190	–	–
	0.1	0.0 (0%)	0.0 (0%)	0.0 (0%)	–	–	–

Note: – indicates that there is no water price, as there are no water exchanges.

Ter and 1000 m^3/ha Foggia correspond to the levels of water availability where the difference in the marginal value of water (demand curve) among farm types is larger, and hence, the gains from trade are higher.

In both cases, the amounts of water availability corresponding to the higher gains from trade are actually very close to the real quantity of water distributed in drought years. However, such amounts could become the norm due to climate change and pressures from other sectors (domestic, recreation), even if exchanges with such sectors are not allowed. This raises the possibility that markets could contribute more to improved water management in the area than indicated in the results of this study.

Tables 5 and 6 show water exchanges among clusters and how they are affected by transaction costs, assuming the level of water availability that

Table 5 Water exchanges among clusters – Water availability = 2000 m^3/ha – Low Ter (Spain) (positive value = buying; negative value = selling)

Transaction cost		Water sold by farm type (m^3/ha)				
Fixed (euro/farm)	Proportional (euro/m^3)	LT.1 – Mixed	LT.2 – Fruit	LT.3 – Livestock	LT.4 – Corn	Total exchange (m^3/ha)
0	0.0	2000	–5099.8	–375.9	954.5	1014.0
	0.05	2000	–5099.8	0	825.6	968.9
	0.1	0	0	0	0	0
500	0.0	2000	–5121.6	0	837.5	973.1
	0.05	2000	–5099.8	0	825.6	968.9
	0.1	0	0	0	0	0
1000	0.0	2000	–5121.6	0	837.5	973.1
	0.05	2000	–5099.8	0	825.6	968.9
	0.1	0	0	0	0	0

Table 6 Water exchanges among clusters – Water availability = 1000 m^3/ha – Foggia (Italy) (positive value = buying; negative value = selling)

Transaction cost		Water sold by farm type (m^3/ha)			
Fixed (euro/farm)	Proportional (euro/m^3)	Fg.1 – Small cereals–tomatoes	Fg.2 – Vegetables	Fg.31 – Large cereals–tomatoes	Total exchange (m^3/ha)
0	0.0	179.1	–741.3	738.1	267.6
	0.05	179.1	–741.3	738.1	267.6
	0.1	17.8	–490.3	622.3	177.0
500	0.0	0	–560.2	738.1	202.2
	0.05	0	–560.2	738.1	202.2
	0.1	0	–472.3	622.3	170.5
1000	0.0	0	–560.2	738.1	202.2
	0.05	0	–560.2	738.1	202.2
	0.1	0	0	0	0

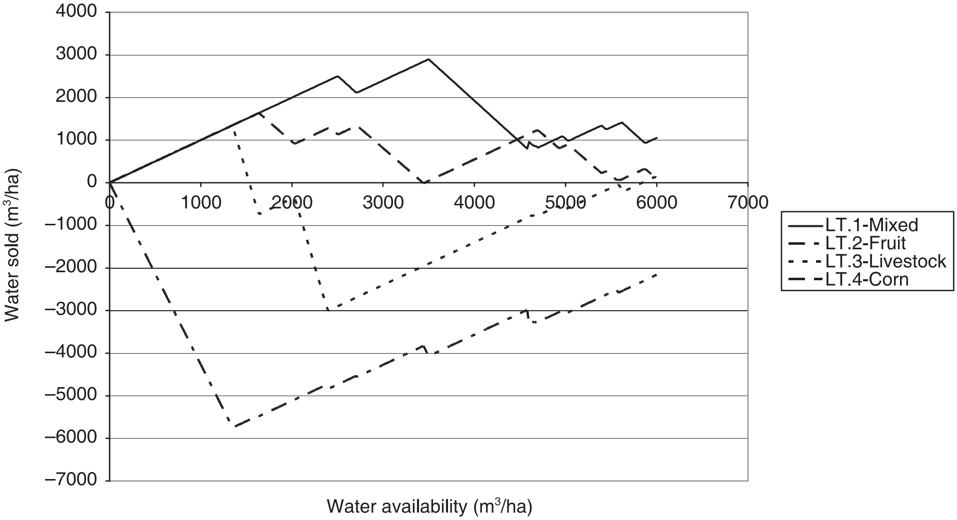

Figure 2 Water exchanges among clusters as a function of water availability (transaction costs = 0) (Low Ter, Spain).

denotes the strongest market impacts (respectively 2000 m^3/ha for Low Ter and 1000 m^3/ha for Foggia).

In both cases, water is mostly bought by one farm type only, namely fruit farms for Low Ter and vegetable farms for Foggia. Livestock farms in Low Ter purchase small volumes of water, but only in the case of zero transaction costs. As expected, proportional transaction costs have an impact mainly on the amount of water sold, whereas fixed transaction costs mainly affect entry and exit from the market. In relation to the amount available, water exchanges are much more significant in Low Ter (about 50 per cent of water availability) than in Foggia (about 25 per cent of water availability). This is due to the stronger heterogeneity of farms in the Low Ter.

A key determinant of water exchange is actual water availability. Figure 2 shows the total water exchange among clusters as a function of the water availability in Low Ter, assuming no transaction costs. The figure highlights the markedly different positions of different kinds of farms with respect to water markets. In Low Ter, clusters 1 and 4 are the main sellers, whereas cluster 3 and, to a lesser extent, cluster 2 are the buyers. In the same way, in the case of Foggia, cluster 2 is the main buyer, denoting a strong concentration of water resources towards intensive vegetable growers (Figure 3). However, the positions of particular clusters as buyers and sellers may reverse depending on water availability.

Water exchanges are closely connected to changes in crop mix patterns. A synthesis of the relevant changes may be represented through the percent changes in the area devoted to fruit in Low Ter and vegetables in Foggia, in the market versus non-market situation. Changes are given by farm type in

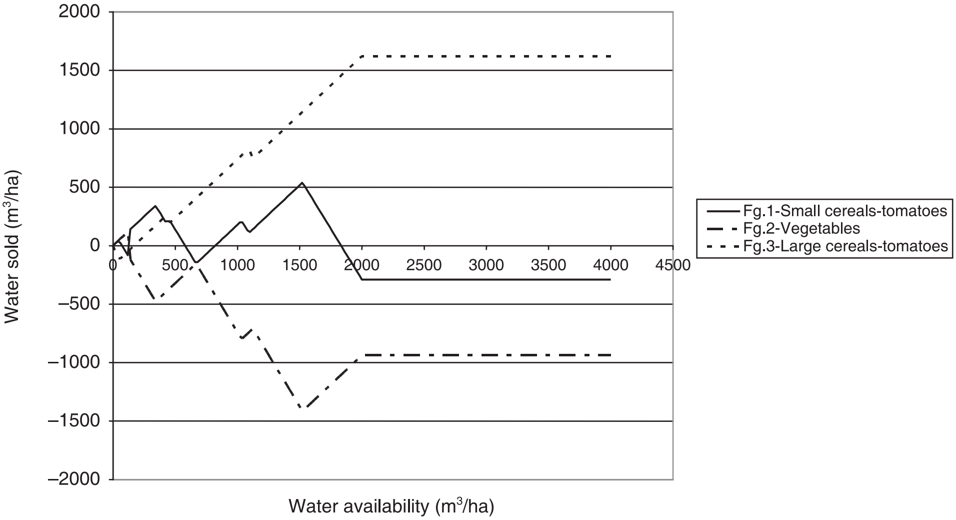

Figure 3 Water exchanges among clusters as a function of water availability (transaction costs = 0) (Foggia, Italy).

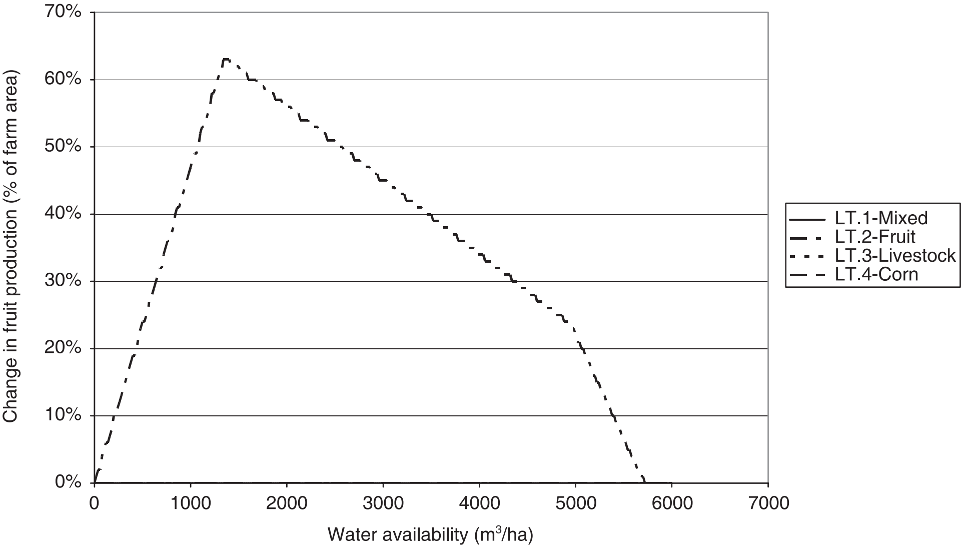

Figure 4 Percentage variation (market vs. non-market) of key crops (fruit) by cluster (Low Ter, Spain).

order to emphasise the different impact on the degree of farm specialisation (Figures 4 and 5).

In both areas, the increase in key crops is highly concentrated on a single farm type. In Foggia, below 1000 m³/ha, the increase in vegetable growing in cluster 3 is compensated by a reduction in vegetable growing in the other clusters. In Low Ter, a net increase in fruit growing in cluster 2 is not compensated by any changes in the other clusters. The main peak of the curve,

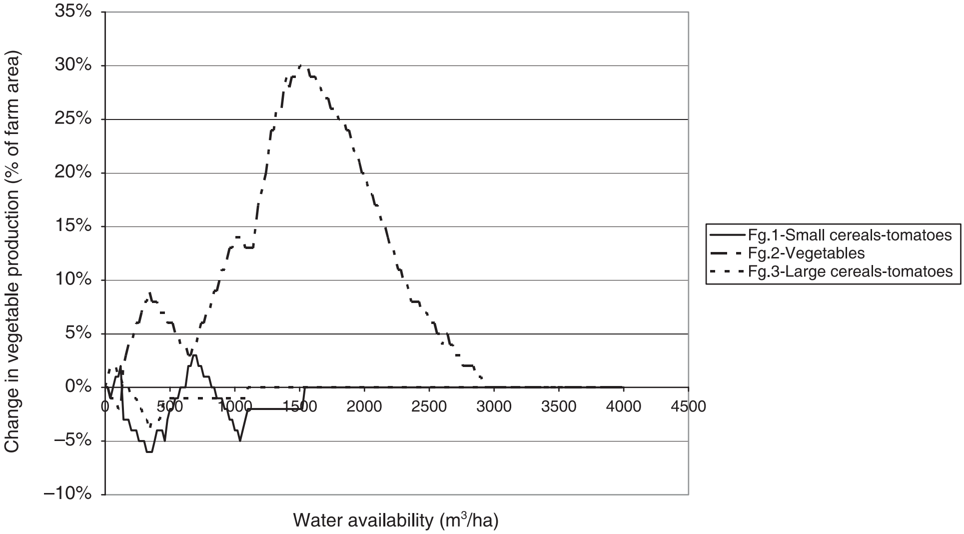

Figure 5 Percentage variation (market vs. non-market) of key crops (vegetables) by cluster (Foggia, Italy).

after which the percent of fruit/vegetables decreases, meaning that the area devoted to these crops has reached the maximum achieveable, that is, the size that would be chosen by the farm if there were no water restrictions. This means that, in Low Ter, if water exchange is allowed, even with a water availability of about 1200 m^3/ha it is possible to grow the same amount of fruit that would be grown if there was plenty of water. The same happens for vegetables in Foggia at about 1500 m^3/ha.

Several aspects of these results call for attention to the instituional framework, which goes beyond simply whether or not to allow water exchanges between private individuals. First, the institutional setting may have a key role in guaranteeing low transaction costs, through a proper regulation of water transactions. Also, there is a strong role of public or collective bodies in maintaining public trust vis à vis a water-allocation mechanism (water market) that may have a rather differentiated impact on different farm types. These results are consistent with those obtained by Garrido (2000) and Gómez-Limón and Martínez (2005) who studied the feasibility of water markets in other areas of Spain (Guadalquivir zone and Duero Valley), with very different features. The institutional framework was also emphasised by Calatrava and Garrido (2005), who proved the importance of providing a reliable market setting for the efficiency of a water market.

6. Concluding comments

This paper confirms that water markets could potentially improve the economic efficiency of water use in the study areas and highlights that the level of benefits depend crucially on the level of transaction costs. Given transaction costs at realistic levels, the level of economic gains from introduction of a market are likely to be modest, at best. If this is added to the likely amount of 'unreportable' transaction costs and to the lack of an adequate legal framework for the years to come, the development of water markets is not to be expected in the near future in the areas under analysis.

The paper also emphasises how different structures (fixed vs. proportional) of transaction costs may lead to different outcomes. However, the consideration of this issue would benefit from further research on the nature of the transaction costs and their effects on decision making. For example, subjectively low shadow prices of farmers' labour may keep transaction costs low, whereas risk perception and uncertainty about the future allocation of water rights would push transaction costs above reported ones.

We can also expect the improvement in water allocation to be reflected in higher specialisation and higher incomes. Hence, the market can contribute to maintain high value-added crops even with relatively low water availability. These achievements, however, may involve a trade-off with equity considerations and homogeneous development of farms.

From the agricultural point of view, this leads to the problem of the choice of agricultural policy objectives (develop a more competitive agriculture vs. maintaining a social-oriented rural development strategy), taking into account how they will be affected by resource policy.

From the water policy point of view, these results highlight the importance of taking into account the complexity of agricultural systems and agricultural policy objectives in designing policies for water conservation matching local objectives.

From both points of view, however, present water policies for irrigated agriculture, mostly based on a subsidisation of agriculture and aimed at giving some opportunities to as many farmers as possible, appear inadequate.

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