AESTIMUM 72, Giugno 2018: 81-107

Ruggiero Sardaro,
Francesco Bozzo,
Vincenzo Fucilli

Department of Agricultural and Environmental Science, University of Bari

E-mail: *ruggiero.sardaro1@uniba.it*, *francesco.bozzo@uniba.it*, *vincenzo.fucilli@uniba.it*

The choice experiment and the stochastic profit frontier: a methodological approach for groundwater preservation policies

Apulia is the fifth Italian region in terms of irrigated area and irrigation water used in agriculture. However, inefficiencies in the management of the regional irrigation consortia force most of farmers to use groundwater by private wells, with negative consequences on soil and crop characteristics, and with grave desertification risk. In the first instance, through a choice experiment survey, the study investigated the aptitude of the regional farmers toward the abandonment of their farm wells in exchange for an improved consortium irrigation network and additional services. Then, through a stochastic profit frontier, the impact of these choices was assessed on the economic performance of farms, providing useful information for suitable and fair groundwater preservation policies.

Keywords: *Groundwater preservation, Water Framework Directive, Choice experiment, Stochastic profit frontier, Wine growing.*
Parole chiave: *acqua di falda, esperimento di scelta, frontiera stocastica del profitto*

JEL: C25, C54, Q12, Q25

1. Introduction

Groundwater represents 98% of all freshwaters available on earth, excluding glaciers and ice caps (Basu and VanMeter, 2014). The importance of this natural resource is related not only to its uses in the potable, agricultural and industrial sectors, but also to its essential role in the hydrological cycle, for maintaining wetlands and river flows and for acting as a buffer during dry periods (Margat, 2008). This natural resource supplies several ecosystem services categorized in: provisioning services (e.g. drinking, irrigation in agriculture, etc.), regulatory services (e.g. storage for heat or coolness, drainage, purifying and filtering effect of groundwater and soil, etc.), cultural services (preservation of cultural–historical and archaeological values, esthetical and ethical values of the groundwater ecosystem, etc.) and supporting services (e.g. water cycling, soil formation, etc.) (Bergkamp and Cross, 2007; Tuinstra and van Wensem, 2014). However, groundwater is under increasing pressure over all in dry regions and territories characterized by a high intensive use of soil and subsoil in agriculture (excessive use of nitrogen fertilisers, pesticides and irrigation practice) and industry (dumping of industrial waste in disposal sites, mines, etc.) (Shah et al. 2007; Fornés et al. 2005). These pressures may lead to scarcity, nutrient loading, pollution, drought and salinization, threating the quality of resource for many decades, with huge use of public and/or private money in order to clean up the contaminated locations. Furthermore, since surface water systems receive inflowing groundwater, the effects of

DOI: 10.13128/Aestimum-23970

human activities on groundwater quality could impact on the quality of aquatic ecosystems (Basu and Van Meter, 2014).

In the last decades, the European Union (EU) has undertaken various initiatives in order to protect the groundwater quality[1]. However, a most coherent and consolidated bundle law in the EU water legislation is fixed by the Water Framework Directive (2000/60/EC). It establishes an innovative approach for water resource management, joining economic principles and methods together with river basin management plans (Griffiths, 2002). In particular, it concerns a programme of measures for the preservation and management of inland surface waters, transitional waters, coastal waters and groundwater in order to ensure a good quantitative and qualitative condition of this natural resource at a river basin level. For this programme, the directive provides for economic tools aimed at recovering costs of water services in line with the "polluter pays" principle, including environmental costs related to damage or negative effects on the aquatic environment. To this end, an economic analysis of water services is required for the various sectors that use the resource (agriculture, industry and households), based on long-term forecasts of demand and supply (art. 9). Therefore, the directive highlights the need to fix a pricing policy able to ensure: the setting of a fair price for all water uses and services; the reduction of water demand, with a decrease of impacts on water bodies; a more efficient allocation of water resources, with positive effects on their use and pollution. Such an approach ensures the sustainability of the resource related to the use (potable, irrigation and industrial sectors), the environment (qualitative and quantitative preservation of ecosystems), the community (fair accessibility and sharing) and the economic convenience (rationalization of water management for an effective and efficient supply).

For the agricultural sector, irrigation through groundwater is important for production and livelihood security, however the over-exploitation of this resource can involve negative effects in dry regions or territories characterized by intensive agriculture. In these cases, the providing of helpful economic information to decision makers for suitable irrigation policies is crucial. These data should be based on the assessment of economic value of groundwater through decision-support tools such as cost–benefit analysis (Alcon, 2014), which allows the setting of regulatory interventions, market instruments or technical choices (Lopez-Gunn et al., 2011; Tsur, 2005). In this connection, groundwater pricing approach is an economically efficient option for enhancing the sustainable use of groundwater (Tuinstra and van Wensem, 2014; Turner et al., 2004). Indeed, farmers are expected to reduce consumption following an increase in prices, nevertheless the groundwater

[1] The directive 80/68/EC was the first law adopted on the protection of this resource from the direct and indirect introduction of pollutants. It was followed mainly by the Construction Product Directive (89/106/EC), the Nitrates Directive (91/67/EC), the Urban Wastewater Treatment Directive (91/271/EEC), the Plant Protection Products Directive (91/414/EEC), the Integrated Pollution Prevention and Control (IPPC) Directive (96/61/EEC), the Drinking Water Directive (98/8/EEC), the Biocides Directive (98/8/EC) and the Landfill Directive (99/31/EC).

demand is more inelastic in case of market oriented and high-value crops, which are characterized by a more intensive use of the resource and a higher productivity (Dinar and Mody, 2004). In these cases, the effectiveness of measures often requests a right and fair mix of policy instruments from an existing portfolio in order to ensure both the supply of optimum groundwater quantities and their quality preservation. This approach could include, in addition to pricing, supplementary services to supply to farmers, such as the use of treated wastewater from residential and industrial areas to face the shortage of conventional groundwater or surface water above all in dry regions (Carr et al., 2011). On the demand side there are various management alternatives, such as the adoption of more efficient irrigation technologies, such as the drip irrigation, or solutions in the field of precision agriculture (Grant et al., 2007; Martín et al., 2007). However, the planning of these measures requests the implementation of equity principles, so that the involvement of local stakeholders contributes to a better success of the selected actions (Martín-Ortega, 2012).

In Italy, irrigation of crops is carried out by public irrigation consortia, but also through private farm wells. These last, in particular, are mainly used where the irrigation consortium network either is absent or deactivated or not fully efficient (Fabiani, 2009), with possible over-exploitation of groundwater above all in the presence of intensive crops. In order to avoid the consequences of the excessive use of the resource, a set of measures can be implemented, such as: expansion and modernization of consortium irrigation network; control of water exploitation in order to reduce unauthorized uses; progressive closing of farm wells, responsible of the degradation of aquifers; setting up of a technical assistance network for favouring the reduction of groundwater use and the increase of its efficiency (ANBI, 2009). However, the implementation of any preservation measure generates also economic impacts on farms, which should be assessed in order to verify the reliability and equity of the selected actions.

Therefore, the aim of this study was twofold. First we detected a set of measures, and respective prices, bent on reducing the groundwater use in agriculture through a bottom up approach, i.e. by involving the main stakeholders (farmers). Then we verified the effects of such measures on the farm profit efficiency (Sardaro et al., 2016; Sardaro et al., 2017). In particular, a choice experiment (CE) survey was carried out for the selection of the actions, while their impact on profit efficiency was valued by a stochastic profit frontier (SPF) model. The study referred to the Apulia region, and in particular to the districts of Adelfia, Noicattaro and Rutigliano, which are part of an irrigation consortium area, but the respective irrigation network is not present, so that the primary water source is groundwater by private farm wells. Besides, the analysis referred to the wine growing sector for the production of table grapes (Figure 1), one of the most profitable regional crops characterized by a significant water demand.

The paper contributes to the literature in two ways. First, no applied economic study investigated farmers' preferences for the preservation of groundwater in the Mediterranean area in general, and in southern Italy in particular, also jointly with the verification of the effects of these preferences on a farm scale. Second, this

Figure 1. Distribution of vineyards in the area of study.

study adds to the growing literature that employs the CE and SPF for the preservation of Mediterranean natural resources. Findings have implications for debates concerning costs and benefits aimed at preserving water resource, allowing the verification of the strategies in force and the planning of *ad hoc* and cost-effective programmes.

The paper proceeds as follows: first, we reported information about the structural characteristics of the irrigation sector in Apulia, highlighting the sizeable use of groundwater by farmers, also due to the inefficiencies of the regional consortium irrigation network. Next, a description of the methodological approach was provided. Then, the preferences of farmers for groundwater preservation and the effects of these choices on their farm profit were presented in the results' section. Discussion and final considerations closed the paper.

2. Structural characteristics of the irrigation sector in Apulia

Apulia is characterized by low annual rainfall, scarce endogenous water and a small hydrographic network. At the same time, agriculture is a very developed sector, as based on intensive olive growing, wine growing and horticulture, so that it is the fifth Italian region in terms of irrigated area and volumes of irrigation water used (Istat, 2010). In particular, the regional UAA is over 1.28 million hectares, equal to 10% of the total national area, of which over 238 thousand hectares (18.5%) are irrigated by 655 million of cubic meters, equal to 2,750 m^3/ha/year (Table 1). More in detail, the Foggia province holds almost one third of the regional

Table 1. Irrigated area and irrigation water used, per province.

Province	UAA (ha)	Irrigated area (ha)	Share of regional UAA (%)	Share of provincial UAA (%)	Irrigation water (m^3)	Share of total irrigation water (%)	Unit volumes (m^3/ha)
Foggia	495,111.10	76,538.67	32.1	15.5	215,029,269.01	32.8	2,809.4
Bari	268,312.23	43,080.59	18.1	16.1	120,376,788.11	18.4	2,794.2
Taranto	135,144.32	32,665.25	13.7	24.2	91,218,291.12	13.9	2,792.5
Brindisi	119,536.96	22,258.61	9.3	18.6	58,678,737.24	9.0	2,636.2
Lecce	161,130.94	18,495.82	7.8	11.5	54,662,612.29	8.3	2,955.4
BT	106,054.35	45,506.78	19.1	42.9	115,324,005.10	17.6	2,534.2
Apulia	1,285,289.90	238,545.72	100.0	18.6	655,289,702.87	100.0	2,747.0

Source: our elaboration on Istat 2010.

irrigated area, followed by the Barletta-Andria-Trani province (BT), with over 45.5 thousand hectares (19.1%). In terms of volumes, in the Foggia province 33% of the regional irrigation water is used, followed by the Bari and BT provinces (18%).

Concerning the provincial districts, 43% of the BT province is irrigated, followed by the Taranto province (24.2%), due to the presence of intensive cultivation systems characterized by high water demand (olive groves, vineyards and citrus orchards). On the irrigated area per crop (Table 2), in the Foggia province vegetables prevail (37.6%), followed by grapes (26%) and olives (14.4%). This last is the most irrigated crop in the Bari province (44.6%), followed by grapes (27%) and fruits (14.2%). The Lecce and Brindisi provinces point out similar data for the olive and vine sector.

Table 2. Irrigated area (hectares), per crop and province.

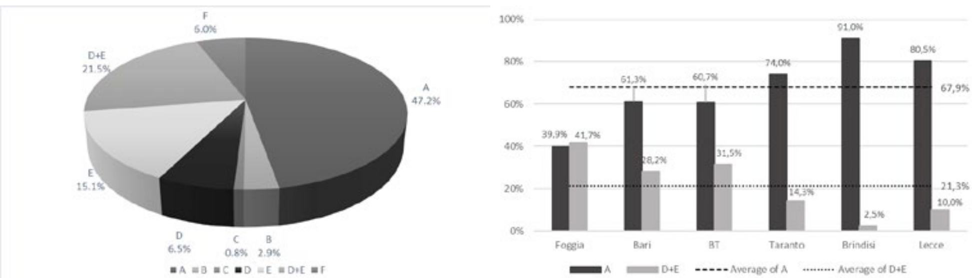
Province	Grapes	Olives	Citrus	Fruits	Grains	Vegetables	Other	Total irrigated area
Foggia	19,842.70	11,059.11	167.15	1,219.26	8,749.06	28,746.43	6,754.96	76,538.67
Bari	11,649.45	19,234.75	162.54	6,114.98	820.68	4,188.92	909.27	43,080.59
Taranto	11,988.57	7,008.01	7,299.27	547.01	1,772.87	2,536.36	1,513.16	32,665.25
Brindisi	2,697.32	10,781.12	47.61	606.73	1,498.72	5,886.71	740.40	22,258.61
Lecce	1,050.21	11,000.27	266.75	161.16	1,292.88	3,201.65	1,522.90	18,495.82
BT	15,860.07	22,654.07	5.22	3,581.76	791.81	2,365.28	248.57	45,506.78
Apulia	63,088.32	81,737.33	7,948.54	12,230.90	14,926.02	46,925.35	11,689.26	238,545.72

Source: our elaboration on Istat 2010.

On the water supplying, in Apulia irrigation water is managed by both public institutions and private users. The first ones operate springs and reservoirs, while the second ones, mostly farmers, manage groundwater collected by their own wells, especially where the consortium irrigation network either is absent or deactivated or not fully efficient (Fabiani, 2009). In particular, in the Bari and BT provinces, 61% of irrigation water comes from groundwater and 28-31% from waterworks or consortia (Table 3, Figure 2). In the Brindisi and Lecce provinces, instead, 80-90% of irrigation water comes from groundwater, while consortia supply only 2-10% of demand. The Taranto province highlights similar trends (74% from groundwater and 14% from waterworks or consortia), while the Foggia province points out a more uniform distribution of demand among sources, so that the use of irrigation water through private wells and consortia/waterworks is equal to 40% and 41%, respectively. Overall, the two main regional sources for irrigation are private farm wells (on average 68%) and consortia or waterworks (on average 21%), these last supplied by the Apulian (Carapelle, Cervaro, Ofanto and Fortore) and Lucan (Sele) streams. The total administered area of the regional consortia covers the whole regional UAA, but the total equipped area is only 13% of the administered area, while the irrigated area is only 6.3% of the administered one (Distretto Idrografico dell'Appennino meridionale, 2010), with a supplied irrigation water of 205.7 million of cubic meters, on average 1,900 m^3/ha/year (Table 4).

Hence, data pointed out on the one hand the sizeable water demand by the Apulian agriculture and on the other hand the scarce capacity of the regional consortia to satisfy it. Indeed, irrigation water supplied is equal to 31% of the used resource and only 23% of the total demand estimated, i.e. 874 million m^3/year (Nino and Vanino, 2009), so that most of farmers are forced to exploit groundwater. This structural state favours the progressive salinization of resource, with negative consequences on soil and crop characteristics and on desertification.

Figure 2. Sources of irrigation water in Apulia (I); irrigation through groundwater and waterworks/consortium, per province (II).



I II

Source: our elaboration on Istat 2010.

Table 3. Volumes of irrigation water (m^3), per source.

Province	Groundwater from farm wells	Surface water within the farm (natural and artificial basins)	Surface water outside the farm (lakes, rivers or waterways)	Waterworks, consortium or other irrigation organization with supply in turn	Waterworks, consortium or other irrigation organization with supply by request	Other sources	Total
	A	B	C	D	E	F	
Foggia	85,709,211.5	12,294,529.6	4,270,827.4	23,713,413.1	65,951,159.4	23,090,128.0	215,029,269.0
Bari	73,775,891.5	3,277,987.8	775,424.2	6,436,422.0	27,536,902.5	8,574,160.2	120,376,788.1
BT	69,976,990.6	2,713,592.6	828,597.6	15,174,145.1	21,127,506.5	5,503,172.7	115,324,005.1
Taranto	67,543,198.7	3,852,521.7	455,657.7	6,801,871.7	6,214,311.2	6,350,730.1	91,218,291.1
Brindisi	53,387,766.1	894,177.9	65,344.9	554,232.3	888,239.9	2,888,976.2	58,678,737.2
Lecce	44,016,701.0	1,585,460.0	314,761.5	1,456,571.0	3,986,893.8	3,302,224.9	54,662,612.3
Apulia	394,409,759.5	24,618,269.6	6,710,613.2	54,136,655.2	125,705,013.2	49,709,392.2	655,289,702.9

Source: our elaboration on Istat 2010.

Table 4. Administered, equipped and irrigated areas by the regional consortia.

Consortium	Admin. area (ha)	Equip. area (ha)	Equip. area/ Admin. area (%)	Irrig. area (ha)	Irrig. area/ Admin. area (%)	Irrig. area/ Equip. area (%)	Irrigation water used (m^3)	Irrigation water used /Irrigated area (m^3/ha)
Terre d'Apulia	569,807	22,659	4.0	16,225	2.8	71.6	16,360,000	1,008
Capitanata	441,545	146,000	33.1	81,000	18.3	55.5	148,302,000	1,831
Arneo	249,425	14,500	5.8	4,800	1.9	33.1	700,000	146
Ugento-Li Foggi	189,494	14,000	7.4	2,500	1.3	17.9	5,000,000	2,000
Stornara e Tara	132,825	22,486	16.9	3,000	2.3	13.3	35,000,000	11,667
Gargano	154,796	2,800	1.8	1,100	0.7	39.3	350,000	318
Total	1,737,892	222,445	12.8	108,625	6.3	48.8	205,712,000	1,894
Average	289,649	37,074	11.5	18,104	4.6	38.4	34,285,333	2,828
Regional UAA	1,285,000	17.31%						
Regional TAA	1,388,899	16.02%						
Regional area	1,954,100	11.38%						

Source: our elaboration on Istat 2010.

3. Materials and methods

3.1 The studied area

Apulia is the Italian leading region in the production of table grapes, with 24 thousand hectares, i.e. over 57% of the total national area, and a production of over 6 million quintals, i.e. more than 56% of the national production (Istat, 2010). The table grapes are mostly used for direct consumption and, in marginal quantities, for grape juices and distillates.

The provinces of Bari and Taranto are leaders in the region, holding 42.3% and 33.2% of UAA, and 46% and 22% of farms, respectively. In the BT province, instead, the production involves 16.7% of UAA and 21% of farms. Therefore, it is possible to identify three distinct areas where this crop is more concentrated: the first one in the south-east of the Bari province, the second one in the west territory of the Taranto province, namely along the Ionian coast, and the third area in the north of the Bari province, i.e. along the Adriatic coast and until the Foggia province.

The study focused on the districts of Adelfia, Noicattaro and Rutigliano (Table 5), characterized by the greatest production of table grapes in the Bari province. The exclusive cultivation system is based on the "tendone" plant, which is irrigated and covered through proper plastic films in order to advance or delay the maturation period. This technique allows an improvement of production quality and extends the sale period, thus from the end of May to January. In the absence of plastic films, vineyards are anyway protected with plastic nets to reduce the risk from adverse climatic events (hail).

The ampelographic composition of the area is based on typical (Italia, Red Globe, Victoria and Michele Palieri) and seedless (Sugraone, Centennial, Thompson and Crimson) varieties, which allow a wider supply, so to answer the variable consumer taste and the recent market diversification. However, Italia is the most widespread variety, covering more than 70% of the studied area, and followed by

Table 5. Structural characteristics of wine growing in the studied area.

District	UAA (ha)	Farms (n)	Wine-growing UAA (ha)	Wine-growing UAA %	Wine-growing farms (n)	Wine-growing farms %	Average wine-growing UAA of farms (ha)	Wine-growing irrigated UAA (ha)	Wine-growing irrigated farms (n)	Unit irrigation water (m^3/ha)
Adelfia	1,383.2	673	666.5	48.2	316	47.0	2.1	591.9	225	1,541.6
Noicattaro	2,330.0	779	1,485.6	63.8	638	81.9	2.3	1,296.6	600	1,336.0
Rutigliano	3,688.9	858	2,172.2	58.9	731	85.2	3.0	1,618.7	657	1,454.1
Tot./Aver.	7,402.2	2,310	4,324.2	56.9	1,685	71.4	2.5	3,507.2	1,482	1,443.9

Source: our elaboration on Istat 2010.

Victoria, Regina, Red Globe, Cardinal and Matilde. Since 2011, table grapes cultivated in the regional territory are recognized through the Protected Geographical Indication named "Uva di Puglia".

3.2 The choice experiment

3.2.1 The questionnaire

The survey questionnaire was divided into three sections. The first one collected the farmers' opinions about some issues related to the use of groundwater in their own farms, to the knowledge about the risks of this natural resource, and to the possible interventions for its preservation. At the end of the first section respondents were informed about the current quality of groundwater in Apulia, therefore, the importance for its preservation was argued in order to favour sustainable agriculture, to preserve soil and crop quality and to ensure environmental protection. In the second section, respondents were asked to make choices about a possible action plan aimed at preserving groundwater through the abandonment of their private farm wells and the use of the consortium irrigation network. For each preference, a final question was inserted in order to investigate its certainty on a 0–5 scale. The section ended with a question about the reasons behind the respondents' choice in order to identify possible protest answers, strategic attitudes, etc. Finally, the third section collected socioeconomic aspects of farmers, such as sex, age, marital status, education level, etc. Interviews lasted circa 50 min and were conducted face-to-face at three agricultural assistance centres in Adelfia, Noicattaro and Rutigliano over the period October 2014 – May 2015 by four trained data collectors.

3.2.2 The survey design

Based on conjoint analysis and discrete choice theory (Louviere and Woodworth, 1983; Train, 2009), the CE was applied for the first time for environmental goods (Adamowicz et al., 1994; Adamowicz et al., 1998) at the beginning of the 90s. The CE is able to estimate the total economic value (TEV), inclusive of use and non-use values which, in the case of environmental goods such as water resource, are often prominent compared to the first ones (Provins et al., 2008). As extension of contingent valuation (Krishna et al., 2013), a stated preference method, the CE allows to express about several alternatives concerning the management of groundwater, selected through experimental designs and inserted in choice tasks. Each alternative is defined by different combination of attributes and respective levels. Hence the researcher asks respondents to choose, for each choice task, the preferred alternative, i.e. the one which gives the greatest relative utility, in order to reveal their preferences (Hensher et al., 2015). The aim is the assessment of the importance (weight) that respondents place on each of the attributes.

In this study, some of the attributes (table 6) referred to the measures listed in the annex VI of the directive 2000/60/EC (1, 4 and 6), while others concerned

Table 6. Attributes used in the choice experiment survey.

N.	Attribute	Levels and respective coding
1	Closing of the farm well and use of the consortium irrigation network able to supply a proper quantity of water (m3/ha/year)	0 (-1) 1,000 (0) 2,000 (+1)
2	Use of treated wastewater from urban and/or industrial areas	No (-1) Yes (+1)
3	Sponsorship of the PGI brand for the Apulian table grapes by the regional institutions	No (-1) Yes (+1)
4	Setting up of a technical assistance network by the regional institutions and based on the precision agriculture for a more efficient use of irrigation water and reduction of water demand	No (-1) Yes (+1)
5	Reduction of the IRPEF tax (%)	0 (-1) 10 (0) 20 (+1)
6	Payment of an annual rate for using irrigation water from the consortium network (€/m3/year)	0, 0.05, 0.10, 0.20, 0.50

services requested by farmers and related both to interventions for the reduction of water demand and to services in return for the payment of the annual rate (2, 3 and 5). The selection of these attributes was carried out through a simplified version of the survey questionnaire, administered to a subsample of 102 farmers.

An important step in the CE survey concerns the experimental design, given the great number of alternatives resulting from the combination of the selected attributes and their respective levels. In this regard, we produced an orthogonal design and, starting from 360 alternatives (2^3x3^2x5^1), besides the "no choice" option, 20 profiles were generated in R[2]. Afterwards, 10 choice tasks were assembled and split into 2 blocks of 5, so that each farmer completed one randomly assigned block (Table 7). In the choice sets, the "no option" ensured conceptual validity of the design for the voluntary nature of participation in a payment-for-groundwater programme. Moreover, the creation of the blocks was necessary as a large number of choice sets could cause a high cognitive effort of respondents (Weller et al., 2014). Finally, the alternatives were unlabelled (Louviere et al., 2000) in order to better investigate the role of the attributes. Based on this survey design, 300 interviews were planned, 150 for each block.

2 https://cran.r-project.org/.

Table 7. Example of choice set used during interviews.

Attributes	Option A	Option B	No option
Closing of the farm well and use of the consortium irrigation network able to supply a proper quantity of water (m^3/ha/year)	1,000	2,000	Neither A nor B. I do not want participate to the payment-for-groundwater programme
Use of treated wastewater from urban and/or industrial areas	No	Yes	
Sponsorship of the PGI brand for the Apulian table grapes by the regional institutions	No	No	
Setting up of a technical assistance network by the regional institutions and based on the precision agriculture for a more efficient use of irrigation water and reduction of water demand	Yes	No	
Reduction of the IRPEF tax (%)	10	10	
Payment of an annual rate for using irrigation water from the consortium network (€/m^3/year)	0.10	0.20	

3.2.3 The model

The CE approach draws from the Lancaster's theory of value (Lancaster, 1966) and the Random Utility Model framework (McFadden, 1974). It assumes that the stakeholder will choose the alternative which provides the greatest utility U, so that individual i chooses the alternative j among n alternatives if and only if $U_{ij} > U_{in}$. However, it is not possible to directly observe all determinants of individual utility, so that it is divided into two components: the first one is an observable or deterministic part (V_{ij}), the second one is a stochastic or random part (ε_{ij}) which includes other factors not observable by researcher. Hence, the utility formula can be written as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad [1]$$

The deterministic component, in turn, can be written as:

$$V_{ij} = \beta_{ijk} \times X_{ijk} \qquad [2]$$

where X_{ijk} is the vector of the k utility determinants, and β_{ijk} is the vector of coefficients indicating the marginal utility.

Assuming that the error terms are independently and identically distributed (IID) with a Gumbel distribution, the Conditional Logit Model (CLM) is obtained. However, it implies the independence of irrelevant alternatives (IIA) and choice homogeneity across respondents, so that the utility coefficient of the attribute k

is the same for all individuals (Louviere et al., 2000). Nevertheless, the imposing of this assumption is rather restrictive as difficult to observe (Train, 2003), so that distortions in the assessment of parameters could be generated. The Random Parameter Logit Model (RPLM), instead, relaxes the IIA assumption and allows a random distribution for parameters of population (Ben-Akiva and Lerman, 1985) in order to catch the heterogeneity of not observable preferences. In this case, the fitting of the model depends on the choice of parameters to be inserted as casual terms and on the functional form of distribution.

In this study, utility from a specific alternative is defined by its attributes and levels, i.e. quantity of irrigation water supplied, rate of irrigation water and services for farmers, besides specific individual characteristics. Hence, the functional form of the deterministic component of utility V_{ij} for the individual i concerning the alternative j can be further expressed as:

$$V_{ij} = \beta_q \; quantity_j + \beta_{ra} \; rate_j + \beta_{serv} \; services_j \qquad [3]$$

where β_q, β_{ra} and β_{serv} refer to the water quantity, rate and services considered in the suggested measures for groundwater preservation. The CE analysis was carried out through NLOGIT 5. About WTP, assuming a linear function of utility, the welfare changes from the implementation of the suggested measures was estimated as:

$$WTP = -\frac{\beta_a}{\beta_{pr}} \qquad [4]$$

where β_a and β_{pr} are the coefficients related to the non-monetary and monetary attributes, respectively. The WTP was assessed by the delta method.

3.3 The stochastic profit frontier

3.3.1 The questionnaire

The questionnaire used in this second part of the study allowed to ask, to the same farmers involved in the CE survey, several characteristics of their own farms, in particular by focusing on labour and cultivation costs, these last referred to irrigation water, pesticides, fertilizers, fuel and power. The interviews, carried out for each farmer after the CE questionnaire, lasted circa 25 min and were conducted face-to-face at the same three agricultural assistance centres in Adelfia, Noicattaro and Rutigliano over the period October 2014 – May 2015 by the same four trained data collectors.

3.3.2 The survey design

In order to assess the effects of the chosen attributes on farm profit, two stochastic profit frontier models were carried out, namely referred to before (ex-ante) and after (ex-post) the implementation of the suggested measures. To that end, the economic results of the sampled farms were analysed through the economic balance sheet. This approach, based on the profit equation, compares the value of the saleable production with the respective production costs, allowing the calculation of the farm income, the study of the economic dynamics which led to its formation and the mechanisms by which the income is allocated among the economic operators (Idda et al., 2010).

The economic balance sheet was based on the following hypotheses. The economic data (revenues and costs) referred to the average values over the period 2010-2014 in order to avoid possible isolated effects from particular climatic and market events. Besides, on the financial situation of the sampled farms, all the short and medium-term debt positions were disregarded, thus avoiding information which, although important, would have been unrealistic, so risking to invalidate the reliability of the results. Based on these aspects, the primary economic data of the sampled farms were collected and analysed by a first SPF model. Then, the CE results were used to make simulations on the variation of the same primary data through the Monte Carlo approach and by using Oracle Crystal Ball. Hence, a second SPF model was performed.

3.3.3 The model

The SPF (Aigner et al., 1977; Meeusen and van den Broeck, 1977; Coelli,1996; Coelli et al., 1998; Kumbhakar et al., 1989; Bauer, 1990) allows to calculate the profit efficiency of farms, defined as the ability to achieve the highest possible profit given the prices and levels of fixed factors (Ali and Flinn, 1989). Besides, it converts any error of the production choice into lower profits (Ali and Flinn, 1989; Wang et al., 1996). In formal terms, a SPF is a combination of two models. The first one is a profit function (Kumbhakar et al., 2015) which models the relationship between profit and several productive costs. For the *i*th farm, and using a Cobb–Douglas stochastic frontier, the econometric formula can be written as:

$$\ln \pi_i = \alpha_0 + \sum_{j=1}^{J} \alpha_j \ln x_{ij} + v_i - u_i \quad [5]$$

where the dependent variable ϖ_i is the annual profit of the i*th* farm, x_i's are the costs of inputs, namely irrigation water, pesticides, fertilizers, labour, fuel and power, α_0 and α_j are the unknown coefficients to be estimated. The error component v_i is assumed to be identically and independently distributed (i.i.d.) as N(0, σ^2_v), while u_i is a nonnegative, unobservable random variable that captures the technical inefficiency of the observations and is assumed to be distributed independently of the normally distributed error term v_i. In the study, the annual profit (€/ha) was calculated as value of the saleable production minus explicit costs (€/ha), these last referred to the aforesaid inputs.

The second model concerns profit inefficiency and investigates the farm-specific characteristics which cause inefficiency. It is expressed as:

$$u_i = \delta_0 + \sum_{m=1}^{M} \delta_m z_{mi} + \omega_i \qquad [6]$$

where z_i's are the explanatory variables that are thought to be the cause of inefficiency, δ_0 and δ_m are the unknown coefficients to be estimated and ω_i is the unobservable random error assumed to be independently distributed with a positive, half-normal distribution.

The independent variables thought to be the cause of inefficiency were obtained by both the CE and the SPF questionnaires, namely sex, age, years of schooling, family members employed in agriculture, living in urban centres, farm size, number of farm plots, irrigation water used on farm (m^3/ha).

The parameters of the two profit functions were estimated simultaneously by the maximum likelihood procedure in Frontier 4.1[3], developed by Coelli (1996). The fitting of the models was tested through the statistics σ^2, γ and γ^*. In particular, the first one indicates the presence of inefficiency affecting the profit of farms, the second one indicates the level of inefficiency on farms and ranges from zero (no inefficiency) to one (maximum inefficiency) (Battese and Coelli, 1995). The third statistics (Coelli et al., 1998) measures the differences of efficiency between the considered farms and the maximum frontier. Finally, the technical efficiency (TE_i) of the i*th* farm was obtained by the predictor:

$$TE_i = E\left[\exp\left(-u_i\right) | \varepsilon_i\right] = E\left[\exp\left(-\delta_0 - \sum_{m=1}^{M} \delta_m z_{mi}\right) | \varepsilon_i\right] \quad \text{where} \quad \varepsilon_i = v_i - u_i \qquad [7]$$

where E is the expectation operator. The technical efficiency of farms is between zero and one and it is inversely related to the inefficiency effect.

4 Results

4.1 Characteristics of the samples

A total of 287 and 262 complete and coherent questionnaires were collected through the CE and the SPF surveys, respectively. Incomplete choice tasks, pro-

[3] http://www.uq.edu.au/economics/cepa/frontier.php.

test responses or aversion in providing economic farm data led to discard some questionnaires (13 for the CE and 38 for the SPF). The sampled farms were characterized by the tendone plant covered by plastic films and the varieties cultivated were: Italia, Red Globe and Victoria, among those with seed; Thompson and Crimson, among the seedless ones. All farms used micro-irrigation system in order to improve the efficiency of water resource. Noteworthy was the high degree of land fragmentation.

Table 8 shows that the CE sample was mainly constituted by 43-years-old male farmers with a high school degree, living within urban centres and with just 1 family member employed in agriculture. The SPF sample, instead, was made up of 3-hectares farms, divided into 3 plots. The value of saleable production was 16,000 €/ha and the incidence of costs was 33%. Finally, the irrigation water used in vineyards was 1,650 m^3/ha, higher than the average of the area, i.e. 1,444 m^3/ha (Istat, 2010).

4.2 CE results

The first section of the questionnaire, concerning some issues related to the use of groundwater (Table 9), highlighted that respondents were aware of the

Table 8. Characteristics of the survey samples.

Variable	N.	Average	Std. dev.	Min.	Max.
CE questionnaire					
Male	287	0.86	0.14	0	1
Age	287	43.13	7.11	21	68
Years of schooling	287	10.25	4.71	5	18
Family members employed in agriculture	287	0.88	0.62	0	3
Living in urban centre	287	0.92	0.10	0	1
SPF questionnaire					
Farm size (ha)	262	3.12	0.51	0.95	28
N. farm plots	262	3.32	0.84	1	6
Production value (€/ha)	262	15,957.24	1,034.10	10,580.60	17,416.29
Fertilizers cost (€/ha)	262	267.11	27.13	181	307
Pesticides cost (€/ha)	262	774.62	105.59	623.88	889.10
Power cost (€/ha)	262	572.00	86.12	469.30	702.66
Labour cost (€/ha)	262	3,370.38	288.70	2,493.48	5,581.92
Fuel cost (€/ha)	262	255.94	39.60	195.14	477.19
Irrigation water (m^3/ha)	262	1,646.13	378	1,223	2,332

Table 9. Opinions of farmers on some issues concerning the preservation of groundwater.

Below you find several statements concerning the use of groundwater for irrigation purposes. Using a 1-5 scale, please indicate your agreement level (1 = I fully disagree; 5 = I fully agree).	Average
Modern agriculture is causing serious damages to groundwater.	4.4
The use of private farm wells does not cause damages to groundwater.	2.1
The Common Agricultural Policy must allocate funds for a better management of groundwater in agriculture.	3.2
Institutions should extent the consortium irrigation networks in Apulia.	4.8
Groundwater is a renewable resource, therefore its bad quality is not an issue for agriculture.	2.2
The preservation of groundwater quality is an important objective for agriculture, avoiding salinization of aquifers and desertification.	4.6

negative consequences from the over-exploitation of the resource and recognized that modern agriculture was playing an important role thereupon, putting at risk the quality of groundwater and its future use. At the same time, most of respondents believed that the regional consortium irrigation network need expansion, ensuring effectiveness and efficiency of supply.

To detect possible sources of heterogeneity and to understand how these last can affect results, respondents were classified according to their attitude towards the preservation of groundwater. In particular, a simplified version of the attitudinal scale of Choi et al. (2007) was carried out in order to group the statements of table 9 into 3 latent variables: awareness about the groundwater value (*GroundVal*); awareness about the worsening of groundwater quality (*GroundWors*); awareness about the need to preserve groundwater quality (*GroundPreserv*). Therefore, a hierarchical cluster analysis was carried out through the Ward method, since characterized by a better fitting compared to other ones. On the detected three groups (Table 10), the first one (*LessGroundwater*) represented 27.5% of the sample (n=79), and the respondents showed a lower sensitivity towards environmental themes concerning groundwater and the need to preserve it, so that the values given to the statements were sensibly lower than the average. The second group (*MoreGroundwater*) represented 57.5% of the sample (n=165) and the values given by the respondents were sensibly higher than the average. The third group (*IndifGroundwater*) consisted of 15.0% of the sample (n=43) and the values assigned were close to the average.

In order to characterize the detected groups, three binary logit models were carried out, by which respondents were correlated with some socioeconomic and farm variables. The analysis (Table 11) pointed out a good fitting of the models. In particular, the farmers with a lower attitude towards groundwater preservation (LessGroundwater) were characterized by older age and lower levels of schooling,

Table 10. Groups of respondents based on their attitudes towards the preservation of groundwater (standard deviation in brackets).

Cluster	N.	%	Average		
			GroundVal	GroundWors	GroundPreserv
LessGroundwater	79	27.5	3.25 (0.50)	1.76 (0.26)	1.58 (0.22)
MoreGroundwater	165	57.5	4.71 (0.14)	4.47 (0.23)	4.82 (0.16)
IndifGroundwater	43	15.0	2.25 (0.36)	2.40 (0.27)	2.54 (0.41)
Total	**287**	100.0	3.40 (0.56)	2.88 (0.67)	2.98 (0.49)

production value and farm size, as well as by higher groundwater use. On the contrary, the farmers with a higher environmental awareness (MoreGroundwater) had substantially opposite characteristics. Finally, the indifferent respondents (IndifGroundwater) showed intermediate characteristics: older age and higher levels of schooling, production value and groundwater use. However, the fitting of this last model was less robust, as shown by the low pseudo-R^2 and the small significance of the explanatory variables.

The attitudinal and characterization analyses showed the presence of heterogeneity among respondents, therefore a RPLM was employed (Table 12) jointly with a CLM for exploration purposes. About the RPLM, the choice of the random parameters, based on Hensher et al. (2015), was effected considering the significance of the standard deviations obtained by different RPLMs based on various sets of parameters (Vecchiato and Tempesta, 2013). Moreover, a triangular distribution was set for the dummy variables (use of wastewater, sponsorship of the PGI brand and technical support), while a normal distribution was set for the remaining attributes (supply of irrigation water and reduction of the IRPEF tax). Besides, the interaction between attributes and attitudinal variables (LessGroundwater and MoreGroundwater) was inspected.

The results pointed out a high significance of the considered attributes, but also a strong difference of their respective levels among the respondents. In particular, the main preference of wine growers was related to the extension of the consortium network and to the closing of their farm wells, but only if a supply of 2,000 m^3/ha/year was guaranteed. On the contrary, a supply of only 1,000 m^3/ha/year, as well as the injection of treated wastewater into the consortium network, were not considered as valid options (negative sign of the respective coefficients). In this connection, the first option was rejected since the water supply of only 1,000 m^3/ha/year was lower than the regional demand for this crop, namely 1,500-2,000 m^3/ha/year, while the second option was not considered probably due to the strong uncertainty related to both the use of treated wastewater in agriculture and the un-

Table 11. Logit results from the characterization analysis.

Variable	LessGroundwater		MoreGroundwater		IndifGroundwater	
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio
Age	0.044	5.22 ***	-0.082	-5.12***	0.102	3.01***
Years of schooling	-0.812	-2.01*	0.681	1.97*	0.005	2.04*
Production value (€/ha)	-0.093	-2.86***	0.010	2.90***	0.438	2.02*
Farm size (ha)	-0.320	-3.13***	0.024	3.20***	1.447	1.33 -
Irrigation water (m^3/ha/year)	1.157	3.88***	-0.315	-2.39**	0.558	2.02*
Constant	1.033	2.61**	1.341	4.15***	-2.103	-1.92 -
Obs.	79		165		43	
Pseudo-R^2	0.19		0.31		0.11	

certain dynamics related to the management of the depuration sector. The sponsorship of the PGI brand and the setting up of a technical assistance network for the improvement of the effectiveness and efficiency in the use of groundwater were considered as positive actions. On the contrary, the reduction of the IRPEF tax of 10%, and above all of 20%, was rejected probably due to the lack of trust towards politics. Finally, the sign of the payment variable was in line with expectations (i.e. negative), to indicate a decrease of the WTP with the increase of the annual rate. On the significant interactions between the random parameters and the characterization variables (only MoreGroundwater), the coefficients had the expected signs. Therefore, the choice including a water supply of 2,000 m^3/ha/year by the consortium network jointly with the closing of the private wells, the sponsorship of the PGI brand by the regional institutions and the setting up of a technical assistance network based on the precision agriculture and aimed at the saving of groundwater was mainly preferred by younger wine growers characterized by larger farms, greater production value, higher schooling and lower use of groundwater.

The WTPs related to the significant and positive attributes/levels were calculated (Table 13), so that for the aforesaid set of measures farmers were willing to pay a total rate of € 0.25/m^3, i.e. 412 €/ha. On the contrary, where the consortium service is available, farmers pay a binary rate of 31 €/ha as fixed fee and 0.31 €/m^3 as variable fee depending on use.

4.3 SPF results

Obtained the primary economic data related to the ex-ante situation, a first SPF model was performed (Table 14). Then, variations of the primary data were simulated and based on the following assumptions derived from the CE results:

- increase of the saleable production value between 10% and 20% consequently to the sponsorship of the PGI brand by the regional institutions, as emerged from a focus group constituted by farmers and retailers;

Table 12. CLM and RPLM results.

	CLM		RPLM	
	Coeff.	t-ratio	Coeff.	t-ratio
Non-random parameters				
ASC	-1.033	-5.61***	-1.430	-5.81***
Irrigation water by consortium network - 1,000 m^3/ha/year	-0.551	-5.18***	-0.682	-3.35***
Irrigation water by consortium network - 2,000 m^3/ha/year	1.877	6.37***		
Use of treated wastewater	-1.101	-5.22***	-0.911	-6.18***
Sponsorship of the PGI brand	1.641	8.11***		
Technical assistance	0.723	2.79***		
Reduction tax of 10%	-0.214	-3.66***	-0.372	-5.38***
Reduction tax of 20%	-0.558	-2.16**	-0.481	-3.21***
Payment of the annual rate (€/m^3/year)	-15.227	-8.14***	-8.411	-8.60***
Random parameters				
Irrigation water by consortium network - 2,000 m^3/ha/year			1.202	4.26***
Sponsorship of the PGI brand			0.925	3.17***
Technical support			0.436	5.93***
Std. Dev. of random parameters distributions				
Irrigation water by consortium network - 2,000 m^3/ha/year			0.009	5.21***
Sponsorship of the PGI brand			0.071	4.89***
Technical support			0.032	4.55***
Interaction (observed heterogeneity)				
Irrigation water 2,000 m^3/ha/year: MoreGroundwater			1.311	6.65***
Sponsorship of the PGI brand: MoreGroundwater			0.698	4.27***
Technical support: MoreGroundwater			0.720	5.48***
Obs.	1,435		1,435	
LL	-2,437.01		-1,432.81	
AIC	1,140		815	
BIC	1,179		807	
McFadden pseudo-R^2	0.25		0.44	

***: sign. 1%; **: sign. 5%; *: sign. 10%.

- reduction of the irrigation cost, which in the ex-ante situation is the sum between the power cost (572 €/year) and the depreciation cost related to the well and the electric pump, namely 1,220 €/year, assuming a technical duration of 20 years. In particular, the depreciation cost was calculated by adding up the drilling and

Table 13. WTPs related to the significant and positive attributes/levels of the RPLM (standard error in brackets).

Attribute/Level	WTP (€/m^3)	WTP* (€/ha)
Irrigation water by consortium network, 2,000 m^3/ha/year	0.12 (0.005)	198
Sponsorship of the PGI brand	0.09 (0.009)	148
Technical assistance for saving groundwater	0.04 (0.007)	66
Total	0.25	412

* Based on the irrigation water used on average by the respondents (1,650 m^3/ha).

coating costs of a 150 m deep-well and the cost of the electric pump (on average 16,500 €), values obtained from four drilling firms in the area. In the ex-post situation, instead, the irrigation cost is 0.25 €/m^3/year, or 412 €/ha/year;

- a further reduction of the irrigation cost by means of the technical assistance network aimed at the reduction of the irrigation water used by farms. In this case, through tensiometric analyses and the measurements of the intensity of chlorophyll pigmentation, an 8.6%-17.0% (on average 12.8%) saving of irrigation water was gained on a sample of ten vineyards, so that the new estimated water demand was 1,435 m^3/ha, with a cost of 359 €/ha (-53 €/ha compared to the ex-ante demand).

The SPF analysis highlighted a good fitting of the models (Table 14). Indeed, for both samples, the statistics σ^2 and γ were different from zero, indicating that the variation of profit in the farms was related to the presence of inefficiency, also confirmed by the rejection of the null hypothesis. In addition, the variance ratio γ^* implied that at least 59-72% of the profit difference between each farm and the maximum profit on the frontier was due to farm inefficiency. About the SPF models, an increase of all input costs caused a decrease of profit in the ex-ante situation, but, by implementing the measures chosen by farmers, the reduction of profit was only related to the increase of the labour and fuel costs. On inefficiency, in the ex-ante situation it was inversely related to the schooling of farmer and to the number of family members employed in agriculture, while it was directly related to the age of farmer, number of plots, farm size and irrigation water used in farm. In the ex-post situation, instead, also the last two variables contributed to the decrease of inefficiency. In other terms, by implementing the preservation measures chosen by the CE survey, younger farmers with higher schooling, assisted by family members and operating in larger farms (so that scale economies are exploited) were able to achieve the highest values of efficiency, with an average increase in farm efficiency of 14.1% (Table 15). Hence, these results highlighted the validity of the chosen attributes on the economic performance of the farms.

Table 14. SPF results.

Variable	Ex-ante		Ex-post	
	Coeff.	t-ratio	Coeff.	t-ratio
Profit function model				
Constant	7.339	9.25***	5.106	7.66***
Fertilizers cost	-0.183	-2.72**	0.158	6.92***
Pesticides cost	-0.252	-4.77***	0.222	4.13***
Power cost	-0.168	-6.45***	0.117	4.25***
Labour cost	-0.362	-5.18***	-0.270	-2.42**
Fuel cost	-0.155	-2.31**	-0.146	-2.73**
Profit inefficiency model				
Constant	-3.241	-3.70***	-2.748	-2.98***
Age	1.660	-2.61**	2.447	-3.27***
Years of schooling	-0.704	-2.25**	-0.682	-2.55**
Family members in agriculture	-1.559	-2.37**	-2.371	-5.91***
Farm plots	2.420	2.76**	1.429	2.37**
Farm size	4.732	3.05***	-3.187	-3.26***
Irrigation water	2.410	2.64**	-2.920	-3.73***
Model fitting				
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.085	7.32***	0.092	5.24***
$\gamma = \sigma_u^2 / \sigma^2$	0.875	4.98***	0.797	5.86***
γ^*	0.718		0.588	
Log likelihood function	97.40		112.80	
H_0: no inefficiency in the profit function (p-value)	0.004		0.007	
Obs.	262		262	

***: sign. 1%; **: sign. 5%; *: sign. 10%.

$\gamma^* = \gamma / \left[\gamma + (1-\gamma)\pi / (\pi - 2)\right]$ (Coelli et al., 1998)

Table 15. Farm inefficiency in the samples.

Variable	Ex-ante	Ex-post
Mean	81.4	95.5
Std. dev.	0.13	0.15
Min.	72.1	82.5
Max.	86.9	98.6

However, the suggested irrigation measures did not relieve the negative impact of land fragmentation, so that further specific actions were desirable in this ambit. Finally, considering the new potential water demand of 1,435 m^3/ha/year in the investigated area (4,324 ha), a price policy based on the payment of 0.25 €/m^3 by wine growers can generate a yield of taxation of 1,550,000 €/year, usable for the extension and modernization of the regional consortium network (including the reservoirs), the sponsorship of the PGI brand and the management of the technical assistance network. Besides, this gain could be considered in broader valuation contexts, such as the cost-benefit analysis.

5. Discussion of results and conclusions

The results allowed to make interesting considerations on the methodological approach used for the identification of a set of measures aimed at the preservation of groundwater in agriculture. The study highlighted the importance given to the resource by farmers, so that the option of closing their own wells can also be considered by a local water policy in the studied area, but provided that a set of services is assured in return. In particular, farmers are willing to pay 0.12 €/m^3 for a safe supply of 2,000 m^3/ha by the consortium network, jointly with the closing of wells. These findings are in line with other results in literature, for which costs usually are 0.02-0.30 US$/$m^3$, depending on country and aquifer (Lopez-Gunn et al., 2011), while other scholars found that the economic cost (value) of groundwater was 0.20-0.30 US$/$m^3$ (Shah et al. 2007). Besides, in this study, the total annual payment could increase up to 0.25 €/m^3 in the presence of other services supplied by the regional institutions, such as the sponsorship of the PGI brand for the table grapes and the setting up of a technical assistance network based on the precision agriculture and aimed at the saving of groundwater during the irrigation practice. However, this study points out a different attitude of the regional farmers compared to the Hispanic ones (Alcon et al., 2014); in particular, these last were willing to pay 0.35 €/m^3 for guaranteed water supply, but without considering new policy changes that could even require participatory efforts. On the contrary, Apulian farmers were willing to renounce a relatively secure water source (wells) in order to contribute to the resource preservation.

The preference of farmers for technical assistance indicates the need of support in the local wine growing. Indeed, this solution could allow an interesting water saving in a region where this resource is a limiting factor in agriculture. The application of the precision-agriculture technique carried out in this study could stabilize yield and farm income, making possible long-term economic planning (Geerts and Raes, 2009). However, such an approach requires additional and considerable expertise, information and instruments, so that institutional support is necessary. Another important aspect concerns the selected PGI attribute, which represents an important policy instrument to preserve agricultural products based on geographical factors and/or human local expertise, favouring the improvement of the economic results of farms. Sponsorship covers a crucial role of the brand strategy, so that farmers, also in this case, requested an institutional support in order to facilitate the spread of the regional PGI on the national and international market. Finally, an important aspect was the involvement of local stakeholders in the setting up of a water policy so to contribute to its success. Indeed, this objective is also fostered by the EU directive, for which participatory and collaborative planning could significantly reduce conflicts, ensuring trust and better policy outcomes (Beierle and Konisky, 1999; Mohanty and Tandon, 2006). On the whole, the wine growers of the area are aware of the importance of the water resource, are willing to contribute for its preservation by closing their wells and paying an annual rate for the use of the consortium network, and have a good knowledge of the business strategies for the improvement of their farm profit, being able to pay also a surtax in order to ensure additional services.

According to the EU directive, the different conditions within the Community territory need specific solutions, so that the planning and implementation of *ad hoc* measures able to resolve the particular issues of the single sites concerning the use and/or the pollution of groundwater is desirable (Giannoccaro et al., 2016; Giannoccaro et al., 2015), also with reference to climate change (Boatto et al., 2017). In addition, the success of the directive depends on information, consultation and participation of community and, above all, of end users. The joint use of the CE, bent on the selection of suitable attributes by farmers, and of the SPF, for the verification of the economic impact of the CE attributes on farm performance, may be a valid methodological approach to support the economic analysis introduced by the art. 9 of the EU directive in the agricultural sector. It makes possible long-term forecasts concerning water supply and demand in the specific river basin district, the estimation of consumption, prices and costs regarding water services and the assessment of investment and related forecasts (annex III of UE directive). This information allows the valuation of water pricing policies, the implementation of cost-benefit analyses of water supply investments and the determination of the optimal water allocation between different users (Storm et al. 2011). Besides, studying the effects of a water price policy on the economic performances of farms identifies the best agricultural practices and structural strategies for groundwater preservation.

Bibliografy

Adamowicz W., Boxall P., Williams M., Louviere J. (1998). Stated preference approaches for measuring passive use values: choice experiments and contingent valuation. *American Journal of Agricultural Economics* 80: 64-75.

Adamowicz W., Louviere J., Williams M. (1994). Combining revealed and stated preferences methods for valuing environmental amenities. *Journal of Environmental Economics and Management* 26: 271-292.

Aigner D.J., Lovell C.A.K., Schmidt P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6: 21–37.

Alcon F., Tapsuwan S., Brouwer R., de Miguel M.D. (2014). Adoption of irrigation water policies to guarantee water supply: a choice experiment. *Environmental Science & Policy* 44: 226-236.

Ali M., Flinn J.C. (1989). Profit efficiency among Basmati rice producers in Pakistan Punjab. *American Journal of Agricultural Economics* 71: 303-310.
ANBI (2009). Relazione annuale.
Basu N.B., Van Meter K. (2014). Sustainability of groundwater resources. *Earth Systems & Environmental Sciences* 4: 57-75.
Battese G.E., Coelli T.J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20: 325-332.
Bauer P.W. (1990). Recent developments in the econometric estimation of frontiers. *Journal of Econometrics* 46: 39-56.
Beierle T., Konisky D. (1999). *Public participation in environmental planning in the Great Lakes region*. Resources for the Future.
Ben-Akiva M., Lerman S. (1985). *Discrete Choice Analysis*. Cambridge, MA, The MIT Press.
Bergkamp G., Cross K. (2007). Groundwater and ecosystem services: options for their sustainable use. In: Ragone S., de la Hera A., Hernandez-Mora N., Bergkamp G., McKay J. (eds.), *Global Importance of Groundwater in the 21st Century: The International Symposium in Groundwater Sustainability*, pp. 233-246. Alicante, Spain, 24-27 January 2006. Westerville, OH: National Groundwater Association Press.
Boatto V., Barisan L., Teo G. (2017). Valutazione della risorsa irrigua di soccorso nella produzione del Conegliano Valdobbiadene Prosecco DOCG. *Aestimum* 70: 31-49.
Carr G., Potter R.B., Nortcliff S. (2011). Water reuse for irrigation in Jordan. Perceptions of water quality among farmers. *Agricultural Water Management* 98: 847-854.
Choi A.S., Papandrea F., Bennett J. (2007). Assessing cultural values: developing an attitudinal scale. *Journal of Cultural Economics* 31: 311-335.
Coelli T.J. (1996). *A guide to FRONTIER Version 4.1: a computer program for stochastic frontier production and cost function estimation*. Working Paper, Centre for Efficiency and Productivity Analysis, University of New England, Armidale.
Coelli T.J., Rao D.S.P., Battese G.E. (1998). *An introduction to efficiency and productivity analysis*. Kluwer Academic Publishers, Boston.
Dinar A., Mody J. (2004). Irrigation water management policies: allocation and pricing principles and implementation experience. *Natural Resources Forum* 28: 112-122.
Distretto Idrografico dell'Appennino Meridionale (2010). *Piano di Gestione Acque (Direttiva Comunitaria 2000/60/CE, D.Lvo. 152/06, L. 13/09)*.
Fabiani S. (a cura di) (2009). *Aspetti economici dell'agricoltura irrigua in Puglia*. Istituto Nazionale di Economia Agraria, Roma.
Fornés J.M., De la Hera A., Llamas M.R. (2005). The silent revolution in groundwater intensive use and its influence in Spain. *Water Policy* 7: 253-268.
Geerts S., Raes D. (2009). Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management* 96: 1275-1284.
Giannoccaro G., Castillo M., Berbel J. (2015). An assessment of farmers' willingness to participate in water trading in southern Spain. *Water Policy* 17: 520-537.
Giannoccaro G., Goduto B., Prosperi M., de Gennaro B.C. (2016). Il metodo del prezzo edonico per la stima del valore della risorsa idrica. Un'applicazione empirica nell'area irrigua della capitanata (Puglia). *Aestimum* 68: 29-44.
Grant O.M., Tronina L., Jones H.G., Chaves M.M. (2007). Exploring thermal imaging variables for the detection of stress responses in grapevine under different irrigation regimes. *Journal of Experimental Botany* 58: 815-825.
Griffiths M. (2002). *The European Water Framework Directive: an approach to integrated river basin management*, European Water Management Online. http://www.ewa-online.eu/tl_files/_media/content/documents_pdf/Publications/E-WAter/documents/85_2002_05.pdf (Accessed August 2017).
Hensher D.A., Rose J.M., Greene W.H. (2015). *Applied Choice Analysis, 2nd edition*. Cambridge University Press, Cambridge.

Idda L., Furesi R., Pulina P. (2010). *Economia dell'allevamento ovino da latte. Produzione, trasformazione, mercato*. Franco Angeli.
Istat (2010). *6° Censimento Generale dell'Agricoltura*. http://www.istat.it/it/censimento-agricoltura/agricoltura-2010.
Krishna V.V., Drucker A.G., Pascual U., Raghu P.T., King E.D.I.O. (2013). Estimating compensation payments for on-farm conservation of agricultural biodiversity in developing countries. *Ecological Economics* 87: 110-123.
Kumbhakar S.C., Wang H.J., Horncastle A.P. (2015). *A practitioner's guide to stochastic frontier analysis using Stata*. Cambridge University Press.
Lancaster K. (1966). A new approach to consumer theory. *Journal of political Economy* 74: 132-157.
Lopez-Gunn E., Llamas M.R., Garrido A., Sanz D. (2011). Groundwater management. *Treatise on Water Science* 1: 97-127.
Louviere J.J., Hensher D.A., Swait J.D. (2000). *Stated Choice Methods: Analysis and Applications*. Cambridge University Press, Cambridge.
Louviere J.J., Woodworth G. (1983). Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data. *Journal of Marketing Research* 20: 350-367.
Margat J. (2008). *Les Eaux Souterraines dans le Monde*, 178 pp. Orleans: BRGM éditions.
Martín P., Zarco-Tejada P., González M.R., Berjon A. (2007). Using hyperspectral remote sensing to map grape quality in "Tempranillo" vineyards affected by iron deficiency chlorosis. *Vitis* 46: 7-14.
Martín-Ortega J. (2012). Economic prescriptions and policy applications in the implementation of the European Water Framework Directive. *Environmental Science & Policy* 24: 83-91.
McFadden N. (1974). Conditional logit analysis of qualitative choice behaviour. In: Zarembka P. (ed.), *Frontiers in Econometrics*. Academic Press, New York.
Meeusen W., van den Broeck J. (1977). Efficiency estimation from Cobb–Douglas production functions with composed error. *International Economic Review* 18: 435-444.
Mohanty R., Tandon R. (2006). *Participatory citizenship: identity, exclusion, inclusion*. Sage Publications, Thousands Oaks, New Delhi, California.
Nino P., Vanino S. (a cura di) (2009). *Uso del suolo e stima dei fabbisogni irrigui nelle aree non servite da reti collettive dei consorzi di bonifica nelle regioni meridionali*. Istituto Nazionale di Economia Agraria, Roma.
Provins A., Pearce D., Ozdemiroglu E., Mourato S., Morse-Jones S. (2008). Valuation of the historic environment: the scope for using economic valuation evidence in the appraisal of heritage-related projects. *Progress in Planning* 69: 131-175.
Sardaro R., Girone S., Acciani C., Bozzo F., Petrontino A., Fucilli V. (2016). Agro-biodiversity of Mediterranean crops: farmers' preferences in support of a conservation programme for olive landraces. *Biological Conservation* 201: 210-219.
Sardaro R., Pieragostini E., Rubino G., Petazzi F. (2017). Impact of Mycobacterium avium subspecies paratuberculosis on profit efficiency in semi-extensive dairy sheep and goat farms of Apulia, southern Italy. *Preventive Veterinary Medicine* 136: 56-64.
Shah T., Burke J., Villholth K. et al. (2007). Groundwater: a global assessment of scale and significance. In: Molden D. (ed.), *Water for Food, Water for Life: Comprehensive Assessment of Water Management in Agriculture*, pp. 395-423. London: Earthscan.
Storm U., Heckelei T., Heidecke C. (2011). Estimating irrigation water demand in the Moroccan Drâa Valley using contingent valuation. *Journal of Environmental Management* 92: 2803-2809.
Train K.E. (2009). *Discrete choice methods with simulation, 2nd edition*. Cambridge University Press, Cambridge.
Tsur Y. (2005). Economic aspects of irrigation water pricing. *Canadian Water Resources Journal* 30: 31–46.
Tuinstra J., van Wensem J. (2014). Ecosystem services in sustainable groundwater management. *Science of the Total Environment* 485-486: 798-803.

Turner R.K., Georgiou S., Clarke R., Brouwer R. (2004). *Economic valuation of water resources in agriculture. From the sectoral to a functional perspective of natural resource management*. FAO Water Report 27, FAO, Rome.
Vecchiato D., Tempesta T. (2013). Valuing the benefits of an afforestation project in a peri-urban area with choice experiments. *Forest Policy and Economics* 26: 111-120.
Wang J., Cramer G.L., Wailes E.J. (1996). Production efficiency in Chinese agriculture: evidence from rural household survey data. *Agricultural Economics* 15: 17-28.
Weller P., Oehlmann M., Mariel P., Meyerhoff J. (2014). Stated and inferred attribute non-attendance in a design of designs approach. *Journal of Choice Modelling* 11: 43-56.