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Evaluation of water management policies in agriculture by measuring the efficiency of different irrigation supply systems

Abstract: *The study aims to furnish insights on the use of new impact indexes for ex-post evaluations in the framework of the post-2020 CAP. In particular, concerning water policies, the use of economic efficiency is considered and applied to three irrigation supply systems in winegrowing farms of northern Apulia, southern Italy. Results make it possible to investigate whether and how different irrigation supply systems interact with the management of productive factors and inputs, so as to understand complex and wider impacts of policies on costs and revenues of farms in the short and long run.*
Economic efficiency, used as impact index, can provide useful information for assessing the multiannual performance in several post-2020 CAP contexts and in connection to the related specific objectives. In particular, this index could be applied to assess the policy performance on farm scale in connection to the supporting of viable farm income; to the enhancement of market orientation and competitiveness; to the improvement of farmers' position in the value chain; to the adoption of climate change mitigation and adaptation measures; to the preservation of natural resources; to the employment of young farmers; to the development of rural areas; to the improvement of agricultural response to community demands on food, health and animal welfare.

Keywords: *policy evaluation; ex-post evaluation; impact indicator; economic efficiency; southern Italy*

Introduction

Historically, the water resources' management was alien to the CAP. The theme began to be present in the 2007-2013 programming period within the Rural Development Programs (Axis II) and was limited to the qualitative protection of water. Even the EU Water Framework Directive of 2000 focused only on the qualitative state of water. In the Commission Communication of 2007 on the Water Deficiency, the theme concerning the water price policy was introduced to encourage the efficient use of the resource (De Filippis and Zucaro, 2019). In the 2014-2020 programming period, the protection of water resource is one of the priority challenges for sustainable development, both in terms of quality (i.e. protection from pollution) and quantity (i.e. more efficient use of the resource). In Italy, the sustainable use of water is a strategic priority of the 21 regional RDPs and in the National RDP (De Filippis and Zucaro, 2019). In this context, the rational use of water resources is a strategic tool for pursuing the economic and environmental sustainability of the agri-food sector. In view of the CAP 2021-2027, the importance of the impact and result indicators is not secondary in the management of the water resource, as well as the assessment of its total economic value (i.e. the sum of use and non-use values). The proposals on the new CAP confirm the structure based on two pillars, and report 3 general objectives articulated in 9 specific objectives that identify a less agricultural and more environmental and territorial CAP. In this framework, the water resource management increases its importance compared to the past, being explicitly mentioned in the specific objective 6 "Efficient management of natural resources such as water, soil and air" (De Filippis and Zucaro, 2019). The challenges of the future CAP concern its governance, with important new features concerning both the New Delivery Model (NDM), representing a shift from a compliance-based to a results-based governance system for CAP in terms of targets to be reached and indicators for evaluating achievements, both in the increasing autonomy of Member States in drafting a national strategic plan for a more flexible application of CAP in line with the national needs.

Agriculture is the economic sector that uses the greatest volumes of water, i.e. 85% of the total, so generating important impacts concerning the quality of produce, employment, environment, landscape, development of rural areas and food safety (La Sala, 2019). Italy is the second European country in terms of irrigated area, with 2.4 million hectares (ISTAT, 2010). The irrigation potentiality (irrigated area/irrigable area) and the propensity to irrigation (irrigated UAA/total UAA) are respectively 65.6% and 19.3% (ISTAT, 2010). About 35% of the water supply used by farms comes from groundwater, while the remaining share comes from the public water network that has an extension of over 210,000 km, though it is very fragmented and characterized by significant water losses (on average 40%) mainly concentrated in the southern regions.

Apulia, in southern Italy, is the fifth most important region in the country in terms of both irrigated area and water volumes used (ISTAT, 2010). The region has a utilized agricultural area (UAA) of over 1.28 million hectares, equal to 10% of the Italian total, of which over 238,000 ha are irrigated (18.6%) using over 655 million cubic meters of water. However, its irrigation sector is structurally weak due to low annual rainfall, as well as to small hydrographic network. Thus, irrigation water is supplied by private wells (on average 68%), which are managed by single or associated farmers and use groundwater, or through collective networks, which are managed by irrigation bodies, irrigation consortia and the Regional government (on average 21%) and use water from springs and reservoirs. In particular, the five irrigation consortia operating in Apulia manage more than 90% of the regional territory, but their equipped area is on average 11.5% of the managed area, while the irrigated area is 4.6% of the equipped area (Distretto Idrografico dell'Appennino meridionale, 2010; ANBI, 2009). Furthermore, the water supplied by these consortia is just 31% of the total water used (655 Mm^3/year) and 23% of estimated needs, i.e. 874 Mm^3/year (Nino and Vanino, 2009). Thus, private wells are the main source of irrigation water for the regional agricultural sector, though their overuse cause salinization of groundwater, worsening of quality of soils and crops, and desertification.

The setting of policies for reducing the use of private wells and increasing the use of collective network is crucial in Apulia. This goal could be reached through the enhancement, expansion and modernization of collective infrastructure (ANBI, 2009). In general, the effectiveness and efficiency of these improvements should be evaluated through context, output, result and impact indicators in the ex-ante and ex-post evaluations, also in line with the results-based governance system of the New Delivery Model (NDM) in the post-2020 CAP. Since these interventions cause impacts on farms, a useful index could be the economic efficiency, and the evaluation target could concern the measurement of the variation of economic efficiency of farms, consequently to the improvement of collective network and to the restrictions in using private well, also compared to other supply systems. Such approach allows a further integration of evaluation indicators and monitoring system for the pillars of the future CAP. In order to verify the suitability of such index for water policies, studies are needed in this field so as to investigate possible negative impacts on economic performance of farms consequently to the modification of the importance of the water supply systems made available to farms (Petrillo and Sardaro, 2014; Acciani and Sardaro, 2014).

Thus, the aim of the paper is the measurement of the economic efficiency of the irrigation water supply systems used by winegrowing farms located in northern Apulia. The results highlight the extent to which different sources of irrigation water influence the management of production factors and inputs, and can provide decision makers with the performance levels of policies for water management in agriculture.

Materials and methods

The study area

In Apulia, the Province of Foggia accounts for one third of the regional irrigated area and one third of the regional demand (ISTAT, 2010). Thus, in this province operates the largest irrigation consortium of Apulia, namely the "Consorzio per la Bonifica della Capitanata" (CBC). It includes 39 municipalities on a total agricultural area (TAA) of 442,000 ha and a utilized agricultural area (UAA) of 415,000 ha. The consortium, on average, supplies 113 million m3 of water during the period from April to November, namely 2,750 m3 ha-1 (ISTAT, 2010), considering an effective water availability of 326 million m3. The main irrigated crops are table and oil olives (9% of UAA), table and wine grapes (7% of UAA) and tomatoes (5 % of UAA).

Due to climatic (drought) and management (network leaks, illegal dumping and unlawful uses) factors, CBC often reduces or even suspends the water supply during the irrigation period, though farms cannot request a proper compensation. Consequently, most of farms use private wells, and the presence of both collective network and private well is a very common characteristic of the farms in the area.

The economic data

In order to investigate the impact of different water supply systems on economic efficiency, winegrowing farms for the production of wine grapes were investigated. Between October 2017 and February 2020, the authors of the paper collected economic data related to the period of 2014-2019 and concerning 152 winegrowing farms located in the CBC. The cultivated varieties were Montepulciano, Uva di Troia, Sangiovese, Lambrusco and Trebbiano.

The methodological approach used in this work and subsequently explained is based on the assessment of the production and efficiency functions. Concerning the estimation of production function, output consists of the produce value (wine grapes), while inputs are farm area, machinery value, number of working days, quantities of technical inputs (fertilizers, pesticides and irrigation water) and year (Table 1). Based on the literature (Bozoğlu and Ceyhan, 2007; Sardaro, Bozzo and Fucilli, 2018; Hansson and Öhlmér, 2008; Rahman, 2003; Tzouvelekas, Pantzios and Fotopoulos, 2001; Tan et al., 2010; Sardaro, Faccilongo and Roselli, 2019) and on the specific characteristics of this study, we also selected variables for the inefficiency function. In particular, farmer's age negatively affects technical innovation, so as to be directly related to inefficiency. Access to credit increases farm's ability to invest money, encouraging modernization and technical innovations, and making it possible to buy inputs, with positive effects on reducing inefficiency. The number of farm plots indicates the level of land fragmentation and is directly related to movement and surveillance costs, thus to inefficiency. The terrain slope has negative influence on mechanized operations and technological level of farm, so that it is directly related to inefficiency.

Finally, the main object of the study is the variable related to water supply systems of farms, i.e. private farm well, collective network and a combination of both. In this connection, the use of private well often allows more flexible irrigation, in terms of both watering frequency and water volumes used. However, the use of private well also entails various costs concerning: drilling of well and its progressive depreciation during its technological life, which lasts on average 25 years in the study area; installation of electric pump; ordinary and extraordinary maintenance; use of irrigation water, which in Apulia requires the payment of a five-year permit.

Table 1 – Economic and efficiency variables

Variables	Code	U.M.	Expected sign
Output			
Production	P	€/ha	
Inputs			
Farm area	L	ha	+
Machinery value	M	€/ha	+
Working days	WD	N./ha	+
Fertilizers	Fe	kg/ha	+
Pesticides	Pe	kg/ha	+
Irrigation water	IW	m3/ha	+
Year	Y	0-1	+/-
Determinants of the technical inefficiency			
Farmer age	Age	Years	+
Dummy = 1: Credit access during the period of 2014-2019	Credit	0-1	-
Number of plots	Plots	N.	+
Terrain slope	Slope	%	+
Dummy = 1: groundwater through private well	Well	0-1	+/-
Dummy = 1: irrigation water through collective network	Network	0-1	+/-
Dummy = 1: irrigation water through well and collective network	Well/Network	0-1	+/-

Source: authors' elaborations on data from direct survey.

Furthermore, and particularly in Apulia, the environmental impacts from using groundwater can cause salinization of aquifers and desertification. Conversely, collective network is less flexible since the use of water is subordinated to rotating shifts and to the payment of both a fixed fee for the ordinary maintenance of the network and a variable fee relating to consumption. In addition, as mentioned, collective network may have problems concerning malfunctioning or leaks, illegal water uses and low supply during dry years, meaning a decrease in water availability. Depending on crop and farming system, these aspects related to different supply systems could affect farm efficiency.

Data related to the variables used in the production and efficiency functions were obtained via a survey form used for face-to-face interviews to farmers. However, information about the terrain slope was taken through the Territorial Information System of the Apulia Region (http://www.sit.puglia.it/). The monetary variables were inflation-adjusted.

The economic model

The analysis was carried out through the production stochastic frontier (PSF) model applied to panel data (Aigner, Lovell and Schmidt, 1977; Meeusen and van den Broeck, 1977; Coelli, 1996; Coelli, Rao and Battese, 1998; Kumbhakar, Biswas and Bailey, 1989) in order to estimate the technical efficiency (TE) related to different irrigation water supply systems in the winegrowing farms of the study area. TE is defined as the farm's aptitude to achieve the maximum output through specific input levels (Ali and Flinn, 1989). In this study TE is output-oriented (Farrell, 1957), i.e. the ratio between the obtained output and the maximum possible output. In formal terms, the PSF was expressed as:

$$P_{it} = f\left(x_{it};\beta\right) + v_{it} - u_{it} \tag{1}$$

where P is the production obtained by the farm i in the year t (i = 1,2, ..., N and t = 1,2, ... T), x is the vector of production factors and inputs, and β is the $Jx1$ vector of the production function parameters. Concerning error, it can be decomposed into two terms, i.e. the symmetric v_{it}, which includes any measurement error or other factors beyond the farm control, and u_{it}, i.e. a non-negative asymmetric term relating to farm inefficiency. The first term is assumed independently and identically distributed (iid) with mean equal to zero and constant variance, so that $N(0, \sigma^2 v)$, while the second terms is also iid, but with half-normal distribution, so that $N^+(0, \sigma^2_u)$. The estimate of maximum likelihood (MLE) enables calculation of the vector of the parameters β, as well as the variance parameters, that is:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

and (2)

$$\gamma = \sigma_u^2 / \sigma^2$$

where γ is between zero (no technical inefficiency effect on the output variation) and one (the output variation is solely generated by the technical inefficiency) (Battese and Coelli, 1995). Hence, the level of TE for each farm can be calculated, according to Jondrow et al. (1982), as:

$$TE_{it} = \frac{P_{it}}{P^*} = \exp\left(-u_{it}\right) \tag{3}$$

where P^* is the output on the frontier. TE is between zero (no TE) and one (full TE) so that a value lower than one indicates that the present technological structure of the farm is inefficient, thus it is able to increase output without any variation of input. Finally, the inefficiency term u_{it} is defined as:

$$u_{it} = \delta_0 + \sum_m \delta_m z_{mit} + \omega_{it} \tag{4}$$

where z is the vector relating to the determinants of inefficiency, δ is the vector of the parameters to estimate, and ω is the unobservable random error that is assumed independently distributed with positive half-normal distribution, zero mean and variance σ^2. Noteworthy is the nonlinear relationship between $E(u_i)$ and the z variables, so that the slope coefficients are not marginal effects (ME). Instead, these can be calculated as:

$$ME = \frac{\partial E(u_i)}{\partial z_m} \tag{5}$$

Assuming a Cobb-Douglas function, the PSF was defined as:

$$\ln P_{it} = \beta_0 + \sum_j \beta_j \ln x_{ijt} + d_t + v_{it} - u_{it} \tag{6}$$

where, in addition to the previously defined components, d_t is the dummy variable referred to each year in which a variation of the production function could occur.

In order to integrate both the unobserved heterogeneity of farm production and the variation of inefficiency over time within the PSF model, the "True Random Effect" (TRE) model was used (Greene, 2004; Greene, 2005), which adds a stochastic iid term related to the farm i, namely w_i, so that:

$$\ln P_{it} = w_i + f\left(\ln x_{it}; \beta\right) + v_{it} - u_{it} \tag{7}$$

where the error component is defined as in the equation (1) and the parameters are estimated with the simulation of the maximum likelihood proposed by Greene (2005). The inefficiency term u_{it} is calculated so that $E[-u_{it} \mid w_i + \varepsilon_{it}]$, while the technical efficiency is assessed as in the equation (3).

The parameters of the production function and the inefficiency determinants were estimated simultaneously through the maximum likelihood (MLE) method according to Battese and Coelli (1993).

The fitting of the model was tested through the statistics γ (previously defined), σ^2, which indicates the inefficiency of the farm output, and γ^* (Coelli et al., 1998), which measures the differences between the inefficiency of the sampled farms and the inefficiency on the frontier. In addition, a number of hypotheses relating to some restrictions of the full model were verified:

i) H_0: $\gamma = \delta_0 = \delta_1 = \ldots = \delta_m$ (there are no determinants of technical inefficiency, so the sampled farms are fully efficient);

ii) H_0: δ_1; δ_2; δ_3; δ_4; δ_5; δ_6; δ_7; δ_8; δ_9; $\delta_{10} = 0$ (No effect on technical inefficiency by each determinant considered).

Checking used the Generalized likelihood-ratio test, which allowed the comparison between the implemented models and the restricted models based on the aforesaid hypotheses. The related statistic index is defined as:

$$-2\left[\ln L\left(H_0\right) - \ln L\left(H_1\right)\right] \tag{8}$$

where L(H_0) and L(H_1) are the likelihood values concerning the implemented model and the restricted models, respectively. The λ statistic can be approximated to a χ^2 distribution, with a number of degrees of freedom equal to the parameters affected by the restriction. Finally, the elasticity of production was calculated through the following equation:

$$\varepsilon_j = \frac{\partial \ln(P)}{\partial \ln(x_j)} = \beta_j + \sum_k \beta_{jk} \ln x_k \tag{9}$$

Results and discussions

Characteristics of the sampled farms

The distributions of farms and related areas per classes of UAA highlighted a good representativeness of the sample compared to the study area (Table 2). Furthermore, the descriptive statistics concerning the inefficiency variables (Table 3) pointed out that farms were managed by middle-age farmers that used sometimes financial credit for funding farm improvements. Properties were located in flat territories and were rather fragmented. Finally, the descriptive statistics concerning the irrigation systems pointed out the presence of private well and mixed supply (both well and network) in about 50% of the sampled farms.

Table 2 – Number of farms and related areas of the sample compared to the study area.

UAA class	Sample				Study area[a]			
	Farms	%	Area	%	Farms	%	Area	%
0-4.9	90	59.2	163.4	28.9	5,546	57.9	8,354.8	26.4
5-19.9	53	34.9	291.0	51.5	3,141	32.8	15,126.6	47.8
20-49.9	6	3.9	76.6	13.6	719	7.5	5,618.1	17.8
≥ 50	3	2.0	34.2	6.0	173	1.8	2,517.8	8.0
Total	152	100.0	565.1	100.0	9,579	100.0	31,617.3	100.0

[a] National Agricultural Census (ISTAT, 2010).

Source: authors' elaborations on data from direct survey.

Table 3 – Characteristics of the sampled farms, per study area (average values in the period of 2014-2019).

Variables	Use of the variable[a]	U.M.	Min.	Max.	Mean	S.D.
P (,000 €)	O	€/ha	6.29	13.51	11.04	9.66
L	I/In	ha	0.63	19.32	3.7	11.85
M (,000 €)	I/In	€/ha	5.01	14.66	8.24	9.39
WD	I/In	N./ha	37.73	57.41	49.25	51.17
Fe	I/In	kg/ha	336.88	658.22	432.70	372.84
Pe	I/In	kg/ha	12.85	17.96	14.59	16.32
IW	I/In	m^3/ha	1,326.51	3,181.80	2,142.80	2,361.08
Y	I	0-1	0	1	0.50	0.71
Age	In	Years	18	64	47.30	39.17
Credit	In	0-1	0	1	0.45	0.41
Plots	In	N.	1	6	3.26	3.72
Slope	In	%	0	2.52	1.26	0.20
Well	In	0-1	0	1	0.47	0.53
Network	In	0-1	0	1	0.26	0.30
No irrigation	In	0-1	0	1	0.05	0.05
Well/Network	In	0-1	0	1	0.22	0.34

[a] O = output variable of the production function; I = input variable of the production function; In = variable of the technical inefficiency.

Source: authors' elaborations on data from direct survey.

The hypotheses relating to the restrictions of the model showed that i) the use of determinants aimed at explaining technical inefficiency provided a sound analysis; ii) the determinants concerning farmer's age, credit access, land characteristics and types of water supply were able to explain the technical inefficiency of the sampled farms (Table 4). The only exception concerned the slope of terrain whose small values (Table 1) caused a scarce impact on technical inefficiency.

Table 4 – Hypotheses tests for restriction of the PSF model.

	Restrictions	λ	**d.f.**	$\chi^2_{0.95}$*	**Decision on H_0**
i)	H_0: $\gamma = \delta_0 = \delta_1 = \ldots = \delta_m$	23.78	11	17.67	Rejected
ii)	H_0: δ_1; δ_2; δ_3; δ_4; δ_5; δ_6; δ_7; δ_8; δ_9; $\delta_{10} = 0$	$5.87 < \lambda < 18.01$	1	2.71	Rejected, except for the Slope variable (λ=1.86)

*** Critic values from Kodde and Palm (1986).**

Source: authors' elaborations on data from direct survey.

Concerning the final model (Table 5), the variance parameters σ^2 and γ were significantly different from zero, indicating how technical inefficiency affected output. In particular, parameter γ was close to one, suggesting that the outcome variations were mainly caused by changes in inefficiency, or, in other terms, that the differences in technical inefficiency among farms were important in explaining the output variation of the winegrowing farms in the study area. Furthermore, γ^*, which best measures the effect of inefficiency on the total output variance, highlighted that 57% of the difference between the output of farms and the output assessed on the frontier was due to farm inefficiency.

Since the output and the regressors were quantified in logarithmic form, the PSF estimates were interpretable as elasticities of output. Thus, the results confirmed that output was positively influenced by the considered factors and inputs. In particular, irrigation water generated the most decisive impact, so that a 1% increase in the use of irrigation water generated an output increase of 1.81%. These findings were due to the pedoclimatic characteristics of Apulia, so that its Mediterranean climate and small hydrographic network create higher water demand for the irrigation of specific crops, such as grapes, tomatoes, etc.

Concerning inefficiency analysis (Table 5, Table 6), farms achieved an efficiency of 83% with their current technology. Thus, based on the output-oriented approach used in this study, these farms can achieve a 17% increase in output by using the current factors and inputs in a more efficient way.

Specifically, technical inefficiency can be reduced by favouring generational change, thus allowing innovative management strategies, while easier credit access could decrease inefficiency by enabling investments in innovations.

The number of plots was positively related to technical inefficiency and strongly connected to organizational and managerial difficulties (increased surveillance time and travel costs, need for different cultivation strategies according to the soil and climatic characteristics of each plot, etc.), while the terrain slope was not analysed due to the restrictions imposed on the model. The considered water supply systems generated important impacts in the study area since all the systems considered contributed to reduced inefficiency (Table 6). The most efficient source was private well, followed by the simultaneous presence of well and collective network and by the network alone. However, as water use increased, well further increased its efficiency, followed by the combination of well and collective network. The presence of collective network alone, instead, increased inefficiency. In other terms, collective network was the least efficient system, and even the most inefficient one in case of greater use of water.

Table 5 – Estimate of the PSF and TE parameters.

Variables	Param.	Coeff.	S.E.	
PSF model				
Constant	β_0	0.152	0.044	***
ln(L)	β_1	0.252	0.050	***
ln(M)	β_2	1.044	0.245	***
ln(WD)	β_3	0.326	0.067	***
ln(Fe)	β_4	1.515	0.233	***
ln(Pe)	β_5	0.372	0.114	***
ln(IW)	β_6	1.806	0.285	***
Y	β_7	0.208	0.081	**
Inefficiency model				
Constant	δ_0	0.269	0.050	***
Age	δ_1	0.078	0.033	**
Credit	δ_2	-0.056	0.021	**
Plots	δ_3	0.041	0.008	***
Slope	δ_4			-
Well	δ_5	-0.775	0.189	***
Network	δ_6	-0.497	0.094	***
Well/Network	δ_7	-0.693	0.141	***
Well x IW	δ_8	-1.504	0.345	***
Network x IW	δ_9	0.419	0.108	***
Well/Network x IW	δ_{10}	-0.838	0.161	***

cont. Table 5.

Variance parameters			
σ_u^2	0.116		
σ_v^2	0.032		
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.148	0.033	***
$\gamma = \sigma_u^2 / \sigma^2$	0.784	0.167	***
$\gamma^* = \gamma / \left[\gamma + (1-\gamma)\pi/(\pi-2)\right]$	0.568		
Log-likelihood	-515.26		
Farms	152		
Obs.	912		
Technical efficiency			
Mean	0.832		
Min.	0.609		
Max.	0.984		
S.D.	0.437		

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

Source: authors' elaborations on data from direct survey.

Table 6 – Marginal effects of the exogenous factors.

Determinants of inefficiency	Param.	Marginal effect on E(ui)	
Age	δ_1	0.031	
Credit	δ_2	-0.046	**
Plots	δ_3	0.063	***
Slope	δ_4	-	
Well	δ_5	-0.759	***
Network	δ_6	-0.263	***
Well/Network	δ_7	-0.618	***
Well x IW	δ_8	-1.111	***
Network x IW	δ_9	0.226	***
Well/Network x IW	δ_{10}	-0.835	***

*** Sign. 10%; ** Sign. 5%; *** Sign. 1%.**

Source: authors' elaborations on data from direct survey.

Regarding the elasticities of production (Table 7), the estimates indicated that fertilizers and irrigation water mainly affected economic performance so that an increase in output can be obtained mostly by levering on these inputs. In particular, *ceteris paribus*, a 1% increase in these factors gave a 0.29% and 0.33% rise in output, respectively. Therefore, winegrowing in the study area was rather elastic regarding the aforesaid inputs, thus allowing farmers to achieve significant improvements in management performance. Finally, the returns to scale showed that farms can obtain 17% more of production by an efficient use of their available resources.

Table 7 – Elasticity and returns to scale.

Inputs	Elasticity	S.D.
L	0.111	0.064
M	0.195	0.117
WD	0.145	0.082
Fe	0.295	0.210
Pe	0.093	0.027
IW	0.328	0.185
Returns to scale	*1.167*	*1.046*

Source: authors' elaborations on data from direct survey.

Discussion and conclusions

The results concerning the use of irrigation water by winegrowing farms in the CBC area highlighted the great importance of private wells, despite the serious environmental problems caused by exploitation of groundwater. Indeed, this supply system is almost free (except for a small fixed fee paid every five years) and allows to meet rapidly the water demand of crops. On the other hand, collective network is more expensive (a fixed fee of 15.50 euro ha^{-1} for ordinary network maintenance, in addition to 0.09-0.24 euro m^{-3} for the water use and depending on volumes) and water demand is not always satisfied. Private well is the key element for the agriculture of the study area by allowing the cultivation of crops characterized by high water demand (tomatoes, artichokes and table grapes) and whose produce contribute to place Apulia among the leading Italian regions in qualitative and quantitative terms.

The outcomes pointed out a low efficiency of collective network in the CBC area, and indicated the need to provide a suitable water management plan able to satisfy the water demand of crops through a more efficient and effective network. This result should be obtained through the modernization of this infrastructure, as well as by including the use of supplementary resources, i.e. wastewater. Indeed, CBC is subject to frequent water supply crises caused by extreme climatic events (drought) typical of the Mediterranean area, but also by structural and technological obsolescence of the network, so as to generate loss of significant water volumes and poor network maintenance. Other factors are inadequate storage systems, insufficient spread of network, poor water quality due to illegal dumping and unauthorized withdrawals (Zucaro et al., 2011).

On the other hand, the water management plan should focus on the preservation of groundwater via a partial or total ban of its use. However, if this ban is not adequately compensated by a contemporaneous improvement of collective network, the winegrowing sector could suffer significant damage for a significant decrease of the farms' efficiency. Obviously, similar trends could affect other crops cultivated in the area and characterized by high water demand, i.e. table grapes, peaches, nectarines, tomatoes, artichokes and melons. The mentioned objectives could also be integrated by promoting efficient irrigation practices and systems for water saving. The overall benefits concern the agricultural sector, but also the community, since irrigation provided by collective network has multifunctional characteristics, especially in the study area. In particular, it is based on reservoirs, i.e. infrastructure for irrigation that have also acquired environmental and recreational functions over the years, generating externalities that are more or less compensated (Sardaro et al., 2018). These are related to the aquifer recharge, the conservation of biodiversity and protected migratory species, the preservation of irrigation agroecosystems and the historical agricultural landscape, the creation of wetlands, the management of supply chains based on irrigated crops, and a general improvement in production quality.

All the mentioned interventions for the private wells and the collective network have direct repercussions on the management of production factors and inputs, hence on the economic efficiency of farms. Impacts of these interventions should be verified by investigating the efficiency level of farms before and after their implementation, and the study proved that the assessment of economic efficiency is a valid approach for policy evaluation. Furthermore, such analysis could be carried out in the context of the Performance Monitoring and Evaluation Framework (PMEF) for the post-2020 CAP (European Commission, 2018). In this context achievement of the new specific objectives will be verified through a more performance-oriented policy based on the establishment of a solid performance framework assessed through a set of common indicators. Such approach is an evolution of the current Common Monitoring and Evaluation Framework (CMEF), which will be streamlined and further developed. Important principles of the PMEF concern i) the selection of a limited and targeted set of indicators able to prove the changes desired by the supported interventions in achieving the objectives; ii) the carrying out of multi-annual assessments for evaluating the policy performance through impact indicators, and the valuation of the annual policy performance follow-up through the full list of result indicators; iii) reliability improvement of relevant performance indicators by synergies between statistical and administrative data. This new approach will generate simplification, result-orientation (rather than compliance) and policy efficiency and effectiveness.

In this context, analyses based on the economic efficiency allow to explore the mechanism by which policy interventions influence costs and returns of farm, i.e. one of the main CAP beneficiaries. This mechanism can be explored for ex-ante and ex-post evaluations in order to assess the impact of policies through a specific economic index that is able to furnish a wider view of policy impacts on farm management. Data useful for this type of analysis could be gathered through the Farm Accountancy Data Network (FADN), though it requires improvements in order to respond to evaluation needs. Improvements concern the possibility to use additional variables concerning the production and the inefficiency functions, thus the adding of new questions in the FADN survey. In addition, the biases of the FADN sample require adjustments that could be implemented through the use of satellite samples or of other databases for larger farms (European Commission, 2020). These improvements should also be ensured for the need to choose proper output and result indicators by Member States in order to produce the Annual Performance Report on the implementation of the CAP Strategic Plan, i.e. the key element of the ongoing monitoring of policy implementation.

References

Acciani, C., Sardaro, R. (2014). Percezione del rischio da campi elettromagnetici in presenza di servitù di elettrodotto: incidenza sul valore dei fondi agricoli. *Aestimum*, No. 64, pp. 39-55. doi: 10.13128/Aestimum-14708.

Aigner, D.J., Lovell, C.A.K., Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics,* No. 6, pp. 21-37. doi: 10.1016/0304-4076(77)90052-5.

Ali, M., Flinn, J.C. (1989). Profit efficiency among Basmati rice producers in Pakistan Punjab. *American Journal of Agricultural Economics*, No. 71, pp. 303–310. doi: 10.2307/1241587.

ANBI (2009). Relazione annuale. Retrieved from: http://www.adb.basilicata.it/adb/Pstralcio/pianoacque/basilicata/Allegato%205%20-%20Uso%20irriguo%20nel%20distretto%20-%20Regione%20BASILICATA.pdf (access date: 15.10.2020).

Battese, G.E., Coelli, T.J. (1993). A stochastic frontier production function incorporating a model for technical inefficiency effects. *Working Paper 93/05*. Department of Econometrics, University of New England, Armidale, Australia.

Battese, G.E., Coelli, T.J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, No. 20, pp. 325-332. doi: 10.1007/BF01205442.

Bozoğlu, M., Ceyhan, V. (2007). Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun province, Turkey. *Agricultural Systems*, No. 94, pp. 649-656. doi: 10.1016/j.agsy.2007.01.007.

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*. Boston: Kluwer Academic Publishers. doi: 10.1007/978-1-4615-5493-6.

De Filippis, F., Zucaro, R. (2019). Politica Agricola Comune (PAC) e gestione delle risorse idriche. In PAC post 2020 e Direttiva Quadro Acque: Consorzi di Bonifica, ANBI e Irrigants d'Europe rilanciano la sfida sulle risorse idriche. ANBI. Tipografia Mariti, Roma. Retrieved from: https://www.anbi.it/public/sezioni/libro-pac-post-2020-definitivo-pdf-20190618082643.pdf (access date: 15.10.2020).

Distretto Idrografico dell'Appennino Meridionale (2010). Piano di Gestione Acque (Direttiva Comunitaria 2000/60/CE, D.Lvo. 152/06, L. 13/09).

European Commission, 2018. COM(2018) 392 final. Brussels. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2018%3A0392%3AFIN (access date: 15.10.2020).

European Commission, 2020. Data management for the assessment of RDP effects - Good Practice Workshop. Retrieved from: https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/20957 (access date: 15.10.2020).

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, No. 120, pp. 253-281. doi: 10.2307/2343100.

Greene, W. (2004). Distinguishing between heterogeneity and inefficiency: stochastic frontier analysis of the World Health Organization's panel data on national health care systems. *Health Economics*, No. 13, pp. 959-980. doi: 10.1002/hec.938.

Greene, W. (2005). Reconsidering heterogeneity in panel data estimators of the stochastic frontier model. *Journal of Econometrics*, No. 126, pp. 269-303. doi: 10.1016/j.jeconom.2004.05.003

Hansson, H., Öhlmér, B. (2008). The effect of operational managerial practices on economic, technical and allocative efficiency at Swedish dairy farms. *Livestock Science*, No. 118, pp. 34–-43. doi: 10.1016/j.livsci.2008.01.013.

ISTAT (2010). 6° Censimento Generale dell'Agricoltura. Retrieved from: http://dati-censimentoagricoltura.istat.it/Index.aspx (access date: 15.10.2020).

Jondrow, J., Lovell, K., Materov, L., Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, No. 19, pp. 233-238. doi: 10.1016/0304-4076(82)90004-5.

Kumbhakar, S.C., Biswas, B., Bailey, D.V. (1989). A study of economic efficiency of Utah dairy farmers: a systems approach. *Review of Economics and Statistics*, No. 71, pp. 595–604. doi: 10.2307/1928101.

La Sala, P. (2019). Prelievo di acqua irrigua in agricoltura e nell'industria agroalimentare italiana. In PAC post 2020 e Direttiva Quadro Acque: Consorzi di Bonifica, ANBI e Irrigants d'Europe rilanciano la sfida sulle risorse idriche. ANBI. Tipografia Mariti, Roma. Retrieved from: https://www.anbi.it/public/sezioni/libro-pac-post-2020-definitivo-pdf-20190618082643.pdf (access date: 15.10.2020).

Meeusen, W., van den Broeck, J. (1977). Efficiency estimation from Cobb–Douglas production functions with composed error. *International Economic Review*, No. 18, pp. 435–444. doi:10.2307/2525757.

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*. Roma: Istituto Nazionale di Economia Agraria.

Rahman, S. (2003). Profit efficiency among Bangladeshi rice farmers. *Food Policy*, No. 28, pp. 487-503. doi:10.1016/j.foodpol.2003.10.001.

Petrillo, F., Sardaro, R. (2014). Urbanizzazione in chiave neoliberale e progetti di sviluppo a grande scala. *Scienze Regionali*, No. 13, pp. 125-134. doi: 10.3280/SCRE2014-002010.

Sardaro, R., Bozzo, F., Fucilli, V. (2018). High-voltage overhead transmission lines and farmland value: evidences from the real estate market in Apulia, southern Italy. *Energy Policy*, No. 119, pp. 449-457, doi: 10.1016/j.enpol.2018.05.005.

Sardaro, R., Grittani, R., Scrascia, M., Pazzani, C., Russo, V., Garganese, F., Porfido, C., Diana, L., Porcelli, F. (2018). The Red Palm Weevil in the City of Bari: A First Damage Assessment. *Forests*, No. 9, 452. doi: 10.3390/f9080452.

Sardaro, R., Faccilongo, N., Roselli, L. (2019). Wind farms, farmland occupation and compensation: Evidences from landowners' preferences through a stated choice survey in Italy. *Energy Policy*, No. 133, 110885. doi: 10.1016/j.enpol.2019.110885.

Tan, S., Heerink, N., Kuyvenhoven, A., Qu, F. (2010). Impact of land fragmentation on rice producers' technical efficiency in South-East China. NJAS-Wageningen *Journal of Life Sciences*, No. 57, pp. 117-123. doi: 10.1016/j.njas.2010.02.001.

Tzouvelekas, V., Pantzios, C. J., Fotopoulos C. (2001). Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms. *Food Policy*, No. 26, pp. 549-569. doi: 10.1016/S0306-9192(01)00007-0.

Zucaro, R., Pontrandolfi, A., Dodaro, G. M., Gallinoni, C., Pacicco, C.L., Vollaro, M. (2011). Atlante nazionale dell'irrigazione. Roma: Istituto Nazionale di Economia Agraria.