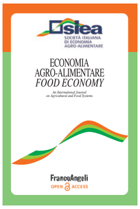
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 23, Iss. 3, Art. 17, pp. 1-20 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag2021oa12779



The impact of irrigation on agricultural productivity: the case of FADN farms in Veneto

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Abstract

The aim of the research is to analyze economic aspects related to the use of water in agriculture, by evaluating the effect of irrigation on agricultural productivity in a sample of FADN farms in the Veneto region in 2018. Specifically, the change of the Gross Saleable Production (GSP) is analysed as against the binary variable use/non-use of irrigation by applying an econometric analysis. To estimate how irrigation might influence GSP we have considered, in addition to the variable use/non-use of irrigation, other explanatory variables that could leverage the GSP, in particular 'variable costs', 'use of land' and 'UAA'. Results of the analysis show that a positive relationship exists between irrigation and the GSP. This result is considered relevant in the context of water resource management policies.

Article info

Type:
Article
Submitted:
15/05/2021
Accepted:
10/10/2021
Available online:
12/01/2022

JEL codes:
Q15, Q25, C01

Keywords:
Irrigation
Land productivity
Water value

Managing Editor:
Lucia Briamonte,
Luca Cesaro,
Alfonso Scardera

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Introduction

The use of irrigation in agriculture is key for the providing the World food supply (FAO, 2003). Irrigation contributes to stabilise crops productivity by providing a controlled quantity of water when rainfalls are not sufficient, or they could not guarantee the adequate agricultural productivity (Rossi, 2019). Agricultural production is strongly dependent from water availability and, therefore, is also exposed to risks related to the lack of it, such as the case of drought. The agricultural sector alone accounts for 40% of the total annual withdrawal of water in Europe (European Environment Agency, 2019). Economic and environmental aspects linked to water use play a key role in relation to policies for water management, such as the Directive 2000/60/EC (Water Framework Directive). The assessment of socio-economic relevance of water uses provides helpful information to recognise the value of water as an input to be used in production processes (Working Group 2.6 - WATECO, 2003).

The literature on this topic includes few studies about the assessment of the economic impact of irrigation.

Kirsten and J. Van Zyl (1990) use the input-output analysis to evaluate the economic impact of the development of irrigation in the South-West of the Orange Free State (today Free State province of the Republic of South Africa). The authors, through the Leontief inverse matrix, show that irrigation produces not only direct impacts on the agricultural sector but also indirect ones on other sectors and consumption.

Babovic *et al.* (2009) compare the economic efficiency of irrigated and dry agricultural production of a farm in the Bačko Gradište village, in the autonomous province of Vojvodina in Serbia. The authors use a comparative analysis of data collected and they analyse the farm's economic performance before and after the introduction of irrigation. Results show the positive effects that irrigation have on production yield and farm profitability.

Columba and Altamore (2006) compare the GSP and the Gross Profit Margin of agricultural holdings of Italian southern regions. They prove that irrigation can enhance production and economic performance of crops, both of those that need irrigation and those that not necessarily need it, but they perform better with the use of water. Authors estimate that half of the national economic value of agricultural production derives from irrigated crops, which account for 1/5 of the Utilised Agricultural Area (UAA).

Rosato and Rotaris (2014), in the framework of the "Rapporto condizionalità ex-ante per le risorse idriche: opportunità e vincoli per il mondo agricolo" (edited by Zucaro, 2014), evaluate the effect of irrigation in Italy starting from the agricultural farmland values and applying an econometric approach. This analysis enabled to estimate a statistically significant relation between the agricultural farmland values and the possibility to irrigate. Results show that irrigation contributes significantly to increase agricultural farmland values, particularly where irrigation and specialised crops are more widespread. Data used to perform the analysis were taken from different sources, such as SIGRIAN (National Information System for the Management of Water Resources in Agriculture), ISTAT Agricultural Census, Revenue Agency, National Agrometeorology Database.

The economic importance of water in agriculture is also highlighted by studies that estimate the impact of drought on irrigated agriculture. Lopez *et al.* (2017) present an integrated framework to predict the direct economic impacts of drought on irrigated agriculture. They consider the uncertainty about water availability and crop price volatility, combining econometric assessment, stochastic projection of inflows and simulation system operation. The authors show that drought has an economic impact in terms of loss of production. Giannoccaro *et al.* (2019) conducted an empirical assessment of the impact that the reduction of water availability has on tomato production in the Capitanata area in the Apulia region. The authors estimate that the drought events that occurred in the period of interest caused losses of 30% compared to the years with regular water availability.

The present research aims to provide additional evidence about the economic impact of irrigation on agricultural productivity, by applying an econometric analysis to the data extracted by the Farm Accountancy Data Network (FADN) of farms for the Veneto region in 2018.

Veneto is among the first four more important Italian agricultural regions; it leads in several productions and can count on agricultural holdings rather diversified. In the last twenty years, agriculture in Veneto has faced various changes due to market trends, the innovations introduced by the reforms of EU policies and those generated by technological progress, as well as the increasingly pressing challenges caused by climate change and environmental problems. From the point of view of adaptation to climate change, one of the major potential risks is represented by the management of water resources, which is not always able to respond to the growing needs of the territory (42% of the regional UAA was irrigated in 2016). In Veneto there is a good availability of water, despite the uneven distribution of rainfall, but the state of the infrastructures still causes losses of this precious resource. Faced with a progressive increase in the demand for irrigation water, technological innovations are being introduced in the distribution systems to improve overall efficiency.

In the 2008-2018 decade agricultural and forestry holdings of the Region decreased of 22.5%, going from 82,582 units in 2008 to 64,182 in 2018. This reduction is in line with the national performance (–18.5%), even though it is slightly higher. This decreasing trend had been registered already since

1997. From 2008 less farms abandoned the sector compared to the previous decade, but despite this the balance between farms leaving the sectors and those entering was still negative. The reduced number of farms matches also the reduction of the UAA that, in the decade considered, decreased of 2.5%, reaching 778,000 ha in 2018. The decline of both number of farms and UAA has become a structural characteristic of the regional agriculture. It is important to note, however, that the UAA changes followed a fluctuating trend, not always negative and with a decline less evident than that registered for the number of holdings. Looking at single crops, cereals (–27,8%), horticulture (–21,1%), orchards (–17,5%), and forage crops (–16%) registered major reductions, while industrial crops increased the most. Important increases have been registered in viticulture (+17%), olive growing (+7,8%), legume vegetables and tuber crops (+4,7%). Despite the negative trend of the UAA and farms' number, the agricultural production value improved of 18.5%, overcoming three billion euros in 2018. This positive result is mainly due to the increased value of production in two sectors, that are industrial crops and viticulture. Between 2013 and 2018 the production of grapes for quality wines increased. The same happened for the cultivation of olive trees, whose economic values is more than duplicated in the same period, even though in absolute terms the growth can be considered marginal (Veneto Agricoltura, 2020).

For what rainfalls are concerned, Veneto has experienced a progressive deterioration of the water balance from the 1980s, with a negative peak in 2003. As a consequence, the water-climate balance in the Veneto region went from positive to negative values (Zucaro e Povellato, 2009). Unfavourable climate trends, such as temperature increase and the changes of rainfalls seasonality, boosted the use of irrigation on agricultural areas, which are limited in terms of extension, but important from an economic point of view, as it is the case of vineyards. Hence, sustainable water management became a priority for the Region. On the light of this, the allocation of financial resources dedicated to agriculture, such as those provided by the rural development policy, is strongly oriented to preserve natural resources, including water. The Veneto region has included in the 2014-2020 Rural Development Programme (RDP), funded by the European Agricultural Fund for Rural Development, a set of measures with the aim to strengthen competitiveness of agricultural holdings in the global market, while addressing environmental objectives, as set up by European, national and regional policies. These measures support: the adoption of innovative solutions, including the introduction of technologies, sustainable also from an ecological perspective; the use of non-productive investments to achieve agro-environmental and climate objectives; investments for the modernisation of those infrastructures needed to ensure the development of agriculture and forestry. Several of the planned measures have positive effects on improving water management and the related infrastructures. It is important to notice that the Veneto RDP assigned almost 9 MEURO to Focus Area 5a "Increasing efficiency in water use by agriculture". Among the interventions that could deploy more positive effects on water use there is sub-measure 4.3 "Investments on forestry and agri-pastoral infrastructures, land consolidation and network services", which allowed the four regional irrigation consortia accessing financial resources to improve water efficiency in agriculture. The implementation of innovation-related measures has also effect on improving water use and management. At least 8 out of 56 Operational Groups (OG) funded in the region target directly improvement of water management, use and quality. Other OGs aiming at reintroducing old plant varieties, improving pest management and reducing the use of chemical inputs are also considered to have positive impact on water, particularly water quality and use. Interventions funded under M1 "Training" and M2 "Advisory services" contribute indirectly to the improvement of water management, by supporting the dissemination of information and knowledge.

The analysis of issues relating to the sustainable and efficient management of water in agriculture should take into account the potential of irrigation to provide several ecosystem services (Zucaro, 2014; Rogers *et al.*, 1998) often provided as positive externalities, since they are not captured by market mechanism (Natali & Branca, 2020). Some of these, such as aquifer recharge, are provided through the excess of water applied to the field and delivery losses (Dages *et al.*, 2009; Grafton *et al.*, 2020) which cause low efficiency. From this point of view, Veneto Region has territorial peculiarities that can generate ambiguous environmental impacts of water efficiency improve. This area is characterized by the spread of groundwater-surface water interactions, which, under specific conditions, might trigger a positive effect of irrigation to the aquifer recharge. The use of traditional irrigation practices, such as furrow and flood irrigation, causes the distribution of excessive quantities of water in the field. This water percolates in the subsoil, replenishes the aquifer and re-emerges on the surface, creating the resurgences phenomena (Fabbri *et al.*, 2016). It is important to note that the aquifer recharge processes through irrigation make it necessary to pay particular attention to the use of chemical inputs that might compromise the status of groundwater. In this paper, the economic aspects of water use in agriculture are addressed in order to verify how much irrigation can affect farms' productivity and viability in a specific area and time frame.

In this work we demonstrate the economic relevance of irrigation, while acknowledging that the comprehensiveness of the analysis would increase by considering additional aspects. For example, technical efficiency, including water use efficiency can influence farm's economic performance (Wichelns *et al.*, 2002; López-Mata *et al.*, 2019). This is not included in the quantitative analysis of this work; however, the results return acceptable estimates and allow for final considerations on the importance to further improve the efficiency of water use, especially through the intervention funded by the CAP (Common Agricultural Policy). The analysis of the economic implications of irrigation might be the basis for future developments of these results, including the analysis of the environmental dimension of the sustainable use of water.

1. Materials and methods

The analysis carried out focuses on the Veneto region. The sample used was extracted from the Farm Accountancy Data Network (FADN) database and refers to 2018. The absence of particular climatic anomalies that could influence the results was verified prior the selection of the time frame for the research. 2018 was not characterized by drought problems; the values recorded by the 12-month and seasonal Standard Precipitation Index (SPI) for 2018 in this region are within the norm (ISPRA, 2019). Furthermore, 2018 data is also the most recent one available in the FADN database.

To estimate the impact of irrigation on the farms' economic performance, we considered the variable GSP per hectare. The GSP includes the revenues strictly connected with the agricultural activity; therefore, the GSP per hectare represents land productivity and provides a preliminary indication of farms profitability. In the FADN database the utilised agricultural area (UAA) does not include the land dedicated to wood arboriculture. However, in order to consider the effects of this cultivation on the GSP, we added it to the UAA.

The dependent variable is represented by the ratio GSP/UAA, while the independent variable is the dummy use/not use of irrigation (IRRIGATION DUMMY in the Table 1), but we also analyse the percentage of irrigated UAA (IRR_UAA/UAA in the Table 1). We included additional control variables with the aim to consider other elements that could have influence on the GSP (Table 1). The UAA has been included to take in consideration potential effects of farm size on efficiency and viability (Hansson, 2008; Reidsma *et al.*, 2007). Variable costs (VC) include specific expenditure (water, crops insurance, chemical inputs, external contracts, seed, poles, etc.), other costs (energy, marketing and communication) and farm use[1]. Variable costs can be used to measure the level of input intensity undertaken by agricultural holdings (Reidsma *et al.*, 2007), which can affect crop yield (Reidsma *et al.*, 2007). Therefore, ratio between VC and UAA has been included in the analysis (VC/UAA).

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[1] Water costs are included in the variable vc.

Table 1 - Variables included in the analysis

Variabile	Meaning
UAA	Utilised agricultural area (included wood arboriculture) (thousand Ha)
AL/UAA	% of arable land compared to the total farm Utilised agricultural area (included wood arboriculture)
ARB/UAA	% of area for tree crops compared to the total farm utilised agricultural area (included wood arboriculture)
Meadow/UAA	% of grassland compared to the total farm utilised agricultural area (included wood arboriculture)
Wood/UAA	% of area for wood arboriculture compared to the total farm utilised agricultural area
VC/UAA	Ratio between Variable Costs and utilised agricultural area (included wood arboriculture) (expressed in thousands of € for each thousand Ha)
IRR_UAA/ UAA	% of irrigated UUA compared to the global UAA (included wood arboriculture)
Irrigation	Dummy variable presence/absence of irrigation
GSP/UAA	Ratio between Gross Sellable Production and Utilised agricultural area (included wood arboriculture) (expressed in thousands € for each thousand Ha)
UAA/AA	Ratio between Utilised agricultural area (included wood arboriculture) and total agricultural area (percentage)

Source: our elaboration on FADN data.

Different types of farming can influence economic results (Coppola *et al.*, 2018), therefore the percentage of different types of farming within the UAA have been considering as control variables, namely: i) share of UAA under tree crops (ARB/UAA); ii) share of UAA under arable land (AL/UAA), ii) share of UAA for wood arboriculture (WOOD/UAA), iii) share of UAA/AA was included to control the percentage of land used specifically for agriculture. In fact, authors expect that farms with a higher percentage of UAA could have a better economic performance than those with higher percentages of land not used for agriculture (in term of GSP/UAA).

A data cleaning procedure was applied to the original dataset, composed by 577 observations. The rational of this operation was justified by the need to remove outliers associated to the variables of interest for the analysis. The cleaned dataset counts 530 valid observations. 47 observations were removed because at least one of the following issues were identified: Total Agricultural Area (AA) was equal to zero; the UAA was bigger than the AA; presence of odd or unexpected values in relation to the ratio GSP/UAA identified through the use of the *boxplot anomaly detection* technique; total agricultural area lower than the sum of the single crops' areas; irrigated area higher than the total agricultural area. We applied the natural logarithm to the variables GSP/UAA and VC/UAA to standardise the values distribution, being it strongly skewed. We implemented a descriptive univariate analysis of the studied variables and we calculated mean and standard deviation of quantitative variables and frequencies of qualitative variables. The linear correlation between quantitative variables was estimated using the Pearson correlation coefficient and illustrated with a matrix scatterplot. We conducted an independent sample t-test to assess if a statistically significant difference, in terms of GSP/UAA, exists between irrigated and non-irrigated farms, accompanied by a bar-plot representing average values and 95% confidence levels. As final step, we constructed a hierarchical multiple linear regression model to assess whether and which factors have a statistically significant impact on the variable under study GSP/UAA. In particular, the dummy variable use/not-use of irrigation was introduced in the first step, while in the second step also the control variables were introduced to assess whether there was a change in the effect and significance of the irrigation variable. In all the analyses mentioned, an alpha significance level of 0.05 was used. IBM SPSS Statistics software version 25 was used for the statistical analysis of the data.

2. Results

Table 2 shows the characteristics of the 530 farms analysed in relation to the variables of interest. With regard to the dichotomous variable that describes the presence or absence of irrigation, it is noted that in 54.3% of cases (equal to 288 holdings), farms resort to irrigation while in the remaining 45.7% of cases (equal to 242 holdings) they choose dry cultivation.

We carried out a correlation analysis to verify if and which variables were significantly correlated with the dependent variable under study (LN(GSP/UAA)). Table 3 shows only the statistically significant correlations, while the corresponding scatter plot (Figure 1) allows a graphical evaluation of the correlation itself. The variables in question are quantitative, therefore, the bivariate correlation index used is the Pearson coefficient.

It is possible to observe how the variable LN(GSP/UAA) is significantly and positively correlated with the variables LN(VC/UAA) ($r = .558$) and ARB/UAA (%) ($r = .392$), while it appears to be negatively correlated with the variables UAA (kha) ($r = -.348$) and UAA/TA (%) ($r = -.101$), despite the latter correlation being very slight.

Table 2 - Descriptive statistics of the variables included in the analysis after data cleaning and preparation

Variable	**N**	**Min**	**Max**	**Mean**	**Std. Dev.**
UAA (thous. Ha)	530	,01	6,14	1,15	1,17
AA (thous. Ha)	530	,02	8,25	1,34	1,35
UAA/AA (%)	530	17,48	100,00	84,77	14,05
LN(GSP/UAA)	530	–1,23	4,87	1,72	1,08
LN(VC/UAA)	530	–1,15	4,40	1,14	1,05
IRR_UAA/UAA (%)	530	,00	100,00	33,60	38,84
AL/UAA (%)	530	,00	100,00	60,74	41,22
ARB/UAA (%)	530	,00	100,00	28,36	38,19
Meadow/UAA (%)	530	,00	100,00	10,33	26,22
Wood/UAA (%)	530	,00	58,27	,57	3,88

Source: our elaboration on FADN data.

Table 3 - Correlation Matrix of the variables included in the analysis

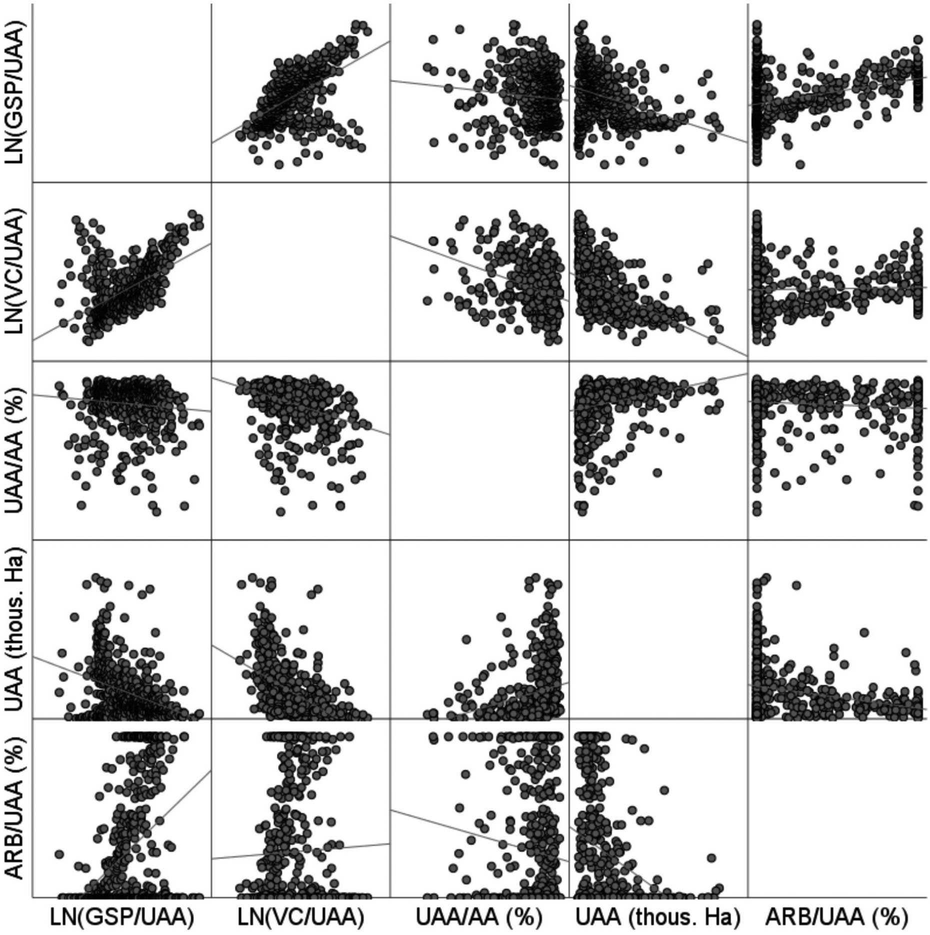
		LN (VC/UAA)	**UAA/AA (%)**	**UAA (thous. Ha)**	**ARB/UAA (%)**
LN(GSP/UAA)	Pearson correlation	,558***	-,101*	-,348***	,392***
	Sign. (two-tailed)	,000	,020	,000	,000
LN(VC/UAA)	Pearson correlation	1	-,342***	-,524***	,033
	Sign. (two-tailed)		,000	,000	,448
UAA/AA (%)	Pearson correlation		1	,250***	-,107*
	Sign. (two-tailed)			,000	,014
UAA (thous. ha)	Pearson correlation			1	-,316***
	Sign. (two-tailed)				,000
ARB/UAA (%)	Pearson correlation				1
	Sign. (two-tailed)				

* Correlation is significant at the 0.05 level (2-tailed significance test; H0: r=0).
** Correlation is significant at the 0.01 level (2-tailed significance test; H0: r=0).
*** Correlation is significant at the 0.001 level (2-tailed significance test; H0: r=0).

Source: our elaboration on FADN data.

An independent sample t-test was carried out to assess whether or not there was a difference in the mean value of LN(GSP/UAA) between farms with irrigation and farms without irrigation (Table 4). Given that the distribution

Figure 1 - Matrix scatter plot of the variables included in the analysis



of the variable LN(GSP/UAA) (Figure 2) can be considered acceptably normal and the adequate sample size, we judged that it was not necessary to use non-parametric tests.

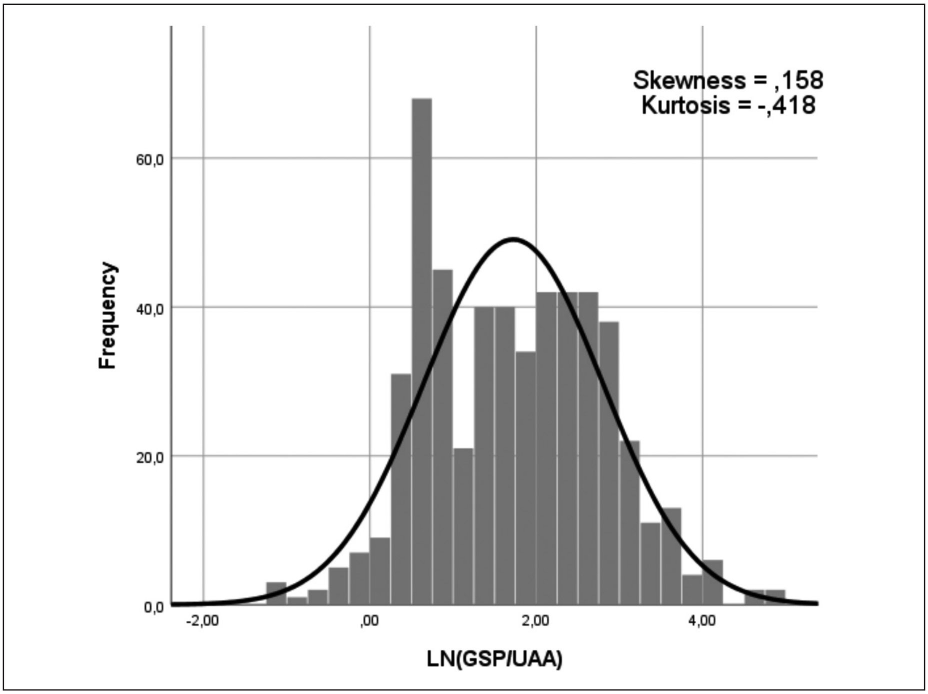
Since the Levene test for the equality of variances in the subgroups was not significant (p = 0.323), no robustness correction was made to the independent-sample t-test, which was found to be not statistically significant (t = -,405; df = 528; p = .686). It was therefore concluded that, in the absence of control variables, the difference in terms of natural logarithm of the GSP/UAA ratio between farms with and without irrigation is not significant. Figure 3 presents this difference through a bar graph with a mean and 95% confidence interval.

Table 4 - Descriptive statistics for the difference of the mean of LN(GSP/UAA) between farms with and without irrigation

	Irrigation	N	Mean	Std. Dev.	Std. Error
LN(GSP/UAA)	No	242	1,7028	1,12257	,07216
	Yes	288	1,7409	1,03919	,06123

Source: our elaboration on FADN data.

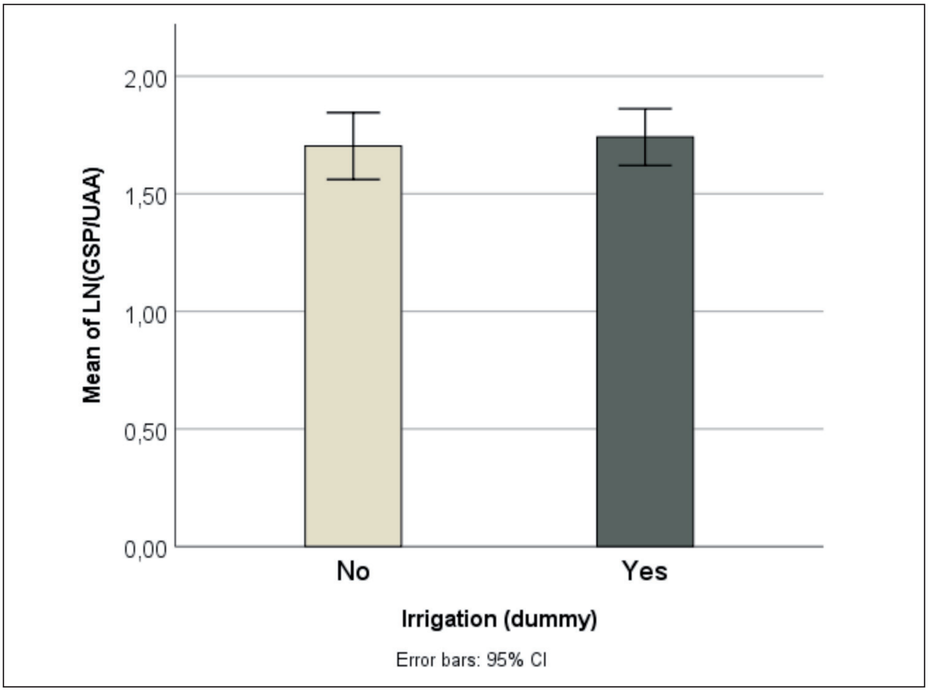
Figure 2 - Histogram of the distribution of the variable LN(GSP/UAA)



Source: our elaboration on FADN data.

The fact of not having observed, through the t-test, statistically significant differences in the presence or absence of irrigation with respect to the variable LN(GSP/UAA) could erroneously lead to think that this evidence is sufficient to exclude an effect of irrigation in terms of productivity of agricultural holdings. However, the two subgroups of farms with and without irrigation might have different dimensional, cultural and structural characteristics, thus making the direct comparison through t-test potentially biased.

Figure 3 - Bar graph of the mean of the LN(PLV/SAU) with and without irrigation



Source: our elaboration on FADN data.

In order to isolate the single effect of irrigation on productivity, we constructed a hierarchical multiple linear regression model, the results of which are shown in Table 5. In the first step, only the dichotomous independent variable "Irrigation" was included in the model, while the control variables LN(VC/UAA), UAA/TAA (%), UAA (kha) and ARB/UAA (%) were added to the second step in order to evaluate and quantify the impact of irrigation for given variable costs, used agricultural area, percentage of the used agricultural area compared to the total agricultural area and the type of crop. During the model selection procedure, all variables linked to the share of different types of farming [AL/UAA (%), ARB/UAA (%), Meadow/UAA (%) and Wood/UAA (%)] have been included. Nevertheless, only the variable ARB/UAA had a strong, significant, and positive effect on economic performance, while the others had non-significant effect. Therefore, only variable ARB/UAA was included, to keep the model specification as simple as possible, in accordance with the parsimony criterion, widely used in multiple linear regression models to avoid collinearity problems.

Table 5 - Hierarchical multiple linear regression models

		Unstandardized coefficients		**Standardized coefficients**			**Collinearity Statistics**	
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Tolerance**	**VIF**
1[a]	(Constant)	1,703	,069		24,572	,000		
	Irrigation (dummy)	,038	,094	,018	,405	,686	1,000	1,000
2[a]	(Constant)	-,297	,250		-1,189	,235		
	Irrigation (dummy)	,155*	,073	,072	2,129	,034	,883	1,133
	LN(VC/UAA)	,639***	,040	,623	15,880	,000	,648	1,544
	UAA/AA (%)	,009**	,003	,121	3,484	,001	,821	1,217
	UAA (thous. Ha)	,070	,037	,076	1,903	,058	,633	1,579
	ARB/UAA (%)	,012***	,001	,425	12,304	,000	,835	1,198

a. Dependent variable: LN(GSP/UAA).
* Statistically significant coefficient at 0,05 level.
** Statistically significant coefficient at 0,01 level.
*** Statistically significant coefficient at 0,001 level.

Source: our elaboration on FADN data.

At the first step, as evidenced by the non-significance of the t-test, the *Irrigation* variable has an estimated coefficient equal to .038 which is not statistically significant (p = .686); moreover, the model appears to be not significant ($F_{1,528}$ = ,164; p = ,686) and the variance explained by the model is close to zero ($R^2 < 0.001$).

In the second step, however, following the addition of the control variables, the estimated coefficient for the Irrigation variable rises to .155 and it is statistically significant at the 0.05 level (p = .034); furthermore, the model appears to be overall significant ($F_{5;524}$ = 95,624; p < .001); (and the variance explained is considerable ($R^2 = 0.477$).

We assume that for given variable costs per hectare of utilised agricultural area, percentage of UAA/TAA and type of crop, irrigation has a positive and statistically significant effect on the productivity of farms, measured as the GSP/UAA ratio.

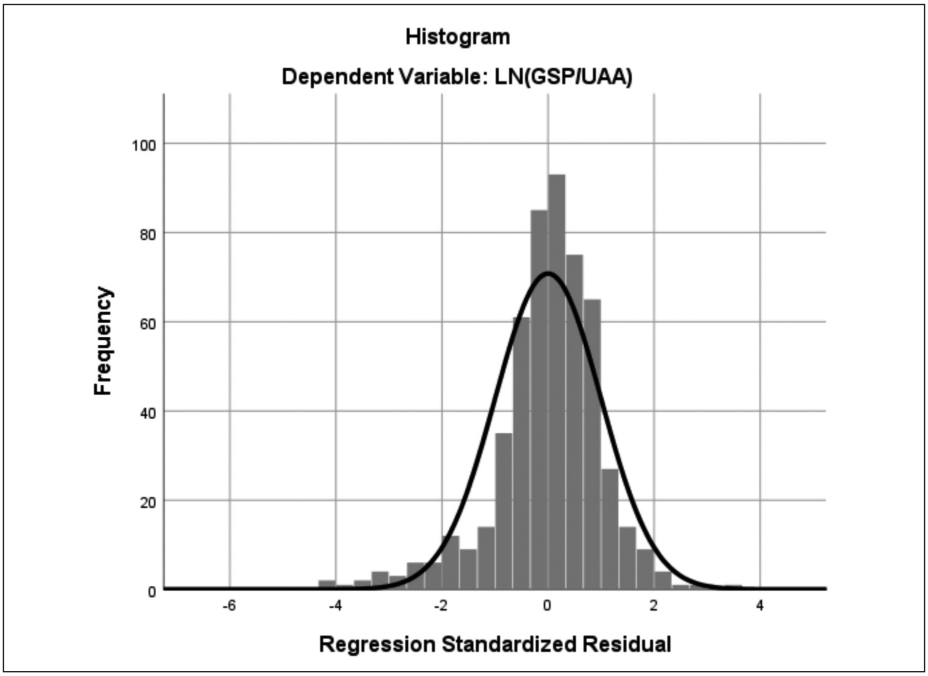
A regression with IRR_UAA/UAA as independent variable has been run but this model had a worse fit and the IRR_UAA/UAA variable had a non-statistically significant estimated coefficient. Therefore, the presence or absence of the irrigation is more predictive than the percentage of the irrigated area, in terms of economic performance of companies.

It is also interesting to observe that the effect for the control variables LN(VC/UAA), UAA/TAA (%) and ARB/UAA (%) is positive and statistically significant, while the effect of the variable UAA (kha) is positive but not statistically significant at the 0.05 level, albeit slightly (p = .058).

Analysing the beta standardized coefficients, it is possible to compare the effects of independent variables on the dependent variable (GSP/UAA). LN(VC/UAA) is the variable with the strongest positive effect on the economic performance (beta = ,632) followed by ARB/UAA (beta = ,425): both these variables have a strongly significant effect and play an important role in explaining the variance of the dependent variable. The other three variables have a positive and significant, but less impacting effect on the dependent variable: UAA/TA (beta = ,121), UAA (beta = ,076) and Irrigation (beta = ,072). This evidence can lead us to conclude that Irrigation has a significant role in determining economic performance, but its role is inevitably less crucial than other variables, such as variable costs and type of farming.

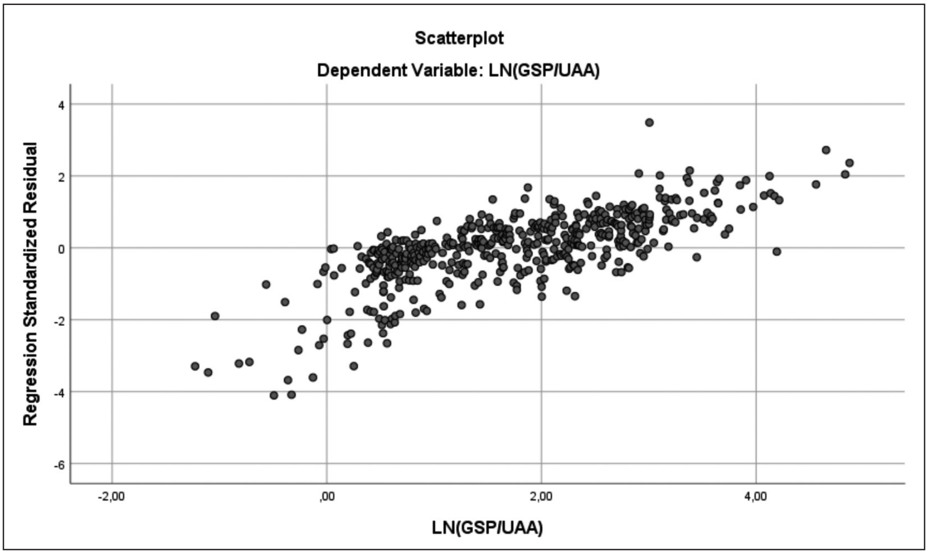
The developed model does not present collinearity problems as the VIF (Variance Inflation Factors) values of the independent variables are close to the unit value. Finally, observing the histogram of standardized residues (Figure 4) and the scatter plot of standardized residues (Figure 5) we can

Figure 4 - Standardized residuals histogram for the model in step 2



Source: our elaboration on FADN data.

Figure 5 - Scatter plot of standardized residuals for the model in step 2



assume that the model has two violations in relation to the assumptions on regression residuals: the distribution is leptokurtic and there is a certain violation of the hypothesis of non-linearity. The authors suggest, for future developments, to introduce additional control variables in order to improve the adaptation of residues and to isolate more precisely the effect that the use of irrigation has on the productivity of farms.

Conclusions

The results obtained from the tests carried out lead to confirm that irrigation positively affects the GSP in the sample considered. This confirms what has already been demonstrated in previous studies concerning the impact of irrigation on the economic performance of farms. The results relating to the control variables considered show that variable costs positively affect the GSP, reflecting the positive impact of input intensity on crop yield.

Furthermore, the results show that even the share of UAA under tree crops have a positive impact on the GSP of the sampled farms. In fact, arboriculture (tree crops) has undergone an increase in recent years in Veneto, mainly because of the good commercial results of the wine sector in some prestigious areas. Veneto leads with other few regions the production of quality wines. Recent experiments in the field of plant protection have allowed the resumption of fruit-bearing productions, such as apple, pear and peach trees. The area used for olive trees is also important, with the production of fine olive oils, confirming that the trend of climate change makes Veneto more and more suitable also for typically Mediterranean crops and dependent on irrigation practice, even if the empirical assessment of the relationship between type of farming and irrigation is not the subject of this analysis. The analyses for the verification of the goodness of fit of the residuals of the model used suggest, however, that the analysis could be refined in the context of future developments, considering additional control variables that might allow to isolate more precisely the effect of irrigation on the productivity of farms.

The results obtained are relevant in the context of water resource management policies, confirming the economic relevance of water for the agricultural sector. The weather-climatic trends and the economic importance of irrigated agriculture make water an increasingly valuable asset for agricultural production. These elements highlight the importance of sustainable water management, an objective pursued by supporting investments to improve the efficiency of farms irrigation systems and, also, by envisaging, within the 2014-2020 Rural Development Programme, a number of interventions for the modernization of infrastructures and the introduction of environmentally sustainable technologies.

The measures to boost efficiency of water use in agriculture certainly have an environmental value, as highlighted by the increasingly ambitious environmental objectives of the Common Agricultural Policy. Results show that a better management of water resources is important not only for the protection of aquatic ecosystems, but also for guaranteeing farms' viability. The analysis does not consider variables related to the efficiency of the use of inputs, including water; this represents a limitation of the analysis and future developments could better investigate this aspect. However, the literature counts several studies that demonstrate the ability of improving efficiency to increase profitability (Wichelns *et al.* 2002; López-Mata *et al.*, 2019). The adoption of technologies to improve the efficiency of water use plays a key role in reducing pressure on water bodies without causing economic losses for farms. This underlines the profound interconnections between the economic and environmental system on which the CAP is based. Moreover, the proposal of the CAP post-2020 regulation is strongly oriented towards promoting environmental protection objectives, while maintaining the objectives of supporting farmers' income. In the specific case of water resources, the provisions laid down by the proposal require to pay particular attention to the coherence between the CAP National Strategic Plan and what is envisaged by the Basin River District Management Plans (RBDPs). Future interventions undertaken under the CAP Strategic Plan and the RBDPs must address both the needs identified by the territorial analysis carried out at district level in relation to the state of water resources and the needs identified for the development of rural areas.

Results show how agricultural policies should continue the effort to improve the efficiency of water use in agriculture, by supporting investments to improve irrigation infrastructures, to spread the adoption of good practices and new technologies at farm level (such as decision support systems to schedule irrigation). These might be complemented by horizontal interventions to promote the access and use of advisory services, training and knowledge transfer actions, that is those measures that might ease the uptake of innovative solutions on farms. The adoption of innovation at farm level appears to be often rather complex, because farmers do not necessarily have access to the new technologies or the technical support they need to transfer them in the field. Already in the current programming, several Regions have used the measures to promote knowledge transfer, advice innovation-related measures for the achievement of water efficiency (focus area 5a).

The future CAP 2023-2027 could offer opportunities in this context, since the Proposal for a Regulation on National Strategic Plans provides for the possibility for Member States to grant support for investments in irrigation in new and existing irrigation systems, taking up many aspects of the current art. 46 of Reg. (EU) 1305/2013. The strengthening of the Agricultural Knowledge and Innovation System, as envisaged by the CAP post-2020, might offer additional opportunities to improve the services to farmers, in terms of access to specialised advice and training, as well as the possibility to cooperate (operational groups or other cooperation interventions) with researchers and other farmers to transfer innovative solutions in the farms.

In order to guarantee sustainable management of water resources, in addition to the aspects covered by this analysis, it is also necessary to reflect on the environmental effects of water use in agriculture, which can be considered both as pressure and benefit, especially in relation to the aquifer recharge processes. In this work, only a part of the effects of water use in agriculture has been analysed, being the main focus on the economic aspects at farm level. The main scope is to provide elements for the assessment of the value of water as an input for agricultural production processes in a context, such as the current one, of significant climate change. The results of the study might raise interest on the implication in terms of overall sustainability of water use, which could become the subject of future development of this work.

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