The influence of agri-environmental policy on Italian farms: an analysis of efficiency

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Abstract

In the literature, there is a gap in respect to the effects of agri-environmental subsidies on the technical efficiency of Italian farms. In particular, there are currently no two-stage estimations of technical efficiency aimed at evaluating the impact of agri-environmental subsidies disbursed through the Common Agricultural Policy. The main purpose of this research, then, was to analyse the effect of agri-environmental subsidies on Italian farms included in the Farm Accountancy Data Network for the years 2004 to 2019, and to assess how the agri-environmental policy impacts on different types of farming. The findings have revealed that the agri-environmental subsidies have had the effect of reducing the level of technical efficiency in all farms included in the Italian FADN dataset. Farms have been differently impacted by these agri-environmental subsidies in function of their particular specialisation, with the most notable effects found in horticulture, wine, and dairy production.

Key words: Data Envelopment Analysis; separability; FADN; second pillar; Common Agricultural Policy

1. Introduction

Since the early 1990s, the European Union Commission has proposed some radical and far-ranging changes to the Common Agricultural Policy (CAP) with the aim of stimulating a significant reduction in the use of chemicals, pesticides, and other chemical inputs in agriculture, and directing the management of farms towards a more environmentally sustainable model. Within this framework, EU Regulation 2078, which was adopted in June 1992, supports agrarian systems of production that have a low environmental impact, such as organic and biological farms, and farms employing new agri-environmental techniques of cultivation based on low levels of pesticide and fertiliser use. The consequences of this change in farm management have been reductions in output, modifications in the allocation of some inputs, and decreases in the level of technical efficiency as well.

The process of reducing the level of inputs in agriculture has been investigated in different countries by focusing on various measures such as organic or agro-environmental actions financed through the Common Agricultural Policy under the Rural Development Programme (Mennig and Sauer, 2020; Bertoni and Olper, 2012). In the Italian literature, on the other hand, there is only an incomplete patchwork of studies aimed at estimating the effects of agri-environmental policy financed through specific subsidies on the technical efficiency of farms (Minviel and Latruffe, 2017). Moreover, the findings of many studies carried out in other EU countries regarding the relationship between agri-environmental financial subsidies allocated through the CAP and the technical efficiency of farms have been mixed and inconclusive (Donati et al., 1993; Minviel and Latruffe, 2017).

The main purpose of agri-environmental policies aimed at reducing the use of exogenous inputs in farming has been to mitigate the effects of climate change and reduce the emission of greenhouses gases into the atmosphere (Vanloqueren and Baret, 2009). However, these policies have brought certain economic impacts for farm management, namely in terms of farm productivity and technical efficiency (Wrzaszcz and Prandecki, 2020). In fact, farmers participating in agri-environmental measures have seen significant a drop in their production yields along with a need to alter the allocations of certain inputs such as labour capital as well as to make greater investments in fixed capital and machinery.

In this framework of environmental protection, the new strategy proposed by the European Union Commission for the next seven-year period of Common Agricultural Policy planning for 2023–2027 is very important. In fact, the main target of the European Union Commission is to reduce the use of pesticides and other chemical inputs in agriculture, emphasising the European Green Deal policy centred on the so-called "farm to fork strategy". The farm to fork strategy aims to stimulate a transition to a greener production with a neutral or positive environmental impact, protecting the landscape and stimulating an increase in biodiversity at the same time.

2. Literature review

A recent literature review has revealed several studies that have investigated, through a quantitative approach, the significant public concern regarding the use of pesticides in farming and their environmental impact (Bakker et al., 2021). These authors have identified a variety of social-psychological constructs influencing farmers to reduce their use of pesticides. The main drivers influencing the decision of farmers to use or not use chemical inputs in farms are the decisions of other nearby farmers to do the same, as well as a good knowledge on their part of other inputs and alternative pest control strategies that could be applied in their place. In fact, though, the decision to reduce the use of pesticides in farms can also be led by a number of agronomic and sociological variables that must be addressed to the productive specialisation and other specific features of the farm (Bakker et al., 2021).

As the theory of planned behaviour (TPB) would suggest, farmers choose to reduce or not reduce their use of chemical inputs according to their level of aversion to productive risk. As such, the higher the farmer's perception of the risk of a drop in their total yield, the lower is the probability that they will choose to reduce their use of chemical products (Damalas, 2021). This planned behaviour is able to encourage farmers to adhere to certain measures of agri-environmental policy financed by the European Union; consequently, public authorities should define agri-environmental measures in such a way as to properly inform farmers regarding the pros and cons of alternative techniques of crop protection, the agro-ecological perspective of farming, and the main implications that an integrated pest management has for farmers and for the environment (Damalas, 2021). Studies recently carried out in China have investigated the real reasons that push farmers to use exogenous chemical inputs as fertilisers and pesticides (Zheng et al., 2020). According to the findings, the cognitive perception of farmland cleanliness is strongly felt by Chinese farmers, and their desire to obtain such a result often acts as the stimulus driving them to an overuse of these products. In EU countries such as Romania, on the other hand, some scholars have highlighted that two variables, the individual's farming knowledge and their perception of the pesticide's risk to the environment and to their own health, are pivotal in the farmer's decision process to use chemical inputs (Petrescu-Mag et al., 2019).

In the framework of the agri-environmental strategies proposed by the European Union Commission for reducing the use of chemical inputs in farms, the most important is centred on organic agriculture. In fact, recent studies have highlighted that Italian organic farms are less technically efficient than conventional farms (Madau, 2007), and in general farmers who are more technically inefficient are those who have decided to convert their system of production from conventional to organic (Latruffe and Nauges, 2016; Lankoski and Thiem, 2020).

Meanwhile, the use of pesticides and other chemical inputs in agriculture is strongly influenced by the farm specialisation and its total production yield, and an intense use of these chemical inputs can represent an economic loss and be technically inefficient for farmers (Singbo et al., 2015). Indeed, the overuse of pesticides is technically inefficient, and has commonly been a bottleneck for Italian farms; hence, it is important for policy makers to stimulate specific actions aimed at reducing the use, and more particularly the overuse, of pesticides in agriculture (Singbo et al., 2015). However, not all the policy measures financed through the Common Agricultural Policy aimed at reducing the use of pesticides in agriculture seem to have gained enough traction among European farmers to have had a significant impact on their overuse within the primary sector (Chèze et al., 2020). These authors have investigated the willingness of farmers to reduce their use of pesticides through a discrete choice experiment approach. Their study has demonstrated that variable risk is the main constraint in the farmer's choice to reduce chemical use, and the injection of external revenue proves to be a good incentive to action, even if farmers are already generally aware that pesticides and other chemical products can have a serious environmental impact.

Reductions in the use of chemical inputs generally lead to reduced production yields and, in turn, increased use of other inputs such as machinery and labour in order to maintain the same levels of output (Manevska - Tasevska et al., 2021; Hansson et al., 2019). In many cases, the choice to reduce the use of a specific input is correlated to a clear management decision on the part of farmers who are not focused on increasing productivity but, instead, are motivated to pursue other, perhaps even inefficient, aims such as environmental protection. Such instances can be defined as rational inefficiency, representing a choice to be technically inefficient in an economic perspective in order to meet particular targets that cannot otherwise be codified according to a traditional economic point of view (Asmild et al., 2003; Bogetoft and Hougaard, 2003).

The estimation of technical efficiency through a non-parametric quantitative approach such as Data Envelopment Analysis (DEA) has been carried out by Skevas et al. (2014 and 2012) to evaluate the impact of environmental spill overs of chemical inputs that reduce the technical efficiency of land capital and cause a drop in total output (Skevas and Lansink, 2014; De Koeijer et al., 2002). According to these authors, through an analysis of technical efficiency, it is possible to quantify by how much it is possible to reduce pesticide use without generating any loss in output. Analysis of the relationships between different types of farming specialisation and the use of chemical inputs reveals that vegetable producers are generally less efficient in their use of pesticides than are other types of farming, due to their overuse of these chemical products. Many studies carried out in countries like Denmark, Germany, the Netherlands, France, and the United Kingdom highlight that various initiatives have been launched by the national authorities in these countries during the last seven-year programming period (2014–2020) of the Common Agricultural Policy aimed at reducing the use of chemical pesticides (Barzman and Dachbrodt-Saaydeh, 2011). These latter two authors have argued that the diffusion of knowledge and skills in rural areas is an important starting point for reducing the use of pesticides in the primary sector. In their study, Cowan and Gunby (1996) found that the control of the use of chemical inputs in the primary sector represents a primary tool in influencing farmers' decision-making, generating a reciprocal and common competition in management choices regarding the use of chemical inputs in farms that is also able to increase the level of environmental protection in rural areas. A recent literature review has underlined that policy decisions regarding a better use of chemical inputs should pay appropriate attention to the heterogeneous behaviour and rational decision making of farmers, and the degree to which conversion to organic methods or other agri-environmental measures financed by the CAP have influenced the technical efficiency of farms (Möhring et al., 2020). However, implementing new farming strategies aimed at reducing chemical inputs in farms is very demanding in terms of labour use, which necessarily becomes very intense (Shattuck, 2021).

Indeed, as Shattuck argues, while adherence to agri-environmental policies has an effect on the environment, it also has a notable impact on the need for investments in capital, the introduction of new technologies, and on farm management.

The main purpose of this research was to analyse the effect of agri-environmental policy on Italian farms, measured in terms of the impact that the financial subsidies allocated under the second pillar of the Common Agricultural Policy have had on farm technical efficiency. The analysis has been carried out on a sample of Italian farms that are part of the Farm Accountancy Data Network (FADN) dataset between 2004 and 2019. The relationship between technical efficiency and agri-environmental subsidies has been investigated considering the main different types of farming in order to assess whether any impact these payments have had on technical efficacy is related to the specific productive specialisation of the farm. This quantitative research has filled the gap in understanding the effect of agri-environmental policies on technical efficiency in farming using a two-stage approach. This represents something new in the Italian literature, since other studies have used only a traditional DEA approach, and their results have been mixed and rather inconclusive. In fact, Minviel and Latruffe (2017) argued that the financial subsidies allocated under the agri-environmental policy have had a negative impact on technical efficiency, but without using a two-stage approach, which is more specific in assessing the direct impact of agri-environmental payments. The policy implications of this study are twofold. It is possible, firstly, to investigate if the impact of agri-environmental policy implies a reduction in the technical efficiency of farms in function of their specialisation and, secondly, to assess whether the allocation of financial support to compensate for the reduction of technical efficiency following new CAP strategies should be stratified according to the type of farming practiced

3. Methodology

The assessment of technical efficiency has been performed using two different approaches: a parametric approach, namely Stochastic Frontier Analysis (SFA) as proposed by Farrell in 1957, and a non-parametric approach, namely Data Envelopment Analysis (DEA) as proposed by Charnes et al. in 1978 and Banker et al. in 1984 (Aigner et al., 1977; Lovell, 1993; Coelli et al., 2005; Battese and Coelli, 1992; Kumbhakar et al., 2015; Charnes et al., 1978; Banker et al., 1984; Bravo-Ureta and Pinheiro, 1993; Battese, 1992; Coelli, 1996). The DEA does not require a well-defined production function, and it is able to use multiple inputs and outputs at the same time. The measurement of technical efficiency in the DEA input-oriented approach is represented simply by the distance of different inputs and outputs from the estimated production function made by a linear programming combination (Coelli et al., 2005; Battese and Coelli, 1995; Charnes et al., 1978; Banker et al., 1984).

In the first stage of the estimation of technical efficiency, the DEA input-oriented approach has been applied to a sample of Italian farms included in the FADN dataset. The following stage has been addressed to assessing the specific and exclusive impact of the agri-environmental subsidies paid by the European Union to the farms in the sample under the second pillar of the Common Agricultural Policy. For this part of the study, the two stage DEA input-oriented approach has been used. This method has the advantage of allowing the estimation of the impact of an environmental variable such as, in this case, the subsidies paid by agri-environmental measures. The two stage DEA input-oriented model considers the agri-environmental payments as an exogenous variable able to influence the level of technical efficiency of farms that has previously been estimated using Data Envelopment Analysis.

In this research the elements used as input variables are: total labour, expressed as total hours of work in a farm over the year; land capital endowment, measured in hectares of usable agricultural area (UAA); specific costs linked to the production, such as crop protection, fertilisers, pesticides, seeds, and other costs with a nexus to the farm output; total farming overhead costs, which are costs linked to production activities but not attributable to specific lines of production; and assets, including agrarian capital, fixed assets, and investments. On the other side, the total output produced in farms represents the entire production of the farm, made up of crops, animals, as well as any other activities such as agritourism, energy, and contracting activities conducted outside the farm. The environmental variable (Z) is the total amount of financial subsidies disbursed through the second pillar of the Common Agricultural Policy in relation to agri-environmental policy measures. All the variables, that is, the inputs, the environmental variable, and the output, are expressed in Euros, and have been discounted using the price index for the year 2015 published by Eurostat in order to make the comparison more stable by eliminating fluctuations in values over time.

In this paper, the estimation of technical efficiency in the first stage has been made using the input-oriented DEA approach with the aim of minimising the level of input by solving a linear programming problem, as proposed by Charnes et al. (1978) in a dual form (Charnes et al., 1978; Banker et al., 1984; Coelli et al., 2005; Bravo-Ureta and Pinheiro, 1993; Battese and Coelli, 1992; 1995; Galluzzo, 2013; 2020). The value of technical efficiency lies between 0 and 1. Where a farm has a value of technical efficiency equal to 1, this implies that the enterprise is operating on the frontier of the optimal technical combination of input-output. Conversely, a technical efficiency value of below 1 implies a surplus in the use of the inputs between the value of technical efficiency estimated by the DEA and the optimal value equal to 1.

In the second phase of this research, the two stage DEA has been used with the aim of estimating the impact of the selected environmental variable, namely the financial subsidies allocated under the agri-environmental policy measures. Through the separability test, the study has assessed whether any change in the technical efficiency is due to the selected environmental variable (Simar and Wilson, 2007; 2011; Daraio et al., 2018; Daraio and Simar, 2005; Kourtesi et al., 2012; Wang and Schmidt, 2002).

The assumption of separability in the two stage DEA is that the environmental variable (Z), in this case the subsidies allocated through the agri-environmental measures, is a vector able to act on the input and output variables and on the production function, changing the shape of the function made by a combination of inputs and outputs with the consequence that the inefficiency is not dependant on the environmental variable (Bădin et al., 2010; 2012; Kourtesi et al, 2012; Wang and Schmidt, 2002). If the hypothesis of separability is verified, this implies that the environmental variable has no impact on the level of technical efficiency, whereas, if the assumption of separability is rejected, it can be said that the environmental variable does have an influence on the level of efficiency (Simar and Wilson, 2011; Kourtesi et al., 2012; Daraio et al., 2018). Drawing some conclusions regarding separability, if the hypothesis is null, the two boundaries of production function with and without the environmental variable are the same (Kourtesi et al., 2012; Wang and Schmidt, 2002; Bădin et al., 2010; 2012; Simar and Wilson, 2007; 2011; Daraio et al., 2018; Daraio and Simar, 2005). This can be estimated, as Daraio et al. proposed (2015 and 2018), according to these two formulae:

$$\hat{\tau}_n = [\textstyle\sum_{i=n}^{n} (\hat{D}'_{FDH,i,n})(\hat{D}_{FDH,I,n})]/n \geq 0 \quad (1)$$

where n is the sample size

$$\hat{D}_{FDH,I,n} = Y_i(\hat{\lambda}_{FDH,i,n}(X_i,Y_i) - \hat{\lambda}_{FDH,i,n}(X_i,Y_i IZ_i) \quad (2)$$

A large value of τ rejects the null hypothesis of separability, meaning the environmental variable has an effect. The null hypothesis has been tested using the global separability test proposed by Daraio et al. (2010) with a level of significance α at 0.05.

4. Results and discussion

The overall sample of Italian farms investigated over the period 2004-2019 comprises 3,576 enterprises spread throughout all 20 Italian regions (Tab. 1). Broken down by farming type, the single largest group of these are specialised in field crops (1,169), with the second most represented type being other permanent crops (695). At the other end of the scale, the smallest cohorts of farming type among the investigated sample of Italian farms are granivores and mixed farming, which accounts for 121 and 97 of the farms, respectively. Focussing attention on economic size, with the distribution of farming types stratified in function of their level of standard output, it emerges that at the lower end, in the cluster of farms with a standard output of 2,000-8,000 Euros, the vast majority are specialised in field crops. In contrast, the Italian farms with a standard output of above 500,000 Euros are, for the most part, specialised in granivores.

The average value of land capital for all farms included in the sample is 32.54 hectares, with a range from between 0.44 and 490.08 hectares. In fact, this average land capital value of 32.54 hectares for the farms included in the sample is well above the average of 8.4 hectares estimated for all Italian farms according to the last Agricultural Census conducted by the National Italian Institute of Statistics (Istat).

The farms with the highest average value of usable agricultural area are those specialised in other grazing livestock, with around 55 hectares. Meanwhile, farms specialised in field crops show an average land endowment of close to 43 hectares, while the figure for milk farms is 48.42. In contrast, the lowest value of usable agricultural areas was found in Italian farms specialised in horticulture. Comparing economic size with physical dimensions, the finding show that a higher level of standard output is directly correlated to a greater usable agricultural area, with average land values ranging from 6.54 hectares in farms with an output of 2,000–8,000 Euros to 101.88 hectares in farms with a production of above 500,000 Euros.

The total labour input in farms ranged between 600 and 54,422 hours per year, in function of the type of farming carried out (Tab. 2). Total output, recorded in constant values over the period of investigation, averaged around 122,760 Euros per year, with a low value of 3,953 Euros and a maximum value of slightly over 4.2 million Euros, found in highly specialised horticultural and milk farms. Specific costs linked to production averaged 38,828 Euros, while total farming overhead costs amounted to an average of around 8,200 Euros. Financial subsides allocated through the Common Agricultural Policy, under both the first and second pillars, were close to 14,000 Euros, of which around one tenth related to subsides allocated by the CAP to environmental support. In contrast, financial payments allocated through the Rural Development Programme, or rather, the second pillar of the CAP, were close to an average of 2,400 Euros per farm (Tab. 1).

Over the period of investigation, the average value of technical efficiency in all Italian farms was equal to 0.5603. As the estimation of techni-

Table 1. Descriptive statistics of total output and agri-environmental subsidies in all Italian farms from 2004 to 2019

		Output			**Agri-environmental subsides**		
Type of farming	**n°**	**mean**	**min**	**max**	**mean**	**min**	**max**
Field crops	1,169	87,966	4,953	1,525,638	1,399.72	0	60,524
Horticulture	191	224,307	15,613	4,242,223	37,64	0	2,416
Wine	474	97,507	7,271	1,886,891	1,174.64	0	18,882
Other permanent crops	695	68,482	3,953	513,095	1,446.68	0	16,531
Milk	340	247,066	11,568	1,776,257	2,465.57	0	30,818
Other grazing livestock	489	85,596	9,054	1,706,173	1,911.31	0	18,981
Granivores	121	551,176	84,006	1,699,548	461.69	0	4,857
Mixed	97	41,324	12,555	247,444	520.36	0	5,679
All	3,576	121,947	3,953	4,242,223	1,421.96	0	60,524

Source: Author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

cal efficiency has been made using a DEA input-oriented, this result implies an excess of inputs of 44%; hence, in general, Italian farms have used a greater quantity of inputs to produce the same level of output.

Comparing the findings of the research, there is a difference of values in the technical efficiency estimated by the input-oriented DEA (0.5603) and the two stages DEA (0.4981). This difference in technical efficiency, estimated with and without the environmental variable, corroborates that the null hypothesis of separability can be rejected. As such, it can be affirmed that the environmental variable investigated does indeed have an important effect on the technical efficiency in Italian farms, as other authors such as Kourtesi et al. (2012) and Daraio et al. (2015 and 2018) have previously asserted.

Drawing some conclusions, these findings confirm that the participation of farmers in agri-environmental policy has a measurable effect on the technical efficiency of the farm. The level of technical efficiency estimated using the two stages DEA approach is lower than that estimated using the input-orientated DEA, meaning that participation in the agri-environmental measures has reduced the level of technical efficiency, as Minviel and Latruffe argued in 2017. However, although the results of both the DEA and the two stages DEA reveal a change in technical efficiency, neither approach is able to illuminate the patterns of inefficiency, or rather, they have not identified which input becomes less technically efficient as a consequence of the participation in the agri-environmental policy. This is one of the main bottlenecks of the DEA and the two stages DEA. In fact, as the findings of this study illustrate, the decision by farmers to participate in

Table 3. Technical efficiency change in all typologies of farming estimated using the DEA and two stages DEA

Type of farming	DEA	2 stages DEA	t-test
Field crops	0.4906	0.4470	16.02***
Horticulture	0.7607	0.6130	10.75***
Wine	0.6167	0.5423	10.10***
Other permanent crops	0.6154	0.5389	11.29***
Milk	0.5398	0.4878	6.63***
Other grazing livestock	0.5070	0.4677	6.60***
Granivores	0.7264	0.6065	7.00***
Mixed	0.4674	0.4322	3.27***
Mean	0.5603	0.4981	20.75***

*** *p-value < 0.01*

Source: Author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

Table 2. Main descriptive statistics of input, output, and environmental variable used in the assessment of technical efficiency in Italian farms

	Output (Y)	Input (X)					Environmental (Z)
	Output (€)	Labour (hours)	Land Capital (ha)	Specific Costs (€)	Farming Overhead Costs (€)	Assets (€)	Agro-environmental Subsidies (€)
Mean	122,759.58	4,247.45	32.54	38,828.26	16,706.01	526,604.24	1,421.96
Median	54,496.45	3,365.11	18.82	11,957.50	8,201.50	312,615.45	396.50
Std. Deviation	220,164.29	3,295.03	42.71	90,953.16	29,075.72	797,965.75	2,854.96
Min.	3,953.00	600.06	0.44	719.00	433.00	37,231.26	0
Max.	4,242,223.00	54,422.15	490.08	1,596,323.00	585,326.00	19,857,546.00	60,524.00
Count	3,576.00	3,576.00	3,576.00	3,576.00	3,576.00	3,576.00	3,576.00

Source: Author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

agri-environmental measures has implied an increase in labour capital, a change in the level of assets invested in farms, and a drop in produced output and productivity, corroborating that, as other authors have previously argued, many variables are involved in the process of adhering to agri-environmental policy (Bertoni and Olper, 2012; Manevska - Tasevska et al., 2021; Garrone et al., 2019; Defrancesco et al., 2018).

Comparing the Kernel density function estimated for all the Italian farms in the sample, it emerges that the technical efficiency estimated by the two stages DEA (Fig. 1) indicates a continuous worsening in the technical efficiency and productivity of farms that are part of the cluster of farms involved in agri-environmental policy, as assessed by other studies (Minviel and Latruffe, 2017; Barath et al., 2020). The findings of this research have confirmed that the reduction or less intense use of pesticides and fertilisers in Italian farms has had the effect of reducing their technical and economic performances, as Skevas et al. proposed in 2014.

Comparing all Italian farms included in the dataset, the findings show that farms that have adhered to the agri-environmental policy have been less technically efficient than farms that have not (Tab. 3). This also underlines that a reduction in the use of pesticides and fertilisers, and the adoption of techniques more respectful of the environment influence the level of technical efficiency in farms. Focusing attention on the 8 main types of farming, a huge drop emerges in the technical efficiency of farms specialised in horticulture and granivores; in contrast, a smaller decrease in technical efficiency has been found in those farms specialised in mixed productions, in field crops, and in other grazing livestock. This implies that, in general, farms specialised in labour-intensive activities such as horticulture and wine making, and in which significant investments have been made in new tech-

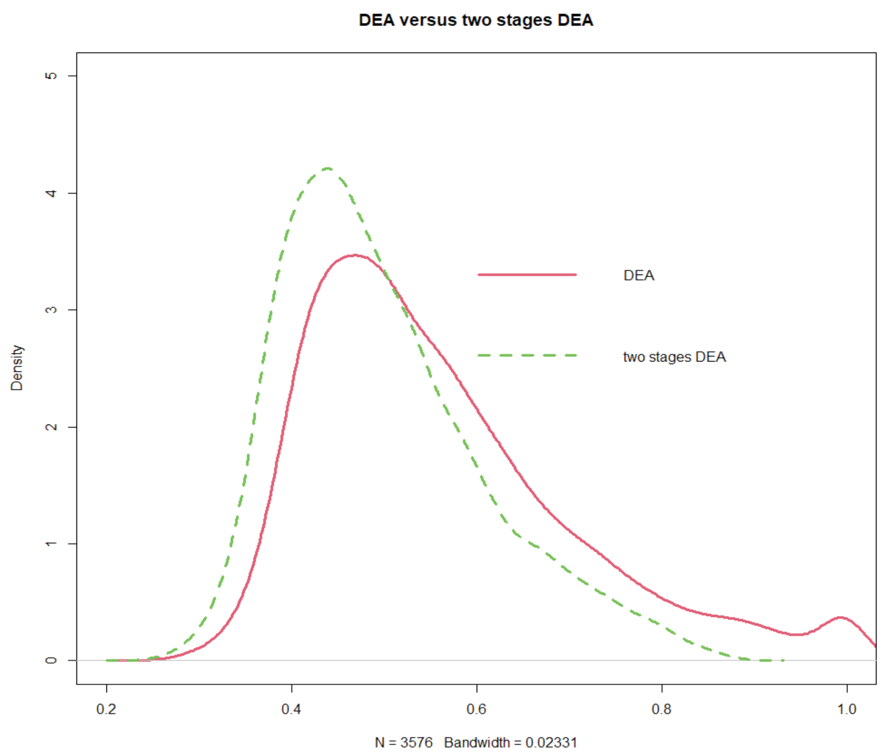

Fig. 1. Density function of the DEA and 2 stages DEA estimated in all Italian farms

Source: Author's own elaboration on data available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html.

nology, have been sensitive to the introduction of policy focused on reducing chemical inputs. In fact, in general, the findings have underlined that the intrinsic features of each farm, namely their specialisation and economic size, are the fundamental variables influencing their use of exogenous inputs such as pesticides and fertilisers and, therefore, their technical efficiency, as investigations in other European countries by Skevas et al. in 2012 and by Möhring et al. in 2020 have also shown.

5. Conclusion

In the European Union's agenda for the next period of Common Agricultural Policy planning for the development and economic growth of rural areas, there are many agri-environmental measures directed at stimulating farmers to adopt different practices. The farm to fork strategy has the primary objective of significantly reducing the use of pesticides and fertilisers in agriculture, generating a new approach in the primary sector and in environmental protection.

This study has clarified the effect that agri-environmental policy payments have had on Italian farms, and by comparing different types of farming using a non-parametric approach, corroborates that adherence to agri-environmental policy has had the effect of reducing the technical efficiency of farms. In fact, a literature review has revealed a vast array of research studies regarding technical efficiency assessed by non-parametric means that have been carried out in different European countries (Minviel and Latruffe, 2017; Galluzzo, 2013; 2018; 2020; Latruffe and Desjeux, 2016; Nowak et al., 2015; 2019; Balezentis, 2014). Although this analysis has not defined the patterns of inefficiency or, rather, excess, in all inputs and outputs due to the bottleneck in the DEA approach, it has filled the gap in Italian literature in defining the effect of agri-environmental financial subsidies on farms, as other studies have previously done for its neighbouring European countries (Minviel and Latruffe, 2017; Garrone et al., 2018).

This research has investigated the changes in the technology used in farms that have resulted from their participation in agri-environmental policies. The findings underline that adherence to the agri-environmental measures introduced by the CAP has led to a reduction in the technical efficiency in farms and that, therefore, this negative consequence of participation should be considered an opportunity cost that must be adequately compensated through specific financial support. The aim of this support should be, on one hand, to compensate for the reduced productivity output and, on the other, to support a radical change in investment for fixed capital, machinery, and for a different use of labour capital. This latter input is overbuilt in case of adherence to agri-environmental policy and the surplus labour should be redeployed to other on-farm activities such as agritourism or contracting. Furthermore, a radical change in farm management has implied an increase in the use of other inputs such as machinery and labour in order to obtain an adequate level of production (Manevska - Tasevska et al., 2021; Hansson et al., 2019). According to these latter authors, the choice of farmers to adopt agri-environmental measures should represent a clear and rational decision, which is counted as a rational inefficiency due to the decision to actively participate in the protection of the environment or to adhere to legislative constraints applied in ecologically vulnerable zones that push farmers to reduce their use of chemical inputs in exchange for adequate financial support to compensate their lower production output.

Farms specialised in growing vegetables as field crop farms have been less sensitive to the drop in technical efficiency than farms specialised in milk, wine, horticulture, or other animal production. This is in line with studies carried out by Singbo et al. in 2015, according to which vegetable productions are less technically efficient in the use of certain chemical inputs such as pesticides. It is important to note how mixed farms, characterised by having the lowest levels of technical efficiency, have a smaller margin in terms of being able to suffer the further reduction in their technical efficiency, considering also that these farms are predominately of small-medium dimension, with a standard output of less than 25,000 Euros. This has pushed farmers belonging to the mixed farming cluster to seek to diversify their activities.

Drawing some conclusions for the future, it is important that policies implemented by the Common Agricultural Policy consider the economic size of farms as well as their level of technical efficiency as a variable influencing their participation in agri-environmental policies. The small farms that represent the vast majority of Italian agricultural enterprises are more sensitive to changes in management and to the reduction of certain inputs. The consequence of a worsening in the economic performances of farms could provoke an exodus from the countryside, with the effect of increasing the socio-economic marginalisation in Italian rural areas. As such, the agri-environmental policy measures instituted and financed by the Common Agricultural Policy must take into consideration the socio-economic aspects of participation, and the level of financial support to small Italian farms must be enhanced, perhaps also, as Van der Ploeg (2009) and Bojnec and Ferto (2012) proposed, offering different types of subsidies tailored to increasing the job opportunities available in rural areas.

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