AGRI-ENVIRONMENTAL PAYMENTS AND TECHNICAL EFFICIENCY IN SOME SPECIALISED ITALIAN FARMS

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Abstract
In the early 1990s the European Union has defined areas characterized by being nitrate vulnerable according to the Council Directive 91/676/EEC. In the same time, some major changes in the Common Agricultural Policy have proposed new actions in farms aimed at reducing the use of fertilizers and pesticides which has been compensated by the payments of agri-environmental measures. The main purpose of this research was to investigate if the technical efficiency of farms in function their location in area nitrate vulnerable whose percentage value is above the average estimated in all Italian regions and if the farming specialization impacts in the technical efficiency. The estimation of these two aspects since 2004 to 2020 using the FADN dataset has been done using the Data Envelopment Analysis (DEA) and the Multidirectional Efficiency Analysis (MEA) able to assess the technical efficiency in each used input and produced output. Research's findings have underlined as farms located in nitrate vulnerable areas have been characterized by an higher level of technical efficiency in and output even if they receive a less amount of agri-environmental payments. The specialization in farms seems to be driver able to impact in the technical efficiency as well.

Keywords: *Data Envelopment Analysis, MEA, cereal farms, milk, FADN, nitrate vulnerable areas.*
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Introduction
The most recent comparative literature review about technical efficiency and financial subsidies allocated by the Common Agricultural Policy in all European Union Member States (Mikus et al., 2021) revealed that the majority of studies have been carried out in well defined and geographically delimited areas comprising, predominantly, northern and western European countries (United Kingdom, Germany, Sweden, Belgium, Denmark) and unique type of crops or livestock. A paucity of studies has involved Central and Eastern European countries, such as Italy, aimed at assessing the reason for farmers in participating in agri-environmental policy measures (Mikus et al., 2021). For these reason the present research aims to fill these gap in literature and it is a novelty in order to investigate what could be the driving factors that pushed Italian farmers to adhere to agri-environmental policies.
Lastra-Bravo et alii (2015) highlighted how the type of agri-environmental policy available plays an important role influencing the farmer's choice to adhere to agri-environmental measures. In fact, the different measures financed by the Common Agricultural Policy implying specific commitments could be a dissuasive factor for the farm household and the rural community to participate in agri-environmental policies. Defrancesco et alii in 2018 argued as farm size, in terms of land capital, especially in farms with large usable agricultural areas in association to the age of farmer were two variables stimulating the farmer's participation to agri-environmental policies.

Unclear in the literature is the relationship between farm location in nitrate vulnerable areas, agri-environmental payments and technical efficiency.

1. Literature review

In literature, there were few aimed at assessing whether participation in agri-environmental policies influenced the overall technical efficiency of the farm (Mikus et al., 2021; Minviel & Latruffe, 2017). This represented a gap in the literature that this research is able to partially fill. In addition, a further aspect that has been not investigated in depth in the literature is to analyze whether farms that decided to adhere to agri-environmental policies had been pushed in this decision by other exogenous variables such as the location of farms in nitrate vulnerable areas as defined by the Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. This last field of study is also a missing topic in the Italian agrarian-economic literature.

Research's findings carried put in other European countries have indicated that the pollution could be reduced with no impact on the output level in some specialized farms hence, incentives to reduce nitrate pollution can impact to the technical efficiency in farms (Latruffe et al., 2013). In the Northern Italy a study carried out in rice, cereals, and livestock farms has analyzed aspects of economic, agronomic and ecological sustainability (Paracchini et al., 2015). According to these authors, results have pointed out as the decision of farms have had impacts to farms performances. In fact, the use of environmentally friendly techniques, imposed by participation in agri-environmental policies and as a result of the agri-environmental commitments, modifies the use of specific inputs, as land, labour, fertilizers, thereby reducing the produced output and consequently the technical efficiency (Hansson et al., 2020; Asmild et al., 2016; Minviel and Latruffe, 2017; Garrone et al., 2019; Latruffe & Nauges, 2014).

Minviel and Latruffe (2017) proposed a recent literature review and throughout a meta-analysis have pointed out as there are lots of researches addressed at estimating the impact of financial subsidies allocated by the Common Agricultural Policy in many European Union (EU) countries to farm's technical efficiency. According to these two authors, the estimation of relationships between public subsidies allocated by the Common Agricultural Policy on farm technical efficiency is a critical issue in policy analysis. In fact, a systematic literature review has found as agri-environmental subsidies are negatively associated with farm technical efficiency in most investigated studies (Minviel & Latruffe, 2017). By contrast, the share of total subsidies on total farm revenues has had negative impacts on technical efficiency in some EU countries (Zhu & Lansink, 2010). The reason of these unclear and contrasting effects is due to the farm size and the degree of specialization as investigated in other European countries (Galluzzo, 2013; 2022; Zhu & Lansink, 2010). Galluzzo in 2021 has also argued as in several European nations such as Italy, France, Slovenia, Hungary and Poland technical and allocative efficiency has been influenced by the crop specialization, by the agri-environmental policy, by the typology of ownership and by the dimension of farm in terms of land capital endowment (Cisilino et al., 2021; Galluzzo, 2016; 2013; Latruffe et al., 2017; Gorton & Davidova, 2004; Latruffe & Nauges, 2014; Bojnec & Latruffe, 2013; Garrone et al., 2019).

Few studies have investigated the patterns of inefficiency in farms participating to agri-environmental policies in all European countries. The literature review it is not able to explain the real reasons which push farmers in being involved in some agri-environmental actions financed by the Common Agricultural Policy (CAP) and specifically some patterns of inefficiency correlated to this decision (Uthes & Matzdorf, 2016). In fact, the participation to the CAP measures such as agri-environmental policies implied a reduction in technical efficiency and this could be a direct consequence of a specific rational choice of farmers explained by the hypothesis of rational inefficiency (Bogetoft & Hougaard, 2003). In conclusion, a recent literature review carried out in two European Union Nations as Italy and Romania have underlined by a non-parametric approach as the effect of the financial subsidies disbursed by the first and second pillar of the CAP can diverge with no positive and unclear effects on the technical efficiency (Romagnoli et al., 2021; Galluzzo, 2021).

2. Aim of the research

In the early 1990s the European Union has defined in all European countries some areas characterized by being nitrate vulnerable. In fact, the Council Directive 91/676/EEC of 12 December 1991 has proposed some constraints to farmers in order to protect water against pollution caused by nitrates from agricultural sources. Using some sources of data published by the Italian Minister of Environment and by the Italian Minister of Agriculture it has been possible to define in each Italian regions the share of usable agricultural areas nitrate vulnerable on the total usable agricultural areas.

Farmers could decide to participate to agri-environmental measures because a significant share of cultivated land is located in nitrate vulnerable areas. Consequently, these constraints have represented pivotal and exogenous pillars in the decision process of participation to the agri-environmental measures financed by the Common Agricultural Policy.

The main purpose of this research was multidimensional and innovative in the field of the Italian studies currently published in the literature about the technical efficiency, namely:

1) to investigate the technical efficiency of farms in function if farms are located in area nitrate vulnerable above the average value estimated in all Italian regions;
2) the participation to the agri-environmental policy diverges from four different specialised typologies of farming such as specialist cereals, oilseeds and protein crops (COP), milk farms (MILK), cattle farms (CATTLE) and mixed crops and livestock (MIXED);
3) to assess the inefficiency patterns between farms located in Italian nitrate vulnerable areas above the average value or not in each input and output variable involved in the production process;
4) to estimate which inputs have been more or less technical inefficient hence, if it is possible to define and address specific policies by the Common Agricultural Policy.

3. Methodology

In general, there are two different methodologies aimed at assessing the technical efficiency; one through a parametric or stochastic modelling (SFA) not used in this research and another by a non-parametric modelling using the Data Envelopment Analysis (DEA) method (Coelli et al., 2005; Kumbhakar et al., 2015; Galluzzo, 2021). The DEA had the positive aspect to estimate multiple inputs and multiple outputs without *a priori* defined functions of production and other specifications in the model (Coelli et al., 2005; Galluzzo, 2021).

In this paper, the DEA approach has been used in an input oriented variable returns to scale (VRS) model with the aim of minimizing inputs as showed in table 1 in all farms included in the Farm Accountancy Data Network dataset since 2004 to 2020. In order to define a dummy variable 0/1 aimed at comparing the location in farms in nitrate vulnerable areas, it has estimated the average value of usable agricultural areas located in nitrate vulnerable areas on the total agricultural areas. If the value of average value of usable agricultural areas located in nitrate vulnerable areas on the total agricultural areas has been above the average national value it has been assigned the value 1 and 0 otherwise.

One of the main bottlenecks of the DEA is due to the incapacity in identifying inefficiency or efficiency patterns in each input and output variables and this weakness of DEA is effectively overcome by a new approach as the Multi-directional Efficiency Analysis or MEA (Bogetoft & Hougaard; 2003; Asmild et al., 2003; Hansson et al., 2020). According to these authors, MEA has the advantage of simultaneously estimating efficiency in multi-input and multi-output models and assessing inefficiency in each of used inputs and produced outputs in the production process (Manevska-Tasevska et al., 2021).

Table 1. Input and output variables used in the estimation of technical efficiency in Italian farms

Variable	Unit	Description
Labour	hours	Time worked in hours by total labour input on holding
Land capital	ha	Usable agricultural areas in farms
Specific cost	Euro	Crop-specific inputs (seeds and seedlings, fertilizers, crop protection products, other specific crop costs), livestock specific inputs (feed for grazing stock and granivores, other specific livestock costs) and specific forestry costs
Overhead farm cost	Euro	Supply costs linked to production activity but not linked to specific lines of production
Assets	Euro	Only fixed and current assets in ownership are taken into account. Capital indicators are based on the value of the various assets at closing valuation
Total output	Euro	Total output produced plus agri-environmental payments allocated by the CAP
Output other activities	Euro	Output produced from other on farm activities

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/ FADNPublicDatabase.html

The MEA approach makes possible to identify some deviations from the production frontier, expressed in terms of productivity change, that are due to variables not incorporated in the analysis of technical efficiency (Bogetoft & Hougaard; 2003, Hansson et al., 2020).
In order to assess the relationships between financial subsidies disbursed by the CAP and the technical efficiency, Baležentis and De Witte in 2015 argued as in Lithuanian farms there was negative correlation between subsidies paid on production and technical efficiency as well. MEA scores take a value between zero for totally inefficient firms and 1 for totally efficient farms without any excess inputs or outputs. Scores of value 1 indicate that there is no potential for improvement on the input/output variable in question while an input efficiency score of less than unity indicates that farms could reduce the input to be efficient. The estimation of the technical efficiency in terms of DEA and the excess in input by the MEA approach has used the RStudio software packages deaR, rDEA and Benchmarking.

4. Results and discussion

Table 2 has pointed out as dairy farms have had the highest level of labour used in the production process with more than 4.500 hours per year with the more significant value of asset in farm. The land capital has been very high in the farms specialized in cattle. The total output has had the highest value in dairy farms. On the contrary mixed farms have had the highest value of output from other activities with a value close to 6.000 euro.

Table 2- Main descriptive statistics in all investigated specialized type of farming.

Type of farming	Labour	Land	Specific costs	Farm overhead cost	Assets	Total output	Other output
COP (n°)	**243**	**243**	**243**	**243**	**243**	**243**	**243**
Average	2123,404	26,69	9150,823	8780,831	402523,5	33982,7	1894,588
St. dev.	547,0099	9,454945	5467,063	4462,81	180551,5	21876,56	2087,153
MILK (n°)	**293**	**293**	**293**	**293**	**293**	**293**	**293**
Average	4546,971	33,58	69722,84	17463,48	692989,1	165661	3622,075
St. dev.	1002,341	13,85478	45079,73	11221,35	367754,8	97616,79	7326,782
CATTLE (n°)	**254**	**254**	**254**	**254**	**254**	**254**	**254**
Average	3300,472	37,97	27356,61	8853,61	434392,4	68785,78	3434,189
St. dev.	717,0503	17,15387	26987,5	6040,577	268821,8	56353,2	10098,73
MIXED (n°)	**255**	**255**	**255**	**255**	**255**	**255**	**255**
Average	3240,777	25,58	18238,18	10114,64	413967,7	58107,14	5859,463
St. dev.	760,3221	11,64563	13188,2	6247,574	238578,9	34942,17	8354,675
TOTAL Sample (n°)	**1045**	**1045**	**1045**	**1045**	**1045**	**1045**	**1045**
Average	3361,692	31,09	32776,8	11558,46	494503,8	85249,15	3720,67
St. dev.	1171,016	14,27927	36958,4	8487,951	303699,3	80716,3	7722,506

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/ FADNPublicDatabase.html

Table 3. Main descriptive statistics in farms located or not located in vulnerable nitrate areas above or below the national average value

	Labour	Land	Specific costs	Farm overhead cost	Assets	Total output	Other output
Farms not located in nitrate vulnerable area (Dummy 0)	**600**	**600**	**600**	**600**	**600**	**600**	**600**
Average	3294,035	31,2435	25613,02	9172,193	425062,3	69125,82	3028,095
St. dev.	1155,884	14,98455	28111,61	5619,835	245645,9	59855,35	5846,753
Farms located in nitrate vulnerable area	**445**	**445**	**445**	**445**	**445**	**445**	**445**

(Dummy 1)							
Average	3452,915	30,90013	42435,84	14775,91	588132,8	106988,5	4654,479
St. dev.	1186,315	13,28325	44528,24	10427,16	346645,5	98290,44	9622,231
Total farms	**1045**	**1045**	**1045**	**1045**	**1045**	**1045**	**1045**
Average	3361,692	31,09728	32776,8	11558,46	494503,8	85249,15	3720,67
St. dev.	1171,016	14,27927	36958,4	8487,951	303699,3	80716,3	7722,506

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

As mentioned in the methods paragraph, in order to assess if the share of land area classified as nitrate vulnerable on the total land has implied some effect in the participation to the agri-environmental payments it has used a dummy variable 0/1 in function of location of the farms in regions where the share of vulnerable areas is under the average value or above the average value.

The descriptive statistics have underlined as farms located in vulnerable areas need more labour than farms located in area with a share of vulnerable nitrate areas under the average value (Tab. 3). Differences do not exist between these two typologies of farms in terms of land capital which has been almost the same. The input specific costs, overhead costs and assets have been higher in farms located in areas where the percentage of land classified as nitrate vulnerable have been above the average value. Addressing the attention to the output variables research's findings have pointed out as farms located in areas with a modest share of land classified as vulnerable under the national average value have had an higher and significant amount of total produced output and output comes from other activities in farms.

Table 4. Technical efficiency estimated by the DEA comparing the two groups of farms

Group	Observation	Mean	Std. Err.	Std. Dev.
Under the average (Dummy 0)	600	0,7124	0,0057	0,1416
Above the average (Dummy 1)	445	0,8726	0,0046	0,0982
Combined	1045	0,7806	0,0045	0,1479
Difference		-0,1601	0,0078	

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

Table 5. MEA estimated comparing the two groups of farms above (dummy 1) and under (dummy 0) the average national value of vulnerable areas

Variable	Labour	Land	Specific costs	Farm overhead cost	Assets	Total output	Other output
Under the average (Dummy 0)	**599**	**599**	**599**	**599**	**599**	**599**	**595**
Average	0,798	0,840	0,836	0,844	0,825	0,795	0,343
St. dev.	0,085	0,065	0,076	0,064	0,076	0,107	0,310
Above the average (Dummy 1)	**445**	**445**	**445**	**445**	**445**	**445**	**440**
Average	0,889	0,911	0,921	0,905	0,887	0,935	0,465
St. dev.	0,082	0,062	0,056	0,074	0,080	0,054	0,349
t-value	-17.32	-17.70	-19.86	-14.01	-12.60	-25.02	-5.91
Significance	***	***	***	***	***	***	***

p-value <0.01

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

The financial subsidies allocated in the second pillar of the CAP such as agri-environmental payments have pointed out in farms classified as under the average value of nitrate vulnerable areas on the total usable agricultural area (dummy 0) have received 1.394 euro per year while farms classified as above the average value of nitrate vulnerable areas on the total usable agricultural area (dummy 1) got 827 euro.
The estimation of the technical efficiency by the VRS input oriented in all Italian farms specialized in COP, MILK, CATTLE and MIXED has been close to 0.78 under the frontier of production and the optimal threshold close to 1 (Tab. 4). On the contrary farms located in areas where the share of incidence of vulnerable areas has been under the average value has been lower than farms located in areas where the percentage of vulnerable areas has been above the average value. In fact, these latter farms have had a value of technical efficiency close to 0.87. The statistical test between these two groups of farms have underlined as there is a statistical difference assessed by the t-test -20.48 with a p-value <0.001.

Table 6. Technical efficiency and MEA estimated comparing typologies of farming belonging to regions with a value of share of vulnerable areas under average national value (Dummy 0)

	DEA	Land	Labour	Specific costs	Farm overhead cost	Assets	Total output	Other output
COP	0.760	0.814	0.870	0.887	0.836	0.834	0.815	0.466
MILK	0.696	0.810	0.840	0.798	0.844	0.797	0.824	0.234
CATTLE	0.655	0.747	0.808	0.803	0.835	0.811	0.732	0.234

	DEA	Land	Labour	Specific costs	Farm overhead cost	Assets	Total output	Other output
MIXED	0.754	0.827	0.848	0.875	0.862	0.867	0.815	0.495
Total	0.712	0.798	0.840	0.836	0.844	0.825	0.795	0.343

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

Farms belonging of regions where the share of vulnerable area on the total usable agricultural areas has been under the average national value have pointed out the highest level of technical efficiency in farms specialized in cereal, oilseeds and protein crops (Tab. 6). Farms specialized in cattle farms have had the lowest level of technical efficiency in all used input and in the produced output. It is important to underline as farms specialized in cereals, oilseeds and protein crops have been more technically efficient for the output produced by other on farm activities.

Table 7. Technical efficiency and MEA estimated comparing typologies of farming belonging to regions with a value of share of vulnerable areas above average national value (Dummy 1)

	DEA	Land	Labour	Specific costs	Farm overhead cost	Assets	Total output	Other output
COP	0.870	0.869	0.924	0.921	0.866	0.868	0.920	0.486
MILK	0.883	0.911	0.908	0.927	0.924	0.898	0.951	0.381
CATTLE	0.864	0.885	0.908	0.909	0.925	0.892	0.928	0.408
MIXED	0.870	0.891	0.902	0.927	0.898	0.891	0.927	0.574
Total	0.872	0.889	0.911	0.921	0.905	0.887	0.925	0.465

Source: https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

Farms part of regions where the share of vulnerable area on the total usable agricultural areas has been above the average national value have been more technical efficiency compare to farms not belonging to this cluster of farms (Tab. 7).
In this case farms specialized in dairy have been more technical efficient in all input compared to the other type of specialized farms even if focusing the attention to the other output farms with a mixed specialization in livestock and crops have had the highest level of technical efficiency.

Conclusions

The technical efficiency is a crucial issue in the management of farms and the role of financial subsidies and other supports allocated by the second pillar of the Common Agricultural Policy do not seem to have driven in a direct and positive way the technical efficiency in farms located in areas with a share of vulnerable nitrate areas on the total usable agricultural areas above the national average value. In fact, these farms have received a modest amount of agri-environmental payments hence, there are an heterogeneity in technology as a fundamental factor driving the technical efficiency.

Farms located areas classified with a vulnerable nitrate areas on the total usable agricultural areas above the average have been more technical efficient than farms not located in areas with a significant incidence of the nitrate vulnerable areas and also they have positively used the modest financial subsidies allocated by the agri-environmental payments. Drawing some further final remarks payments allocated by the second pillar of the CAP in this case have had a positive effect and this is a novelty in this topic of study, in fact, previous studies have pointed out and ambiguous, mixed and sometime unclear affect of agri-environmental payments to the technical efficiency in farms (Minviel & Latruffe, 2017).

Furthermore, research's findings have underlined as farms located in vulnerable areas have used this constraint in order to improve their technical efficiency and they have been characterized by an higher level of technical efficiency in all used input and in all produced output. The specialization in farms seems to be a variable able to impact in a more o less efficient use of some input in farms.

References

1. Alexandri, C., Saman, C., & Pauna, B. (2021). Exploring the Relationship Between Farm Productivity and CAP Subsidies for the NMS. *Romanian Journal of Economic Forecasting*, *24*(4), 124.
2. Asmild, M., Hougaard, J.L., Kronborg, D., & Kvist, H.K. (2003). Measuring inefficiency via potential improvements. *Journal of productivity analysis*, *19*(1), 59-76.
3. Baležentis, T., & De Witte, K. (2015). One-and multi-directional conditional efficiency measurement–Efficiency in Lithuanian family farms. *European Journal of Operational Research*, *245*(2), 612-622.
4. Baráth, L., Fertő, I., & Bojnec, Š. (2020). The effect of investment, LFA and agri-environmental subsidies on the components of total factor productivity: the case of Slovenian farms. *Journal of Agricultural Economics*, *71*(3), 853-876.
5. Bogetoft, P., & Hougaard, J.L. (2003). Rational inefficiencies. *Journal of Productivity Analysis*, *20*(3), 243-271.
6. Bojnec, Š., & Fertő, I. (2018). Assessing and understanding the drivers of farm income risk: Evidence from Slovenia. *New Medit*, *17*(3), 23-35.
7. Bojnec, Š., & Latruffe, L. (2013). Farm size, agricultural subsidies and farm performance in Slovenia. Land use policy, 32, 207-217.
8. Bonfiglio, A., Henke, R., Pierangeli, F., & Pupo D'Andrea, M. R. (2020). Effects of redistributing policy support on farmers'technical efficiency. *Agricultural Economics*, *51*(2), 305-320.
9. Cisilino, F., Madau, F. A., Furesi, R., Pulina, P., & Arru, B. (2021). Organic and conventional grape growing in Italy: a technical efficiency comparison using a parametric approach. *Wine Economics and Policy*, *10*(2), 15-28.
10. Coelli, T.J., Rao, D.S.P., O'Donnell, C.J. & Battese, G.E. (2005). An introduction to efficiency and productivity analysis. *Springer Verlag. Berlin.*
11. Defrancesco, E., Gatto, P., & Mozzato, D. (2018). To leave or not to leave? Understanding determinants of farmers' choices to remain in or abandon agri-environmental schemes. *Land use policy*, *76*, 460-470.
12. Galluzzo, N. (2013). Farm dimension and efficiency in Italian agriculture: a quantitative approach. *American Journal of Rural Development*, *1*(2), 26-32.
13. Galluzzo, N. (2016). An analysis of the efficiency in a sample of small Italian farms part of the FADN dataset. *Agricultural Economics*, *62*(2), 62-70.

14. Galluzzo, N. (2020). A technical efficiency analysis of financial subsidies allocated by the CAP in Romanian farms using stochastic frontier analysis. *European Countryside*, *12*(4), 494-505.
15. Galluzzo, N. (2021). Estimation of the impact of CAP subsidies as environmental variables on Romanian farms. *Economia Agro-alimentare*, *23*(3), 1-24.
16. Galluzzo, N. (2022). Farms specialization, economic size and technical efficiency in Italian farms using a non-parametric approach. *Bulgarian Journal of Agricultural Science*, *28*(1), 36-41.
17. Garrone, M., Emmers, D., Lee, H., Olper, A. & Swinnen, J. (2019). Subsidies and agricultural productivity in the EU. *Agricultural Economics*, *50*(6), 803-817.
18. Gorton, M. & Davidova, S. (2004). Farm productivity and efficiency in the CEE applicant countries: a synthesis of results. *Agricultural economics*, *30*(1), 1-16.
19. Hansson, H., Manevska-Tasevska, G., & Asmild, M. (2020). Rationalising inefficiency in agricultural production–the case of Swedish dairy agriculture. *European Review of Agricultural Economics*, *47*(1), 1-24.
20. Kumbhakar, S.C., Wang, H.J. & Horncastle, A.P. (2015). A practitioner's guide to stochastic frontier analysis using Stata. *Cambridge University Press. Cambridge*.
21. Lastra-Bravo, X.B., Hubbard, C., Garrod, G., & Tolón-Becerra, A. (2015). What drives farmers' participation in EU agri-environmental schemes?: Results from a qualitative meta-analysis. *Environmental Science & Policy*, *54*, 1-9.
22. Latruffe, L., & Nauges, C. (2014). Technical efficiency and conversion to organic farming: the case of France. *European Review of Agricultural Economics*, *41*(2), 227-253.
23. Latruffe, L., Bravo-Ureta, B.E., Carpentier, A., Desjeux, Y., & Moreira, V.H. (2017). Subsidies and technical efficiency in agriculture: Evidence from European dairy farms. *American journal of agricultural economics*, *99*(3), 783-799.
24. Latruffe, L., Desjeux, Y., Bakucs, Z., Fertő, I., & Fogarasi, J. (2013). Environmental pressures and technical efficiency of pig farms in Hungary. *Managerial and Decision Economics*, *34*(6), 409-416.
25. Mikus, O., Vrtar, D., Hadelan, L., Susac, M.Z., & Rogelj, M.J. (2021). Policy impact and factors of farmers' participation in agri-environmental measures. *Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development*, 21(1).
26. Minviel, J.J., & Latruffe, L. (2017). Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. *Applied Economics*, *49*(2), 213-226.
27. Nowak, A., Kijek, T., & Domańska, K. (2015). Technical efficiency and its determinants in the European Union. *Agricultural Economics*, *61*(6), 275-283.
28. Paracchini, M.L., Bulgheroni, C., Borreani, G., Tabacco, E., Banterle, A., Bertoni, D., Rossi, G., Parolo, G., Origgi, R., & De Paola, C. (2015). A diagnostic system to assess sustainability at a farm level: The SOSTARE model. *Agricultural Systems*, *133*, 35-53.
29. Romagnoli, L., Giaccio, V., Mastronardi, L., & Forleo, M. B. (2021). Highlighting the Drivers of Italian Diversified Farms Efficiency: A Two-Stage DEA-Panel Tobit Analysis. *Sustainability*, *13*(23), 12949.
30. Uthes, S., & Matzdorf, B. (2016). Budgeting for government-financed PES: Does ecosystem service demand equal ecosystem service supply?. *Ecosystem Services*, *17*, 255-264.
31. Zhu, X., & Lansink, A. O. (2010). Impact of CAP subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden. *Journal of Agricultural Economics*, *61*(3), 545-564.