Effect of subsidies on technical efficiency excluding or including environmental outputs: An illustration with a sample of farms in the European Union

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Abstract:

With a sample of farms in the European Union (EU) and Farm Accountancy Data Network (FADN) data completed by additional data, we illustrate how the effect of farm subsidies on technical efficiency changes when environmental (good or bad) outputs are incorporated in the calculation of technical efficiency. Results indicate that the effect of the Common Agricultural Policy (CAP) operational subsidies on farm technical efficiency changes when environmental outputs (in this study: greenhouse gas emissions, nitrogen balance and ecological focus areas) are taken into account in the efficiency calculation: some effects change significance, and more importantly, some effects change sign.

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Abstract

With a sample of farms in the European Union (EU) and Farm Accountancy Data Network (FADN) data completed by additionally collected data, we illustrate how the effect of farm subsidies on technical efficiency changes when environmental outputs are incorporated in the calculation of technical efficiency. Results indicate that the effect of the Common Agricultural Policy (CAP) operational subsidies on farm technical efficiency changes when environmental outputs (namely greenhouse gas emissions, nitrogen balance and ecological focus areas) are taken into account in the efficiency calculation: some effects change significance, and more importantly, some effects change sign.

Keywords: **Technical efficiency; Subsidies; Environmental Outputs; Farms; European Union**

1 Introduction

Farm technical efficiency is a productivity indicator considering all outputs produced and all inputs used by the farms that enables to assess whether farms use the existing technology at best, by producing the highest possible level of output. As such, it is a component of competitiveness. The Common Agricultural Policy (CAP) in the European Union (EU) aims at promoting farm competitiveness, and hence a legitimate question is whether the CAP subsidies received by farms contribute to enhance their technical efficiency.

Several studies have investigated the effect of CAP subsidies on farms' technical efficiency, and in general the effect reported is negative (see e.g. Latruffe and Minviel, 2016). The main argument put forward to explain this negative effect is that subsidies have a negative effect on farmers' effort and hence on their technical efficiency (Martin and Page, 1983). Another, more recent, argument is that subsidies change farmers' attitude to risk and hence change their choice of (risky or not) inputs (Serra et al., 2008).

However, most studies investigating the effect of subsidies on technical efficiency consider only marketed outputs, i.e. food (and fibre and feed) sold and generating revenue. Non-marketed outputs such as environmental and social outputs are generally not considered. From a technical point of view, it is important to account for such outputs when possible so that farms producing such outputs are not penalised. Indeed, the calculation of classic technical efficiency includes all inputs used on the farm; however, some of the inputs may be used to produce some environmental good outputs (e.g. labour to plant hedges, hence increasing biodiversity) or to reduce some environmental bad outputs (e.g. capital in the form of manure cleaning-facilities, hence mitigating climate change effects). If such goods are not accounted for in the classical technical efficiency calculation, a farm using more inputs to produce environmental good outputs or to reduce environmental bad outputs, will appear less efficient than a farm producing the same marketed output but no environmental outputs (and hence using less inputs). This has also some importance from a policy point of view: a farm that uses subsidies so as to implement actions to increase environmental good outputs or to reduce environmental bad outputs, may have a lower classic technical efficiency compared to a farm receiving the same level of subsidies but using them for producing marketed outputs only. Hence, for the former farm, the effect of subsidies on classic technical efficiency would be negative, while it may be positive for the latter farm. This is even more relevant that there has been a gradual shift in policy interests, visible in the stronger focus on environmental and social goods in the CAP reforms. Competitiveness is now viewed not only in terms of food production, but also in terms of environmental and social sustainability. Hence, investigating the determinants of technical efficiency should be done by using an efficiency measure that considers marketed as well as non-marketed outputs.

An important obstacle to this investigation is the lack of data on non-marketed outputs. There exist a few studies that calculate farms' technical efficiency with environmental outputs: e.g. Oude Lansink and Reinhard (2004), Asmild and Hougaard (2006), Coelli et al. (2007), Piot-Lepetit and Le Moing (2007), Yang et al. (2008) and Latruffe et al. (2013) in the case of nutrients; Shortall and Barnes (2013), Toma et al. (2013), Njuki and Bravo-Ureta (2015) and Dakpo et al. (2016b) in the case of greenhouse gases (GHG); and Berre et al. (2013) in both cases. However, no study so far has investigated the effect of subsidies on such technical efficiency except for a preliminary work by Dakpo and Latruffe (2016) on a small sample of French livestock farms and for CAP agri-environmental subsidies. The authors find that being recipient of such subsidies decreases the sample farms' classic technical efficiency, but the effect is not significant when GHG emissions are accounted for in the calculation of technical efficiency. In addition, the level of CAP agri-environmental subsidies has no significant effect on the classic technical efficiency but a positive effect on technical efficiency accounting for GHG.

Here we contribute to this issue by incorporating various environmental outputs in the calculation of technical efficiency and performing the analysis of the effect of CAP subsidies on technical efficiency for a large sample of European farms. Our analysis relies on farm-level data for a sample of farms of the Farm Accountancy Data Network (FADN) in several EU countries (The Netherlands, Hungary, Finland, Poland, Spain, Ireland, Greece, France and Germany). The data include accountancy data from FADN as well as additional data collected via face-to-face survey or merging of existing data, depending on the country. All data relate to accountancy year 2015, except for France and Germany for which it is 2014.

This paper is organised as follows. The next section explains the methodology and describes the data. The following two sections present the results, while the last section concludes.

2 Methodology and data

2.1 Methodology

2.1.1 Calculation of technical efficiency

Technical efficiency is calculated here with the non-parametric method Data Envelopment Analysis (DEA), which constructs a frontier that envelops the sample at hand (see Coelli et al., 2005). Farms are located on or below the frontier. Farms on the frontier are the best performing farms of the sample, and are given a score of 1. Farms below the frontier are inefficient. They are provided a score below 1 and the distance to the frontier indicates the extent of their inefficiency.

Several methods have been proposed in the literature to incorporate environmental outputs in technical efficiency calculation (see Dakpo et al., 2016a for a review). Environmental outputs may be included as additional inputs or additional outputs under the weak disposability assumption, but this violates the materials balance principle and may result in unrealistic situations (e.g. where a polluting output is freely substitutable with a good output). For this reason, we follow the most recent method proposed in the literature, the one by Dakpo (2016). This method, called the extended by-production, consists in modelling two production technologies (one for the marketed output and one for the environmental output) and linking them with a constraint (see the application to French livestock farms in Dakpo et al., 2016b).

FADN data are used here to calculate the classic technical efficiency, that is to say with only the marketed output (food, feed and fibre). Four inputs are used in the DEA model to calculate this efficiency: land, in terms of the number of hectares (ha) of utilised agricultural area (UAA); labour, in terms of the number of annual working units (AWU) on the farm; capital, in terms of the value of fixed assets; and operational costs, in terms of specific costs to crops and livestock in Euros. One single output is used: the (marketed) food output, proxied by the value of total output produced by the farm.

After having calculated the classic technical efficiency (EFF), we calculate various technical efficiencies including environmental outputs. Before describing the various efficiencies calculated, it should be firstly noted that for the technology of the environmental output in the extended by-production model used here, it is assumed that capital and operational costs are pollution-generating inputs. We calculate five technical efficiencies with one or several non-marketed outputs, the above mentioned marketed output and the same four inputs described above:

- EFF_GHG: we include one bad environmental output, namely the quantity of GHG emissions at the farm level in tonnes of CO_2 equivalent (indicator computed from FADN and additionally collected data).
- EFF_N: we include one bad environmental output, namely the farm gate nitrogen (N) balance, calculated as N imported on the farm minus N exported from the farm, in kg of N ((indicator computed from FADN and additionally collected data).
- EFF_GHGN: we include the two bad environmental outputs, namely GHG emissions and N balance.
- EFF_EFA: we include one good environmental output, namely the number of hectares of Ecological Focus Areas (EFA) on the farm (indicator computed from additionally collected data).
- EFF_ENV: we include two bad environmental outputs (namely GHG emissions and N balance) and one good environmental output (namely EFA).

The six scores of technical efficiency (EFF, EFF_GHG, EFF_N, EFF_GHGN, EFF_EFA and EFF_ENV) are calculated separately for three sub-samples, depending on the production specialisation, since the technologies (and hence the efficient frontiers) differ across specialisations: farms specialised in field crops, farms specialised in grazing livestock, and farms with mixed crops-livestock. Output oriented frontiers are constructed, under the assumption of variable returns to scale (VRS).

2.1.2 Analysis of the effect of CAP subsidies

Technical efficiency is calculated with DEA in a first stage (six efficiency scores), as previously explained. In a second stage, the effect of CAP subsidies is analysed (for each efficiency score separately). The subsidies considered are all operational subsidies that is to say payments linked to production operations. They include, among others, direct payments to crops and livestock, Single Farm Payments (SFP), agri-environmental payments and Less Favoured Areas (LFA) payments; and exclude investment payments. The effect of the level of subsidies is investigated with the help of Ordinary Least Squares (OLS) regressions on each of the six technical efficiency scores. The explanatory variables in the OLS are UAA in hectares for crop farms or number of LU for livestock farms; labour in AWU; capital in Euros; capital to labour in Euros per AWU; share of rented land in UAA (for crop farms only); share of hired labour in total labour; share of crop output in total output; share of livestock output in total output; country dummies; and a subsidy proxy. In a first set of OLS regressions the subsidy proxy is the level of subsidies per hectare of UAA for crop farms, or the level of subsidies per LU for livestock farms. Field crop farms are considered as crop farms, while grazing livestock farms are considered as livestock farms. For farms with mixed crops-livestock both subsidies per hectare and subsidies per LU are included, in turn in separate regressions. In a second set of OLS regressions the subsidy proxy is the level of subsidies related to total output, for all farms.

2.2 Data

The sample used includes 772 farms. Table 1 provides descriptive statistics of the data used for each sub-sample. The average UAA of field crop farms is 160 hectares (ha). As for livestock farms, farms specialised in grazing livestock operate 74 ha and breed 100 LU on average, while the respective figures for farms with mixed crops-livestock are 173 ha and 144 LU.

In terms of subsidisation, all farms or almost all farms receive the CAP operational subsidies in the grazing livestock and mixed crops-livestock farm sub-samples. On average, field crop farms receive the lowest level of subsidies per ha: 108 Euros of subsidies per ha of UAA, compared to 379 for grazing livestock farms and 206 for mixed crop-livestock farms. The latter receive a higher average level of subsidies per LU compared to grazing livestock farms, namely 397 Euros per LU compared to 337 Euros. When subsidies are related to total output, grazing livestock farms are the most subsidised on average, with 0.229, indicating that for every Euro of output produced, these farms receive 22.9 cents.

<< *Table 1 about here* >>

3 Results

3.1 Technical efficiency with and without environmental outputs

Table 2 shows descriptive statistics of the technical efficiency scores. The number of farms are different depending on the technical efficiency score calculated because of missing information on some of the environmental outputs considered. In terms of classic technical efficiency (EFF), the average efficiency scores are quite moderate for field crop farms (0.577), grazing livestock farms (0.588) and, to a lesser extent, mixed crops-livestock farms (0.684). Such moderate scores indicate that farms are not clustered towards the efficient frontier, and indicate a higher heterogeneity of farm practices in the field crop and grazing livestock farm sub-samples, although the higher level of efficiency for mixed crops-livestock farms may be due to the smaller size of this sub-sample (curse of dimensionality).

When accounting for GHG (EFF_GHG), the average score is much higher for field crop farms, while it is slightly lower for grazing livestock and mixed crops-livestock farms. When N balance is accounted for (EFF_N), all sub-samples perform worse on average than when it is not accounted for. By contrast, when GHG and N balance are both included in the calculation of technical efficiency (EFF_GHGN), all sub-samples perform better than when the classic technical efficiency is considered. When EFA is included in the DEA model (EFF_EFA), then farms perform worse than in the case of classic technical efficiency for TF1 (field crop farms), TF4 (grazing livestock farms), and TF8 (mixed crops-livestock farms). Mathematically, it is expected that average technical efficiency scores are higher when the DEA model includes additional outputs, as the frontier envelops the sample more closely. Also, the number of farms is reduced when environmental outputs are included, which should also increase the average technical efficiency. Hence, the lower average scores of EFF_GHG for grazing livestock and mixed crops-livestock farms clearly indicate that farms within this sample are heterogeneous in terms of practices that lead to the production of GHG. The same conclusion can be drawn for all sub-samples in terms of N balance (EFF_N) and EFA (EFF_EFA).

<< *Table 2 about here* >>

3.2 Effect of the level of subsidies on technical efficiency

Table 3 presents the results when subsidies are related to UAA (crop farm sub-samples) or to the number of LU (livestock farm sub-samples), while Table 4 presents the results when subsidies are related to total output (all farm sub-samples). Table 3 indicates that the level of subsidies per ha or LU has a negative effect on the classic technical efficiency (EFF) for all three sub-samples (when subsidies are per LU in the case of mixed crops-livestock farms). When GHG emissions are included in technical efficiency (EFF_GHG), the significant negative effect is confirmed only for mixed crops-livestock farms (when subsidies are per ha or per LU), while the effect becomes non-significant for field crop farms and significant positive for grazing livestock farms. All this is confirmed when technical efficiency includes not only GHG but also N balance and EFA (EFF_GHGN and EFF_ENV). As for technical efficiency including N balance only (EFF_N) no significant effect is found. Regarding technical efficiency including EFA (EFF_EFA), the effect of the level of subsidies is significant (and negative) only for mixed crops-livestock farms when related to the number of LU.

When subsidies are related to total output in Table 4, compared to Table 3 some significant effects are confirmed: negative effects on technical efficiency (EFF) for grazing livestock farms and mixed crops-livestock farms; positive effect on the three scores of technical efficiency including GHG (EFF_GHG, EFF_GHGN, EFF_ENV) for grazing livestock farms; negative effect on technical efficiency with GHG (EFF_GHG) for mixed crops-livestock farms. However, some effects become non-significant when subsidies are related to output (Table 4) compared to when they are related to UAA or the number of LU (Table 3). This is the case for mixed crops-livestock farms and technical efficiency with GHG and N balance (EFF_GHGN), with EFA (EFF_EFA) and with all three environmental outputs (EFF_ENV). In addition, some effects that were not significant in Table 3 are now significant in Table 4: subsidies when related to output have a positive effect on technical efficiency with N balance (EFF_N) for grazing livestock farms, and a positive effect on technical efficiency with EFA (EFF_EFA) for field crop farms. But the biggest change in effect is on the classic technical efficiency for field crop farms: while subsidies per ha have a negative (significant) effect (Table 3), subsidies per output have a positive (significant) effect (Table 4). However, as underlined by Minviel and Latruffe (2016), it is likely that there are some endogeneity issues in the case where subsidies per total output are introduced as an explanatory variable because total output is already the dependent variable. Hence, these results should be considered with caution.

<< *Table 3 about here* >>

<< *Table 4 about here* >>

4 Conclusion

In this paper we investigated the effect of CAP operational subsidies on the technical efficiency of a selection of farms in the EU, when technical efficiency is considered in the classic way (that is to say with only the marketed output which is agricultural output), as well as when technical efficiency includes environmental outputs (GHG, N balance, EFA). The investigation of the effect of subsidies was performed with the level of subsidies related to a size variable (UAA or number of LU; total output) as an explanatory variable in OLS regressions on each technical efficiency score.

Whatever the size to which subsidies are related (physical size in number of ha or LU, or monetary size in terms of the value of output), our analysis highlights that the effect of subsidies on farms' technical efficiency changes when environmental outputs are taken into account in the efficiency calculation. (i) Some effects that are not significant on the classic technical efficiency become significant effects when environmental outputs are accounted for in the calculation of technical efficiency. This is for example the case for the effect of the level of subsidies per ha for mixed crops-livestock farms: no significant effect on the classic technical efficiency but negative significant effect on technical efficiency including GHG. (ii) Some effects that are significant on the classic technical efficiency become non-significant effects when environmental outputs are accounted for. This is for example the case for the effect on technical efficiency with most environmental outputs for field crop farms which is non-significant, while it is significant (negative or positive, depending on the subsidy proxy) on the classic technical efficiency. (iii) Finally, and more importantly, some effects that are negative on the classic technical efficiency become positive effects when environmental outputs are accounted for. This is for example the case for the effect of the subsidy proxy (whether per LU or per output) for grazing livestock farms: the effect on the classic technical efficiency is negative significant while the effect on technical efficiency with GHG alone or with N balance, or with N balance and EFA, is significant and positive.

Here we have used a selection of environmental outputs (GHG, N balance and EFA) but the choice may depend on the policy objectives and may be adapted to the main specialisation of the farms. The limiting factor to such analyses is however the availability of information on environmental outputs. Such information is generally complex to collect (e.g. a long list of information is needed to compute nutrient balances), may not be reliable (e.g. if farmers have not understood properly the definition of EFA elements), may not be provided (e.g. if farmers are afraid of governmental controls), and may be used along with specific assumptions (e.g. technical coefficients for the calculation of GHG emissions). The example here with a selection of farms from the EU FADN nevertheless clearly shows that accounting for environmental outputs may change the conclusions and policy recommendations, and hence efforts should be made to collect the necessary information.

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Tables

Table 1: Descriptive statistics of the data used per sub-sample

	Field crops farms	**Grazing livestock farms**	**Mixed crops-livestock farms**
Averages			
Total output (Euros)	231,516 (255)	194,473 (409)	256,788 (108)
UAA (ha)	160 (255)	74 (409)	173 (108)
Number of LU	8 (255)	100 (409)	115 (108)
Labour (AWU)	3.13 (255)	1.95 (408)	3.76 (108)
Capital (Euros)	1,111,268 (255)	1,025,139 (409)	817,110 (108)
Operational costs (Euros)	683,771 (255)	556,531 (408)	264,991 (108)
Capital to labour (Euros per AWU)	71,949 (254)	91,444 (409)	124,638 (108)
Share of rented land in UAA (%)	60 (255)	49 (409)	51 (108)
Share of hired labour in total labour (%)	19 (255)	11 (408)	16 (108)
Share of crop output in total output (%)	90 (255)	12 (409)	50 (108)
Share of livestock output in total output (%)	3 (255)	85 (409)	46 (108)
Subsidies (Euros)	22,208 (255)	25,580 (409)	46,002 (108)
Subsidies per ha (1,000 Euros)	0.108 (255)	0.379 (409)	0.206 (108)
Subsidies per LU (1,000 Euros)	7.493 (56)	0.337 (409)	0.397 (107)
Subsidies per output	0.173 (255)	0.229 (409)	0.193 (108)
Dummy=1 if farm subsidised	0.74 (255)	0.98 (409)	0.94 (108)
GHG emissions (t CO_2 equivalent)	22.5 (153)	479.5 (267)	307.7 (70)
N balance (kg N)	207 (151)	281 (266)	157 (71)
EFA (ha)	20 (255)	4 (409)	13 (108)
Total number of farms	**255**	**409**	**108**

Note: number of valid observations in brackets.

Source: the authors, based on FADN and additionally collected data

Table 2: Descriptive statistics of technical efficiency per sub-sample

	Field crops farms	Grazing livestock farms	Mixed crops-livestock farms
Classic technical efficiency (EFF)			
Number of farms	254	408	108
Efficiency mean	0.577	0.588	0.684
Efficiency standard deviation	0.252	0.223	0.228
Technical efficiency with GHG (EFF_GHG)			
Number of farms	152	266	70
Efficiency mean	0.815	0.532	0.572
Efficiency standard deviation	0.266	0.269	0.349
Technical efficiency with N balance (EFF_N)			
Number of farms	150	265	71
Efficiency mean	0.478	0.420	0.595
Efficiency standard deviation	0.333	0.316	0.302
Technical efficiency with GHG and N balance (EFF_GHGN)			
Number of farms	150	265	70
Efficiency mean	0.837	0.617	0.759
Efficiency standard deviation	0.243	0.265	0.231
Technical efficiency with EFA (EFF_EFA)			
Number of farms	254	408	108
Efficiency mean	0.472	0.332	0.502
Efficiency standard deviation	0.337	0.279	0.315
Technical efficiency with GHG, N balance and EFA (EFF_ENV)			
Number of farms	150	265	70
Efficiency mean	0.841	0.619	0.759
Efficiency standard deviation	0.240	0.266	0.231

Source: the authors, based on FADN and additionally collected data

Table 3: Results from OLS estimation on technical efficiency of subsidies per ha or LU

	Field crops farms	**Grazing livestock farms**	**Mixed crops-livestock farms**	
	Subsidies per 1,000 ha	Subsidies per 1,000 LU	Subsidies per 1,000 ha	Subsidies per 1,000 LU
Classic technical efficiency (EFF)				
Coefficient	-0.101	-0.093	-0.379	-0.143
t-value, significance	-1.66*	-2.7***	-1.46	-2.94***
No. of observations	254	408	108	108
Technical efficiency with GHG (EFF_GHG)				
Coefficient	-0.794e-3	0.212	-1.07	-0.214
t-value, significance	-0.01	4.46***	-1.86*	-2.27**
No. of observations	152	266	70	70
Technical efficiency with N balance (EFF_N)				
Coefficient	-0.124	0.042	-0.362	0.029
t-value, significance	-1.38	0.64	-0.82	0.38
No. of observations	150	265	71	71
Technical efficiency with GHG and N balance (EFF_GHGN)				
Coefficient	0.002	0.136	-0.818	-0.008
t-value, significance	0.03	2.74***	-2.17**	-0.13
No. of observations	150	265	70	70
Technical efficiency with EFA (EFF_EFA)				
Coefficient	-0.111	0.005	-0.054	-0.161
t-value, significance	-1.21	0.11	-0.13	-2.08**
No. of observations	254	408	108	108
Technical efficiency with GHG, N balance and EFA (EFF_ENV)				
Coefficient	0.002	0.129	-0.825	-0.008
t-value, significance	0.03	2.6***	-2.19**	-0.12
No. of observations	150	265	70	70

Note: The coefficient, t-value and significance are shown only for the subsidy proxy (subsidies per 1,000 ha of UAA or subsidies per 1,000 LU). The results for the other explanatory variables are not shown. *, **, *** indicate significance at the 10, 5, 1% level respectively. For mixed crops-livestock farms, both subsidies per 1,000 ha and subsidies per 1,000 LU are used in turn in separate regressions.

Source: the authors, based on FADN and additionally collected data

Table 4: Results from OLS estimation on technical efficiency of subsidies per output

	Field crops farms	Grazing livestock farms	Mixed crops-livestock farms	
			with UAA	with LU
Classic technical efficiency (EFF)				
Coefficient	0.027	-0.201	-0.386	-0.423
t-value, significance	1.88*	-6.99***	-3.36***	-3.67***
No. of observations	254	408	108	108
Technical efficiency with GHG (EFF_GHG)				
Coefficient	0.001	0.188	-0.86	-0.858
t-value, significance	0.02	3.15***	-3.03***	-3.15***
No. of observations	152	266	70	70
Technical efficiency with N balance (EFF_N)				
Coefficient	-0.054	0.19	0.261	0.284
t-value, significance	-0.82	2.39**	1.13	1.26
No. of observations	150	265	71	71
Technical efficiency with GHG and N balance (EFF_GHGN)				
Coefficient	0.009	0.185	-0.183	-0.146
t-value, significance	0.25	3.04***	-0.91	-0.76
No. of observations	150	265	70	70
Technical efficiency with EFA (EFF_EFA)				
Coefficient	0.039	0.048	-0.129	-0.156
t-value, significance	1.74*	1.1	-0.66	-0.82
No. of observations	254	408	108	108
Technical efficiency with GHG, N balance and EFA (EFF_ENV)				
Coefficient	0.014	0.178	-0.184	-0.146
t-value, significance	0.39	2.91***	-0.92	-0.76
No. of observations	150	265	70	70

Note: The coefficient, t-value and significance are shown only for the subsidy proxy. The results for the other explanatory variables are not shown. *, **, *** indicate significance at the 10, 5, 1% level respectively. For mixed crops-livestock farms, two regressions are performed in turn: the first column 'with UAA' indicates that UAA and the share of rented land are used in a first regression and not the number of LU; the second column indicates that the number of LU is used in a second regression and not UAA nor the share of rented land.

Source: the authors, based on FADN and additionally collected data