FLINT

CAP SUBSIDIES AND TECHNICAL EFFICIENCY INCLUDING ENVIRONMENTAL OUTPUTS: THE CASE OF EUROPEAN FARMS

Laure LATRUFFE[1], Hervé DAKPO[1], Yann DESJEUX[1], Giffona JUSTINIA HANITRAVELO[1]

[1] SMART, INRA, 35000, Rennes, France

26 December 2016

Public

D5.2B

agriXchange is funded by the European Commission's 7th

ABOUT THE FLINT PROJECT

FLINT will provide an updated data-infrastructure needed by the agro-food sector and policy makers to provide up to date information on farm level indicators on sustainability and other new relevant issues. Better decision making will be facilitated by taking into account the sustainability performance of farms on a wide range of relevant topics, such as (1) market stabilization; (2) income support; (3) environmental sustainability; (4) climate change adaptation and mitigation; (5) innovation; and (6) resource efficiency. The approach will explicitly consider the heterogeneity of the farming sector in the EU and its member states. Together with the farming and agro-food sector the feasibility of these indicators will be determined.

FLINT will take into account the increasing needs for sustainability information by national and international retail and agro-food sectors. The FLINT approach is supported by the Sustainable Agriculture Initiative Platform and the Sustainability Consortium in which the agro-food sector actively participates. FLINT will establish a pilot network of at least 1000 farms (representative of farm diversity at EU level, including the different administrative environments in the different MS) that is well suited for the gathering of these data.

The lessons learned and recommendations from the empirical research conducted in 9 purposefully chosen MS will be used for estimating and discussing effects in all 28 MS. This will be very useful if the European Commission should decide to upgrade the pilot network to an operational EU-wide system.

PROJECT CONSORTIUM:

1	DLO Foundation (Stichting Dienst Landbouwkundig Onderzoek)	Netherlands
2	AKI - Agrargazdasagi Kutato Intezet	Hungary
3	LUKE Finland	Finland
4	IERiGZ-PIB - Instytut Ekonomiki Rolnictwa i Gospodarki Zywnosciowej-Panstwowy Instytut Badawcy	Poland
5	INTIA - Instituto Navarro De Tecnologias e Infraestructuras Agrolimentarias	Spain
6	ZALF - Leibniz Centre for Agricultural Landscape Research	Germany
7	Teagasc - The Agriculture and Food Development Authority of Irelan	Ireland
8	Demeter - Hellenic Agricultural Organization	Greece
9	INRA - Institut National de la Recherche Agronomique	France
10	CROP-R BV	Netherlands
11	University of Hohenheim	Germany

MORE INFORMATION:

Drs. Krijn Poppe (coordinator) e-mail: krijn.poppe@wur.nl

Dr. Hans Vrolijk e-mail: hans.vrolijk@wur.nl

LEI Wageningen UR phone: +31 07 3358247

P.O. Box 29703

2502 LS The Hague www.flint-fp7.eu

The Netherlands

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

ATT	Average Treatment effect on the Treated
AWU	Annual Working Units
CAP	Common Agricultural Policy
DEA	Data Envelopment Analysis
EFA	Ecological Focus Areas
EU	European Union
FADN	Farm Accountancy Data Network
GHG	GreenHouse Gases
LFA	Less Favoured Areas
LU	Livestock Units
OLS	Ordinary Least Squares
SFP	Single Farm Payments
TF	Type of Farming
UAA	Utilised Agricultural Area
VRS	Variable Returns to Scale

EXECUTIVE SUMMARY

Farm technical efficiency is a global productivity indicator in the sense that it considers all outputs produced and all inputs used by the farms. The Common Agricultural Policy (CAP) aims at promoting farm competitiveness, and hence a legitimate question is whether the CAP subsidies received by farms contribute to enhance their technical efficiency. Studies investigating the effect of subsidies on technical efficiency so far have considered only marketed outputs, that is to say, food (and fibre and feed) sold and generating revenue. Non-marketed outputs such as environmental and social outputs are not considered.

Here we contribute to this issue by incorporating environmental outputs in the calculation of technical efficiency and performing the analysis of the effect of CAP subsidies on technical efficiency for more than one thousand farms across nine countries of the European Union, with Farm Accoutancy Data network (FADN) data of 2014/2015 and additional data collected via the FLINT project.

Results indicate the effect of 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. Accounting for environmental outputs may thus change policy recommandations, but it is important to account for such outputs when possible so that farms producing such outputs are not penalised in the calculation of technical efficiency.

1 INTRODUCTION

Farm technical efficiency is a global productivity indicator in the sense that it considers all outputs produced and all inputs used by the farms. It enables to assess whether farms use the existing technology at best, by producing the highest possible level of output and is a component of competitiveness (Latruffe, 2010). The Common Agricultural Policy (CAP) 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 et al., 2016; Desjeux and Latruffe, 2016; 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) onputs (Serra et al., 2008).

However, studies investigating the effect of subsidies on technical efficiency consider only marketed outputs, that is to say, food (and fibre and feed) sold and generating revenue. Non-marketed outputs such as environmental and social outputs are not considered. However, 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 in doing this analysis has up to now been 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 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 the data collected via the FLINT project. These are farm-level data for a sample of farmers of the Farm Accountancy Data Network (FADN) in several European Union (EU) countries (The Netherlands, Hungary, Finland, Poland, Spain, Ireland, Greece, France and Germany). The data include accountancy data from FADN (here after: 'FADN data'), as well as additional data on economic, environmental and social sustainability of farms. These additional data, the 'FLINT data', were collected via face-to-face survey or merging of existing data, depending on the country. The FADN and FLINT data relate to accountancy year 2015, except for France and Germany for which it is 2014.

This deliverable is organised as follows. The next section explains the methodology and describes the data. The following two sections presents the results. And 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) (SE025 in FADN data); labour, in terms of the number of annual working units (AWU) on the farm (SE010 in FADN data); capital, in terms of the value of fixed assets (SE436 in FADN data); and operational costs, in terms of specific costs to crops and livestock in Euros (SE281 in FADN data). One single output is used: the (marketed) food output. It is proxied by the total value of output produced by the farm (SE131 in FADN data).

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 non-marketed output (with the same inputs described above, and the same marketed output):

- 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 E_14_1 in FLINT 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 E_5_1 in FLINT 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 (computed with the FLINT data as (Z5_GR_1030_A + Z5_GR_1040_A + Z5_GR_1050_A + Z5_GR_1060_A + Z5_GR_1070_A + Z5_GR_1080_A + Z5_GR_1090_A + Z5_GR_1100_A + Z5_GR_1110_A + Z5_GR_1120_A) / 100).
- 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 each type of farming (TF) that is to say each production specialisation, since the technologies (and hence the efficient frontiers) differ across specialisations. Eight TFs are

considered: farms specialised in field crops (TF1), farms specialised in horticulture (TF2), farms specialised in permanent crops (TF3), farms specialised in grazing livestock (TF4), farms specialised in granivores (TF5), farms with mixed cropping (TF6), farms with mixed livestock (TF7), and farms with mixed crops-livestock (TF8). Output oriented frontiers are constructed, under the assumption of variable returns to scale (VRS).

2.1.2 Analysis of the impact of CAP subsidies

Technical efficiency is calculated with DEA in a first stage, as explained in the previous sub-section. In a second stage, the impact of CAP subsidies is analysed. The latter (SE605 in FADN data) include 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 analysis of the impact of CAP subsidies is done in two ways.

1) Firstly, matching techniques are used. Matching analysis enables assessing the impact of a treatment (here, the provision of subsidies to farms) on an outcome (here, farm technical efficiency) by comparing the outcome of treated farms (that it to say those receiving subsidies) to the outcome if they had not been treated. However, as it is not possible to observe the situation where treated farms are untreated (since we have only one year of observation), the outcome of treated farms is compared to a counterfactual outcome. The latter is the outcome of untreated farms that are similar to the treated farms. In other words, for each treated farm, a similar untreated farm is found in the database, and the technical efficiency of both farms is compared.

Farms are considered similar here if they are in the same TF group and and if they have the same structure: UAA in hectares (SE025 in FADN data) for crop farms (TF 1, 2, 3, 6, 8) or number of livestock units (LU) (SE080 in FADN data) for livestock farms (TF 4, 5, 7, 8); labour in AWU (SE010 in FADN data); capital in terms of the value of fixed assets in Euros (SE436 in FADN data); capital to labour in Euros per AWU (SE436/SE010 in FADN data); share of rented land in UAA for crop farms only (SE030*100/SE025 in FADN data); share of hired labour in total labour (SE020*100/SE010 in FADN data); share of crop output in total output (SE135*100/SE131 in FADN data); and share of livestock output in total output (SE206*100/SE131 in FADN data). The similar farm is the nearest (untreated) neighbour of the considered treated farms in terms of all structural characteristics listed above. As mixed crop-livestock farms (TF8) have non negligible UAA as well as livestock, for this sample two analyses are run: either using UAA or using the number of LU to find similar farms in the matching process.

When the similar farms are identified, the average treatment effect (ATT) is computed, that is to say the difference in technical efficiency between the treated farms and the untreated farms. The analysis is performed in turn for each technical efficiency described in the above sub-section: EFF, EFF_GHG, EFF_N, EFF_GHGN, EFF_EFA and EFF_ENV. In order to provide meaningful results, the analysis is not carried out when the number of subsidised farms or the number of unsubsidised farms is less then three.

2) Secondly, the effect of the level of subsidies is investigated with the help of Ordinary Least Squares (OLS) regressions. While the matching procedure described above enables investigating the effect of being recipient of subsidies, whatever the level of subsidies received, in this second analysis we perform OLS regressions on each technical efficiency (EFF, EFF_GHG, EFF_N, EFF_GHGN, EFF_EFA and EFF_ENV). The explanatory variables 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, and country dummies.

In addition, a subsidy proxy is used in the explanatory variables. In a first set of OLS regressions the proxy is the level of subsidies per hectare of UAA (SE605/SE025) for crop farms or the level of subsidies per LU for livestock farms (SE605/SE080). For farms with mixed crops-livestock (TF8) 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 (SE605/SE131) for all farms.

2.2 Data

The sample used includes 1090 farms. Table 1 provides descriptive statistics of the data used for each TF. The average UAA of farms is 160.24 ha in TF1 (field crops), 23.67 ha in TF2 (horticulture), 20.82 ha in TF3 (permanent crops), and 122.73 in TF6 (mixed crops). As for livestock farms, farms in TF4 (grazing livestock) operate 74.09 ha and breed 100.37 LU on average, while the respective figures for farms in TF5 (granivores) are 28.05 ha and 464.36 LU, for farms in TF7 (mixed livestock) 71.44 ha and 126.32 LU, and for farms in TF8 (mixed crops-livestock) 172.83 ha and 143.8 LU.

In terms of subsidisation, all farms or almost all farms receive the CAP operational subsidies in TF4 (grazing livestock), TF7 (mixed livestock) and TF8 (mixed crops-livestock). The lowest share of subsidised farms within a TF is in TF2 (horticulture) (31%). On average, field crop farms (TF1) receive the lowest level of subsidies per ha among all crop TFs: 108 Euros of subsidies per ha of UAA, compared to 385 for horticulture farms (TF2), 174 for permanent farms (TF3), 171 for mixed crop farms (TF6) and 206 for mixed crop-livestock farms (TF8). The latter receive the highest average level of subsidies per LU within all livestock TFs, namely 397 Euros per LU, compared to 337 Euros for grazing livestock farms, 49 Euros for granivores farms and 128 for mixed livestock farms. When subsidies are related to total output, grazing livestock farms (TF4) are the most subsidised on average, with 0.229, indicating that for every Euro of output produced, these farms receive 22.9 cents. The least subsidised farms in terms of subsidies per output are horticulture farms (TF2) which are almost not subsidised (value of 0.005), permanent crop farms (TF3) (value of 0.043) and granivores farms (TF5) (value of 0.053).

Table 1: Descriptive statistics of the data used per type of farming

	TF1 – Field crops	TF2 – Horticulture	TF3 – Permanent crops	TF4 – Grazing livestock	TF5 – Granivores	TF6 – Mixed cropping	TF7 – Mixed livestock	TF8 – Mixed crops-livestock
Averages								
Total output (Euros)	231516 (255)	1276964 (35)	150000 (165)	194473 (409)	390557 (80)	269775 (21)	135717 (15)	256788 (108)
UAA (ha)	160.24 (255)	23.67 (35)	20.82 (165)	74.09 (409)	28.05 (82)	122.73 (21)	71.44 (15)	172.83 (108)
Number of LU	7.83 (255)	3.07 (35)	1.1 (165)	100.35 (409)	464.36 (82)	0.52 (21)	126.32 (15)	114.8 (108)
Labour (AWU)	3.13 (255)	8.43 (35)	2.71 (165)	1.95 (408)	2.42 (81)	3.64 (21)	2.35 (15)	3.76 (108)
Capital (Euros)	1111268 (255)	2011834 (35)	466851 (165)	1025139 (409)	1175509 (82)	1075608 (21)	484072 (15)	817110 (108)
Operational costs (Euros)	683771 (255)	487751 (35)	205785 (165)	556531 (408)	545093 (81)	451000 (21)	210271 (15)	264991 (108)
Capital to labour (Euros per AWU)	71949 (254)	379851 (35)	14456 (165)	91444 (409)	285313 (80)	65664 (21)	62491 (15)	124638 (108)
Share of rented land in UAA (%)	59.99 (255)	28.04 (35)	36.4 (165)	49.4 (409)	37.74 (65)	60.5 (21)	49.84 (15)	51.38 (108)
Share of hired labour in total labour (%)	18.66 (255)	57.56 (35)	30.18 (165)	10.84 (408)	19.04 (81)	42.1 (21)	6.25 (15)	15.63 (108)
Share of crop output in total output (%)	90.2 (255)	91.76 (35)	93.68 (165)	12.33 (409)	15.06 (80)	90.41 (21)	18.24 (15)	49.64 (108)
Share of livestock output in total output (%)	2.5 (255)	0.1 (35)	3.15 (165)	85.31 (409)	81.17 (80)	3.09 (21)	74.63 (15)	46.34 (108)
Subsidies (Euros)	22208 (255)	2748 (35)	3714 (165)	25580 (409)	16811 (82)	20754 (21)	8059 (15)	46002 (108)
Subsidies per ha (1000 Euros)	0.108 (255)	0.385 (35)	0.174 (165)	0.379 (409)	6.113 (65)	0.171 (21)	0.176 (15)	0.206 (108)
Subsidies per LU (1000 Euros)	7.493 (56)	Insuff. obs.	0.454 (32)	0.337 (409)	0.049 (82)	2.953 (3)	0.128 (15)	0.397 (107)
Subsidies per output	0.173 (255)	0.005 (35)	0.043 (165)	0.229 (409)	0.053 (80)	0.119 (21)	0.097 (15)	0.193 (108)
Dummy=1 if farm subsidised	0.74 (255)	0.31 (35)	0.62 (165)	0.98 (409)	0.79 (82)	0.76 (21)	1.00 (15)	0.94 (108)
GHG emissions (t CO_2 equivalent)	22.47 (153)	0.53 (33)	1.46 (101)	479.51 (267)	756.38 (49)	2.15 (15)	189.89 (9)	307.73 (70)
N balance (kg N)	206.84 (151)	835.88 (33)	61.86 (101)	280.59 (266)	989.16 (49)	173.69 (14)	149.57 (9)	156.72 (71)
EFA (ha)	20.11 (255)	1.96 (35)	1.77 (165)	4.00 (409)	1.93 (82)	7.76 (21)	5.77 (15)	12.55 (108)
Number of farms								
Total	**255**	**35**	**165**	**409**	**82**	**21**	**15**	**108**

Note: number of farms in brackets. 'Insuff. obs' means less than three farms with valid value; in this case the average figure is not shown for statistical confidentiality reasons.

Source: the authors based on FLINT and FADN data

3 RESULTS ABOUT BEING A RECIPIENT OF SUBSIDIES

Here we show the results for the first strand of analysis (1), namely the matching analysis regarding being recipient of subsidies or not.

3.1 General samples

In this section we perform the analysis for the samples at hand, that is to say that we do not make data manipulations even if some information is missing.

3.1.1 Technical efficiency

Table 2 shows the results for the technical efficiency calculations. The number of farms are different depending on the technical efficiency score calculated because of missing information on environmental outputs in some TFs. In terms of classic technical efficiency (EFF), several TFs have a high average efficiency score: horticulture farms (0.915), granivores farms (0.823), mixed cropping farms (0.900) and mixed livestock farms (0.839). The highest score for the horticulture TF, 0.915, indicate that on average horticulture farms could increase their output by 9.290% (i.e. 1/0.915-1) with the same level of input use. Such high scores indicate that farms are clustered towards the efficient frontier, and indicate a high homogeneity of farm practices in the sample. By contrast, there is a high heterogeneity for field crop farms (0.577), permanent crop farms (0.556), grazing livestock farms (0.588) and, to a lesser extent, mixed crops-livestock farms (0.684). It should be noted that the difference in the level of efficiency across samples may also arise from the fact that the samples do not have the same number of farms. Mathematically, in samples with few farms (such as horticulture, mixed cropping and mixed livestock), there is a higher chance that many farms are used to construct the efficient frontier and hence they have a score of 1 (curse of dimensionality).

When accounting for GHG (EFF_GHG), the average scores are higher for field crops, horticulture, permanent crops and mixed livestock TFs, and are lower for grazing livestock, granivores, mixed cropping and mixed crops-livestock farms. Mathematically, it is expected that technical efficiency scores are higher when the DEA model includes one additional output, as the frontier envelops the sample more closely. Hence, the lower average scores for grazing livestock, granivores, mixed cropping and mixed crops-livestock farms clearly indicate that farms within this sample are heterogenous in terms of practices that lead to the production of GHG. When N balance is accounted for (EFF_N), most TFs perform worse on average than when it is not accounting for, except for permanent crop, mixed cropping and mixed livestock TFs. When GHG and N are both included in the calculation of technical efficiency (EFF_GHGN), all TFs perform better than when the classic technical efficiency is considered. This is probably explained by the two additional dimensions (i.e. two additional outputs) in the DEA model, meaning that the efficient frontier closely envelops the sample and hence many farms are on the frontier. 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 ivestock farms), TF5 (granivores farms), (TF6) mixed cropping and TF8 (mixed crops-livestock farms). The other TFs perform better.

Table 2: Descriptive statistics of technical efficiency per type of farming: general samples

	TF1 – Field crops	TF2 – Horti-culture	TF3 – Permanent crops	TF4 – Grazing livestock	TF5 – Grani-vores	TF6 – Mixed cropping	TF7 – Mixed livestock	TF8 – Mixed crops-livestock
Classic technical efficiency (EFF)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.577	0.915	0.556	0.588	0.823	0.900	0.839	0.684
Efficiency std dev.	0.252	0.119	0.289	0.223	0.171	0.178	0.221	0.228
Technical efficiency with GHG (EFF_GHG)								
Number of farms	152	33	101	266	48	15	9	70
Efficiency mean	0.815	0.992	0.916	0.532	0.723	0.872	0.885	0.572
Efficiency std dev.	0.266	0.027	0.166	0.269	0.276	0.330	0.228	0.349
Technical efficiency with N balance (EFF_N)								
Number of farms	150	33	101	265	48	14	9	71
Efficiency mean	0.478	0.777	0.576	0.42	0.773	0.92	0.863	0.595
Efficiency std dev.	0.333	0.383	0.392	0.316	0.285	0.225	0.210	0.302
Technical efficiency with GHG and N balance (EFF_GHGN)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.837	0.992	0.955	0.617	0.888	0.983	0.921	0.759
Efficiency std dev.	0.243	0.027	0.118	0.265	0.168	0.062	0.168	0.231
Technical efficiency with EFA (EFF_EFA)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.472	0.937	0.676	0.332	0.763	0.714	0.846	0.502
Efficiency std dev.	0.337	0.161	0.242	0.279	0.236	0.327	0.242	0.315
Technical efficiency with GHG, N balance and EFA (EFF_ENV)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.841	0.997	0.955	0.619	0.895	0.983	0.951	0.759
Efficiency std dev.	0.240	0.008	0.118	0.266	0.156	0.062	0.116	0.231

Note: 'std dev.' stands for 'standard deviation'.

Source: the authors based on FLINT and FADN data

3.1.2 Impact of CAP subsidies

For each TF and each technical efficiency, Table 3 displays the results of the investigation of the effect of subsidies on technical efficiency with method 1). More precisely, it displays ATT that is to say the difference in technical efficiency between treated (i.e. subsidised farms) and untreated (i.e. non-subsidised farms), as well as its significance. For statistical validity, the analysis is not performed when the number of (unsubsidies or subsidised) farms is less than three, and hence no results are shown. Only for two TFs, being recipient of subsidies changes the classic technical efficiency (EFF): it decreases it for granivores farms (TF5) and increases it for mixed cropping farms (TF6). Being recipient of subsidies has a negative effect on the technical efficiency with GHG (EFF_GHG) and with EFA (EFF_EFA) for permanent crop farms (TF3) and grazing livestock farms (TF4). By contrast, being recipient of subsidies has a positive effect on the technical efficiency with N balance (EFF_N) for permanent crop farms (TF3).

Table 3: Average treatment effect (ATT) of CAP operational subsidies on technical effciency per type of farming: general samples

	TF1 - Field crops	TF2 - Horti-culture	TF3 - Permanent crops	TF4 - Grazing livestock	TF5 - Grani-vores	TF6 - Mixed cropping	TF7 - Mixed livestock	TF8 - Mixed crops-livestock	
								UAA used in matching	LU used in matching
Classic technical efficiency (EFF)									
ATT	0.06	-0.04	0.03	-0.03	-0.11	0.43			-0.11
t-value, significance	1.17	-0.38	0.43	-0.22	-1.75**	4.03***			-1.03
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with GHG (EFF_GHG)									
ATT	0.01	0.00	-0.06	-0.27		-0.29			
t-value, significance	0.27	inf***	-1.55*	-1.37*		-1.00			
No. of observations (unsubsidised-subsidised)	23-129	23-10	41-60	3-263	2-46	3-12	0-9	0-40	0-30
Technical efficiency with N balance (EFF_N)									
ATT	0.06	0.00	0.18	-0.30					
t-value, significance	0.74	inf***	1.36*	-1.17					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-47	2-12	0-9	0-40	0-31
Technical efficiency with GHG and N balance (EFF_GHGN)									
ATT	0.01	0.00	-0.02	-0.18					
t-value, significance	0.37	inf***	-0.73	-0.93					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30
Technical efficiency with EFA (EFF_EFA)									
ATT	0.05	-0.03	-0.07	-0.30	-0.12	0.01			0.04
t-value, significance	0.71	-1.00	-1.4*	-1.91**	-0.53	0.02			0.42
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
ATT	0.01	0.00	-0.02	-0.20					
t-value, significance	0.38	inf***	-0.73	-1.15					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30

Note: *, **, *** indicate significance at the 10, 5, 1% level respectively. 'inf' indicates infinite t-value.

Source: the authors

3.2 Samples with imputed data

One explanation to why the effect of subsidies is different whether only the classic technical efficiency is considered or technical efficiency with environmental output is considered, may be that the samples for both analyses are different (for several farms there is no available data for the environmental outputs considered). Despite the FLINT project being targeted at collecting information on environmental outputs, it has not always been possible to collect it, for various reasons.

In order to have constant samples we redo the analysis after having imputed missing data. More precisely, we consider the samples used to calculate the classic technical efficiency and we keep the same farms to calculate technical efficiency with environmental outputs. For the farms for which the environmental outputs are missing, we impute them with the mean of the TF sample. In other words, we assume that for these farms the value of their environmental output is the mean value of the environmental output of the farms (in the same TF) that have a non-missing environmental output. Table 4 displays the descriptive statistics of technical efficiency for these 'imputed samples' and shows that the number of farms used to calculate the classic technical efficiency is the same as to calculate the five technical efficiencies with environmental outputs. Table 5 displays the matching results. They show differences similar to results obtained when the general samples are considered (Table 3). While in Table 3 being a recipient of subsidies significantly reduced technical efficiency with GHG and EFA for permanent crops and grazing livestock TFs, the effect is not significant inTable 5. By contrast, some effects that were identified as not significant in Table 3 (general samples) are significant in Table 5 (imputed samples): this is the case for technical efficiency with GHG (EFF_GHG), with GHG and N balance (EFF_GHGN), and with GHG, N balance and EFA (EFF_ENV) for field crops farms (TF1) where the effects are positive. An even more striking difference is the effect of being a recipient of subsidies on the technical efficiency including N balance (EFF_N) for permanent crop farms (TF3): the effect was significant and positive in Table 3 (general sample) while it is significant and negative in Table 5 (imputed sample).

Table 4: Descriptive statistics of technical efficiency per type of farming: imputed samples

	TF1 – Field crops	TF2 – Horti-culture	TF3 – Permanent crops	TF4 – Grazing livestock	TF5 – Grani-vores	TF6 – Mixed cropping	TF7 – Mixed livestock	TF8 – Mixed crops-livestock
Classic technical efficiency (EFF)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.577	0.915	0.556	0.588	0.823	0.9	0.839	0.684
Efficiency std dev.	0.252	0.119	0.289	0.223	0.171	0.178	0.221	0.228
Technical efficiency with GHG (EFF_GHG)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.603	0.993	0.886	0.382	0.658	0.714	0.78	0.387
Efficiency std dev.	0.359	0.026	0.158	0.286	0.323	0.422	0.297	0.373
Technical efficiency with N balance (EFF_N)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.438	0.790	0.432	0.349	0.712	0.733	0.802	0.524
Efficiency std dev.	0.301	0.376	0.369	0.318	0.329	0.362	0.264	0.305
Technical efficiency with GHG and N balance (EFF_GHGN)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.677	0.993	0.903	0.454	0.824	0.866	0.829	0.613
Efficiency std dev.	0.310	0.026	0.141	0.308	0.258	0.263	0.235	0.286
Technical efficiency with EFA (EFF_EFA)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.472	0.937	0.676	0.332	0.763	0.714	0.846	0.502
Efficiency std dev.	0.337	0.161	0.242	0.279	0.236	0.327	0.242	0.315
Technical efficiency with GHG, N balance and EFA (EFF_ENV)								
Number of farms	254	35	165	408	62	21	15	108
Efficiency mean	0.680	0.997	0.903	0.457	0.828	0.866	0.830	0.614
Efficiency std dev.	0.309	0.007	0.141	0.308	0.246	0.263	0.234	0.285

Note: 'std dev.' stands for 'standard deviation'

Source: the authors based on FLINT and FADN data

Table 5: Average treatment effect (ATT) of CAP operational subsidies on technical effciency per type of farming: imputed samples

	TF1 - Field crops	TF2 - Horti-culture	TF3 - Permanent crops	TF4 - Grazing livestock	TF5 - Grani-vores	TF6 - Mixed cropping	TF7 - Mixed livestock	TF8 - Mixed crops-livestock	
								UAA used in matching	LU used in matching
Classic technical efficiency (EFF)									
ATT	0.058	-0.037	0.025	-0.031	-0.11	0.425			-0.111
t-value, significance	1.17	-0.38	0.43	-0.22	-1.75**	4.03***			-1.03
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with GHG (EFF_GHG)									
ATT	0.196	0	-0.021	-0.022	-0.17	0.297			0.276
t-value, significance	2.56***	inf***	-0.67	-0.12	-0.52	0.55			3.31***
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with N balance (EFF_N)									
ATT	0.066	0	-0.12	-0.031	-0.167	0.099			0.083
t-value, significance	1.17	inf***	-1.49*	-0.16	-0.58	0.25			0.48
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with GHG and N balance (EFF_GHGN)									
ATT	0.182	0	-0.015	0.04	-0.097	0.175			0.084
t-value, significance	2.91***	inf***	-0.49	0.22	-0.34	0.46			0.51
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with EFA (EFF_EFA)									
ATT	0.049	-0.03	-0.07	-0.129	-0.123	0.005			0.042
t-value, significance	0.71	-1	-1.40*	-0.81	-0.53	0.02			0.42
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
ATT	0.181	0.00	-0.015	0.041	-0.09	0.175			0.087
t-value, significance	2.9***	inf***	-0.49	0.23	-0.31	0.46			0.52
No. of observations (unsubsidised-subsidised)	67-187	24-11	63-102	9-399	6-56	5-16	0-15	1-54	5-48

Note: *, **, *** indicate significance at the 10, 5, 1% level respectively. 'inf' indicates infinite t-value.

Source: the authors based on FLINT and FADN data

3.3 Reduced samples

In order to test the robustness of our results, after treating missing data with imputation with means, we use another treatment here: we remove the observations for which there is at least one missing data in the inputs and outputs used for the calculation of technical efficiencies. In this way, for each TF we have a constant (but reduced) sample across all efficiencies calculation.

Table 6 shows the descriptive statistics of technical efficiency. For each TF, the number of farms used to calculate the classic technical efficiency is the same as to calculate the five technical efficiencies with environmental outputs, but it is less than the original number (as seen for EFF in Tables 2 and 4). Table 7 shows the matching analysis results. Compared to Table 3 with the general samples, Table 7 shows similar results except for the permanent crops sample (TF3) and technical efficiency including EFA: the effect is not anymore significant (Table 7), while it was significant (and negative) for the general sample (Table 3).

Table 6: Descriptive statistics of technical efficiency per type of farming: reduced samples

	TF1 – Field crops	**TF2 – Horti-culture**	**TF3 – Permanent crops**	**TF4 – Grazing livestock**	**TF5 – Grani-vores**	**TF6 – Mixed cropping**	**TF7 – Mixed livestock**	**TF8 – Mixed crops-livestock**
Classic technical efficiency (EFF)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.622	0.914	0.588	0.637	0.839	0.938	0.914	0.686
Efficiency std dev.	0.265	0.117	0.264	0.218	0.145	0.157	0.117	0.236
Technical efficiency with GHG (EFF_GHG)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.813	0.992	0.916	0.534	0.727	0.873	0.885	0.572
Efficiency std dev.	0.267	0.027	0.166	0.269	0.278	0.327	0.228	0.349
Technical efficiency with N balance (EFF_N)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.478	0.777	0.576	0.42	0.768	0.920	0.863	0.590
Efficiency std dev.	0.333	0.383	0.392	0.316	0.286	0.225	0.210	0.300
Technical efficiency with GHG and N balance (EFF_GHG)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.837	0.992	0.955	0.617	0.888	0.983	0.921	0.759
Efficiency std dev.	0.243	0.027	0.118	0.265	0.168	0.062	0.168	0.231
Technical efficiency with EFA (EFF_EFA)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.536	0.933	0.898	0.521	0.849	0.885	1.00	0.572
Efficiency std dev.	0.353	0.165	0.110	0.233	0.172	0.245	0.00	0.293
Technical efficiency with GHG, N balance and EFA (EFF_ENV)								
Number of farms	150	33	101	265	47	14	9	70
Efficiency mean	0.841	0.997	0.955	0.619	0.895	0.983	0.951	0.759
Efficiency std dev.	0.240	0.008	0.118	0.266	0.156	0.062	0.116	0.231

Note: 'std dev.' stands for 'standard deviation'

Source: the authors based on FLINT and FADN data

Table 7: Average treatment effect (ATT) of CAP operational subsidies on technical effciency per type of farming: reduced samples

	TF1 - Field crops	TF2 - Horti-culture	TF3 - Permanent crops	TF4 - Grazing livestock	TF5 - Grani-vores	TF6 - Mixed cropping	TF7 - Mixed livestock	TF8 - Mixed crops-livestock	
								UAA used in matching	LU used in matching
Classic technical efficiency (EFF)									
ATT	0.08	-0.037	-0.051	-0.161					
t-value, significance	1.26	-0.38	-0.62	-0.72					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30
Technical efficiency with GHG (EFF_GHG)									
ATT	0.002	0.00	-0.057	-0.261					
t-value, significance	0.08	inf***	-1.55*	-1.34*					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30
Technical efficiency with N balance (EFF_N)									
ATT	0.059	0.00	0.175	-0.304					
t-value, significance	0.74	inf***	1.36*	-1.17					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30
Technical efficiency with GHG and N balance (EFF_GHGN)									
ATT	0.007	0.00	-0.02	-0.176					
t-value, significance	0.37	inf***	-0.73	-0.93					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30
Technical efficiency with EFA (EFF_EFA)									
ATT	0.085	-0.03	-0.021	-0.444					
t-value, significance	0.91	-1.00	-0.65	-20.99***					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
ATT	0.007	0.00	-0.02	-0.196					
t-value, significance	0.38	inf***	-0.73	-1.15					
No. of observations (unsubsidised-subsidised)	23-127	23-10	41-60	3-262	1-46	2-12	0-9	0-40	0-30

Note: *, **, *** indicate significance at the 10, 5, 1% level respectively. 'inf' indicates infinite t-value.

Source: the authors based on FLINT and FADN data

4 RESULTS ABOUT THE LEVEL OF SUBSIDIES

Here we show the results for the second strand of analysis (2), namely the OLS regressions including the level of subsidies, either per ha or per LU, or per Euro of output.

4.1 General samples

In this first section we perform the analysis for the samples at hand, that is to say that we do not make data manipulations even if some information is missing.

Table 8 presents the results when subsidies are related to UAA (crop farms) or to the number of LU (livestock farms), while Table 9 presents the resutls when subsidies are related to total output (all farms). Table 8 indicates that the level of subsidies per ha or LU has a negative effect on technical efficiency (EFF) for field crops farms (TF1), grazing livestock farms (TF4), granivores farms (TF5) and mixed crops-livestock farms (TF8) (when subsidies are related to LU). When GHG emissions are included in technical efficiency (EFF_GHG), the significant negative effect is confirmed only for mixed crops-livestock farms, while the effect becomes significant positive for grazing livestock farms and it is non significant for the other TFs. All this is confirmed when technical efficiency includes not only GHG but N balance and EFA as well (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 per ha or LU is significant (and negative) in only two cases: granivores farms (TH5) and mixed crops-livestock farms (TF8).

When subsidies are related to total output in Table 9, compared to Table 8 some significant effects are confirmed: negative effects on technical efficiency (EFF) for for field crops farms (TF1), grazing livestock farms (TF4), granivores farms (TF5) and mixed crops-livestock farms (TF8); 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 (in Table 9) compared to when subsidies are related to UAA or the number of LU (Table 8). This is the case for mixed crops-livestock farms (TF8) and technical efficiency with GHG and N balance (EFF_GHGN), with EFA (EFF_EFA) and with all three environmental outputs (EFF_ENV). This is also the case for granivores farms (TF5) and technical efficiency with EFA (EFF_EFA). In addition, some effects that were not significant in Table 8 are now significant in Table 9: subsidies when related to output have a negative effect on technical efficiency with GHG (EFF_GHG) for granivores farms (TF5), 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 (TF1), while the effects were non significant when subsidies were related to UAA or number of LU.

However, results with subsidies related to output should be considered with caution as underlined by Minviel and Latruffe (2016). It is likely that there is some endogeneity issues in the case where subsidies per total output is introduced as an explanatory factor because total output is already the dependent variable.

Table 8: Results from OLS estimation on technical efficiency of subsidies per ha or LU: general samples

	TF1 - Field crops	TF2 - Horti-culture	TF3 - Permanent crops	TF4 - Grazing livestock	TF5 - Grani-vores	TF6 - Mixed cropping	TF7 - Mixed livestock	TF8 - Mixed crops-livestock	
	Subsidies per 1000 ha	Subsidies per 1000 ha	Subsidies per 1000 ha	Subsidies per 1000 LU	Subsidies per 1000 LU	Subsidies per 1000 ha	Subsidies per 1000 LU	Subsidies per 1000 ha	Subsidies per 1000 LU
Classic technical efficiency (EFF)									
Coefficient	-0.101	0.009	0.033	-0.093	-0.724	0.079	1.306	-0.379	-0.143
t-value, significance	-1.66*	0.78	0.57	-2.7***	-1.82*	0.04	1.49	-1.46	-2.94***
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG (EFF_GHG)									
Coefficient	-0.794e-3	0.649e-3	0.004	0.212	-0.721	3.617	2.27	-1.07	-0.214
t-value, significance	-0.01	0.31	0.1	4.46***	-0.93	0.85	1.46	-1.86*	-2.27**
No. of observations	152	33	101	266	48	15	9	70	70
Technical efficiency with N balance (EFF_N)									
Coefficient	-0.124	0.025	0.108	0.042	-1.339	-4.017	1.052	-0.362	0.029
t-value, significance	-1.38	0.73	0.82	0.64	-1.65	-1.34	0.55	-0.82	0.38
No. of observations	150	33	101	265	48	14	9	71	71
Technical efficiency with GHG and N balance (EFF_GHGN)									
Coefficient	0.002	0.651e-3	-0.001	0.136	-0.813	1.12	1.691	-0.818	-0.008
t-value, significance	0.03	0.31	-0.03	2.74***	-1.47	0.84	1.26	-2.17**	-0.13
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with EFA (EFF_EFA)									
Coefficient	-0.111	0.806e-3	-0.021	0.005	-1.278	-0.621	0.724	-0.054	-0.161
t-value, significance	-1.21	0.05	-0.36	0.11	-1.8*	-0.2	0.42	-0.13	-2.08**
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
Coefficient	0.002	0.401e-3	-0.001	0.129	-0.853	1.12	1.113	-0.825	-0.008
t-value, significance	0.03	0.5	-0.03	2.6***	-1.66	0.84	1.1	-2.19**	-0.12
No. of observations	150	33	101	265	47	14	9	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.

Source: the authors based on FLINT and FADN data

Table 9: Results from OLS estimation on technical efficiency of subsidies per output: general samples

	TF1 - Field crops	TF2 - Horti-culture	TF3 - Permanent crops	TF4 - Grazing livestock	TF5 - Grani-vores	TF6 - Mixed cropping	TF7 - Mixed livestock	TF8 - Mixed crops-livestock	
								with UAA	with LU
Classic technical efficiency (EFF)									
Coefficient	0.027	-0.217	-0.225	-0.201	-0.771	1.092	-1.079	-0.386	-0.423
t-value, significance	1.88*	-0.16	-1.43	-6.99***	-2.3**	0.43	-0.78	-3.36***	-3.67***
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG (EFF_GHG)									
Coefficient	0.001	-0.076	-0.109	0.188	-2.555	-3.241	-1.759	-0.86	-0.858
t-value, significance	0.02	-0.31	-1.11	3.15***	-2.76***	-0.19	-0.25	-3.03***	-3.15***
No. of observations	152	33	101	266	48	15	9	70	70
Technical efficiency with N balance (EFF_N)									
Coefficient	-0.054	0.875	0.011	0.19	-0.859	-17.614	-6.106	0.261	0.284
t-value, significance	-0.82	0.22	0.04	2.39**	-0.8	-1.9	-1	1.13	1.26
No. of observations	150	33	101	265	48	14	9	71	71
Technical efficiency with GHG and N balance (EFF_GHGN)									
Coefficient	0.009	-0.076	-0.07	0.185	-0.983	-2.839	-0.352	-0.183	-0.146
t-value, significance	0.25	-0.31	-0.85	3.04***	-1.37	-0.45	-0.06	-0.91	-0.76
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with EFA (EFF_EFA)									
Coefficient	0.039	-0.681	0.039	0.048	-0.33	-7.682	2.108	-0.129	-0.156
t-value, significance	1.74*	-0.4	0.24	1.1	-0.53	-3.25**	0.89	-0.66	-0.82
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
Coefficient	0.014	0.042	-0.07	0.178	-1.132	-2.839	0.197	-0.184	-0.146
t-value, significance	0.39	0.46	-0.85	2.91***	-1.72*	-0.45	0.05	-0.92	-0.76
No. of observations	150	33	101	265	47	14	9	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 TF8, the first column 'with UAA' indicates that UAA and the share of rented land are used in the regression and not the number of LU; the second column indicates that the number of LU is used and not UAA nor the share of rented land.

Source: the authors based on FLINT and FADN data

4.2 Samples with imputed data

In this section we perform the analysis for the full samples in which we have imputed the means of the TF sample when information was missing for some farms.

Table 10 presents the results when subsidies are related to UAA or to the number of LU, while Table 11 presents the results when subsidies are related to total output. Compared to the general samples (Table 8 and 9), results generally show a decrease in significance. When subsidies are related per ha or LU, results with general samples (Table 8) and with imputed samples (Table 10) are similar except for technical efficiency with GHG and N balance alone (EFF_GHGN) and also EFA (EFF_ENV), for which the few effects identified as significant with the general samples are now non significant. Similarly, when subsidies are related to output, the effects become non significant for the imputed samples (Table 11 compared to Table 9) for grazing livestock farms (TF4) and four technical efficiency scores (EFF_GHG, EFF_N, EFF_GHGN, EFF_ENV), and for granivores farms (TF5) and two technical efficiency scores (EFF_GHG, EFF_ENV).

Table 10: Results from OLS estimation on technical efficiency of subsidies per ha or LU: imputed samples

	TF1 - Field crops	**TF2 - Horti-culture**	**TF3 - Permanent crops**	**TF4 - Grazing livestock**	**TF5 - Grani-vores**	**TF6 - Mixed cropping**	**TF7 - Mixed livestock**	**TF8 - Mixed crops-livestock**	
	Subsidies per 1000 ha	Subsidies per 1000 ha	Subsidies per 1000 ha	Subsidies per 1000 LU	Subsidies per 1000 LU	Subsidies per 1000 ha	Subsidies per 1000 LU	Subsidies per 1000 ha	Subsidies per 1000 LU
Classic technical efficiency (EFF)									
Coefficient	-0.101	0.009	0.033	-0.093	-0.724	0.079	1.306	-0.379	-0.143
t-value, significance	-1.66*	0.78	0.57	-2.7***	-1.82*	0.04	1.49	-1.46	-2.94***
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG (EFF_GHG)									
Coefficient	0.034	0.748e-3	-0.003	0.13	-0.315	2.335	1.851	-0.29	-0.171
t-value, significance	0.45	0.32	-0.11	2.85***	-0.31	0.59	1.03	-0.64	-2.05**
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with N balance (EFF_N)									
Coefficient	-0.08	0.026	-0.018	0.03	-1.285	-5.67	1.224	-0.328	-0.016
t-value, significance	-0.97	0.72	-0.2	0.55	-1.36	-1.66	0.76	-0.89	-0.23
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG and N balance (EFF_GHGN)									
Coefficient	0.033	0.749e-3	0.002	0.075	-0.437	-0.308	1.282	-0.561	-0.017
t-value, significance	0.47	0.32	0.07	1.54	-0.58	-0.09	0.87	-1.64	-0.26
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with EFA (EFF_EFA)									
Coefficient	-0.111	0.806e-3	-0.021	0.005	-1.278	-0.621	0.724	-0.054	-0.161
t-value, significance	-1.21	0.05	-0.36	0.11	-1.80*	-0.20	0.42	-0.13	-2.08**
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
Coefficient	0.033	0.399e-3	0.002	0.071	-0.423	-0.308	1.264	-0.554	-0.017
t-value, significance	0.47	0.51	0.07	1.46	-0.58	-0.09	0.86	-1.62	-0.26
No. of observations	254	35	165	408	62	21	15	108	108

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.

Source: the authors based on FLINT and FADN data

Table 11: Results from OLS estimation on technical efficiency of subsidies per output: imputed samples

	TF1 - Field crops	**TF2 - Horti-culture**	**TF3 - Permanent crops**	**TF4 - Grazing livestock**	**TF5 - Grani-vores**	**TF6 - Mixed cropping**	**TF7 - Mixed livestock**	**TF8 - Mixed crops-livestock**	
								with UAA	with LU
Classic technical efficiency (EFF)									
Coefficient	0.027	-0.217	-0.225	-0.201	-0.771	1.092	-1.079	-0.386	-0.423
t-value, significance	1.88*	-0.16	-1.43	-6.99***	-2.3**	0.43	-0.78	-3.36***	-3.67***
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG (EFF_GHG)									
Coefficient	0.023	-0.122	-0.043	0.021	-0.418	-7.536	0.663	-0.503	-0.523
t-value, significance	1.25	-0.46	-0.54	0.53	-0.47	-1.93*	0.24	-2.46**	-2.61**
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with N balance (EFF_N)									
Coefficient	0.033	0.264	0.076	0.039	-0.739	-4.488	1.927	-0.071	-0.064
t-value, significance	1.66*	0.06	0.30	0.81	-0.9	-1.03	0.84	-0.41	-0.38
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG and N balance (EFF_GHGN)									
Coefficient	0.022	-0.122	-0.034	-0.001	-0.406	-3.233	1.403	-0.242	-0.219
t-value, significance	1.3	-0.46	-0.44	-0.03	-0.63	-0.84	0.65	-1.52	-1.41
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with EFA (EFF_EFA)									
Coefficient	0.039	-0.681	0.039	0.048	-0.33	-7.682	2.108	-0.129	-0.156
t-value, significance	1.74*	-0.4	0.24	1.1	-0.53	-3.25**	0.89	-0.66	-0.82
No. of observations	254	35	165	408	62	21	15	108	108
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
Coefficient	0.022	0.039	-0.034	-0.003	-0.238	-3.233	1.423	-0.24	-0.218
t-value, significance	1.30	0.44	-0.44	-0.07	-0.38	-0.84	0.66	-1.51	-1.40
No. of observations	254	35	165	408	62	21	15	108	108

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 TF8, the first column 'with UAA' indicates that UAA and the share of rented land are used in the regression and not the number of LU; the second column indicates that the number of LU is used and not UAA nor the share of rented land.

Source: the authors based on FLINT and FADN data

4.3 Reduced samples

In this section we perform the analysis for the 'minimum' samples, that is to say the samples for which all information necessary for the calculation of all efficiencies is available.

Table 12 presents the results when subsidies are related to UAA or to the number of LU, while Table 13 presents the results when subsidies are related to total output. Compared to the general samples (Table 8 and 9), results show that the main differences occur for the granivores sample (TF5). For those farms, subsidies per LU and per output have no significant effect on the classic technical efficiency (EFF) of the reduced sample (Table 12 and Table 13) while it had a negative significant effect for the general sample (Table 8 and Table 9). By contrast, subsidies per LU have a significant (negative) effect on the technical efficiency with N balance (EFF_N) for the reduced sample (Table 12) and subsidies per output have a significant (negative) effect on technical efficiency with EFA (EFF_EFA), while the effects were non significant for the general sample (Table 8 and Table 9). Other changes concern the effect of subsidies per output on classic technical efficiency (EFF) for permanent crops (TF3): the effect was found non significant with the general sample (Table 9) but is significant with the reduced sample (Table 13). By contrast, the effect of subsidies per output on technical efficiency with EFA (EFF_EFA) was found significant for the general samples of field crop farms (TF1) and mixed cropping farms (TF6) (Table 9), but non significant for the reduced samples (Table 13).

Table 12: Results from OLS estimation on technical efficiency of subsidies per ha or LU: reduced samples

	TF1 - Field crops	**TF2 - Horti-culture**	**TF3 - Permanent crops**	**TF4 - Grazing livestock**	**TF5 - Grani-vores**	**TF6 - Mixed cropping**	**TF7 - Mixed livestock**	**TF8 - Mixed crops-livestock**	
	Subsidies per 1000 ha	Subsidies per 1000 ha	Subsidies per 1000 ha	Subsidies per 1000 LU	Subsidies per 1000 LU	Subsidies per 1000 ha	Subsidies per 1000 LU	Subsidies per 1000 ha	Subsidies per 1000 LU
Classic technical efficiency (EFF)									
Coefficient	-0.121	0.009	-0.069	-0.086	-0.552	2.714	1.261	-0.386	-0.149
t-value, significance	-2.04**	0.75	-0.88	-2.42**	-1.36	0.83	1.86	-1.21	-2.85***
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with GHG (EFF_GHG)									
Coefficient	-0.002	0.649e-3	0.004	0.212	-0.758	3.777	2.27	-1.07	-0.214
t-value, significance	-0.03	0.31	0.10	4.46***	-1.00	0.84	1.46	-1.86*	-2.27**
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with N balance (EFF_N)									
Coefficient	-0.124	0.025	0.108	0.042	-1.384	-4.017	1.052	-0.453	0.027
t-value, significance	-1.38	0.73	0.82	0.64	-1.69*	-1.34	0.55	-0.99	0.35
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with GHG and N balance (EFF_GHGN)									
Coefficient	0.002	0.651e-3	-0.001	0.136	-0.813	1.12	1.691	-0.818	-0.008
t-value, significance	0.03	0.31	-0.03	2.74***	-1.47	0.84	1.26	-2.17**	-0.13
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with EFA (EFF_EFA)									
Coefficient	-0.14	0.748e-3	0.026	0.015	-1.29	-1.247		-0.661	-0.159
t-value, significance	-1.45	0.05	0.78	0.33	-2.42**	-0.26		-1.37	-2.04**
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
Coefficient	0.002	0.401e-3	-0.001	0.129	-0.853	1.12	1.113	-0.825	-0.008
t-value, significance	0.03	0.5	-0.03	2.6***	-1.66	0.84	1.1	-2.19**	-0.12
No. of observations	150	33	101	265	47	14	9	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. The estimation was not performed for EFF_EFA and TF7 as all farms in this TF had a score of 1 for EFF_EFA.

Source: the authors based on FLINT and FADN data

Table 13: Results from OLS estimation on technical efficiency of subsidies per output: reduced samples

	TF1 - Field crops	TF2 - Horti-culture	TF3 - Permanent crops	TF4 - Grazing livestock	TF5 - Grani-vores	TF6 - Mixed cropping	TF7 - Mixed livestock	TF8 - Mixed crops-livestock	
								with UAA	with LU
Classic technical efficiency (EFF)									
Coefficient	-0.083	-0.106	-0.343	-0.228	-0.868	-7.063	-3.82	-0.397	-0.441
t-value, significance	-1.94*	-0.08	-1.95*	-5.45***	-1.68	-0.46	-1.42	-2.51**	-2.83***
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with GHG (EFF_GHG)									
Coefficient	0.781e-3	-0.076	-0.109	0.188	-2.618	-9.603	-1.759	-0.86	-0.858
t-value, significance	0.02	-0.31	-1.11	3.16***	-2.93***	-0.45	-0.25	-3.03***	-3.15***
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with N balance (EFF_N)									
Coefficient	-0.054	0.875	0.011	0.19	-0.914	-17.614	-6.106	0.254	0.279
t-value, significance	-0.82	0.22	0.04	2.39**	-0.84	-1.9	-1	1.08	1.24
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with GHG and N balance (EFF_GHGN)									
Coefficient	0.009	-0.076	-0.07	0.185	-0.983	-2.839	-0.352	-0.183	-0.146
t-value, significance	0.25	-0.31	-0.85	3.04***	-1.37	-0.45	-0.06	-0.91	-0.76
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with EFA (EFF_EFA)									
Coefficient	-0.06	-0.641	-0.005	0.081	-2.218	-19.507		-0.266	-0.252
t-value, significance	-0.85	-0.36	-0.06	1.45	-3.44***	-5.1		-1.06	-1.05
No. of observations	150	33	101	265	47	14	9	70	70
Technical efficiency with GHG, N balance and EFA (EFF_ENV)									
Coefficient	0.014	0.042	-0.07	0.178	-1.132	-2.839	0.197	-0.184	-0.146
t-value, significance	0.39	0.46	-0.85	2.91***	-1.72*	-0.45	0.05	-0.92	-0.76
No. of observations	150	33	101	265	47	14	9	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 TF8, the first column 'with UAA' indicates that UAA and the share of rented land are used in the regression and not the number of LU; the second column indicates that the number of LU is used and not UAA nor the share of rented land. The estimation was not performed for EFF_EFA and TF7 as all farms in this TF had a score of 1 for EFF_EFA.

Source: the authors based on FLINT and FADN data

5 CONCLUSION

In this paper we investigated the effect of CAP operational subsidies on the technical efficiency of several TFs 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 was performed in two ways: 1) the effect of being recipient of subsidies (whatever the level of subsidies) on each technical efficiency (with a matching analysis); 2) the effect of the level of subsidies related to a size variable (UAA or number of LU; total output) on each technical efficiency (OLS regression). As the information on the environmental outputs was missing for several farms, we did the analysis not only for the samples at hand for each TF (the 'general samples'), but also for the full samples in which the missing data were replaced by the TF sample's mean (the 'imputed samples'), as well as for the 'reduced samples' where only farms that had all information were kept (removal of farms in their entirety, rather than imputation to keep the farms).

Two main conclusions can be drawn from this analysis.

Firslty, 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 negative effects when environmental outputs are accounted for. This is for example the case for the effect of the level of subsidies per output on technical efficiency with EFA for mixed cropping farms. (ii) Some effects that are not significant on the classic technical efficiency become positive effects when environmental outputs are accounted for. This is for example the case for the effect of being recipient of subsidies on technical efficiency with N balance for permanent crop farms. (iii) Some effects that are negative on the classic technical efficiency become non significant effects when environmental outputs are accounted for. This is for example the case for the effect of the level of subsidies per ha on technical efficiency with any environmental outputs (GHG, N balance, EFA) for field crop farms. (iv) Some effects that are positive on the classic technical efficiency become non significant effects when environmental outputs are accounted for. This is for example the case for the effect of being recipient of subsidies on technical efficiency with EFA for mixed cropping farms. (v) Finally, 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 level of subsidies per LU on technical efficiency with GHG alone or with N balance, or with N balance and EFA, for grazing livestock farms.

Some of these changes in effects' signs and significance are also observed when using the imputed samples and the reduced samples. There is no general conclusion possible on the effect of subsidies on farms' technical efficiency. What is clear however, is that accounting for environmental outputs may change the conclusions and policy recommandations. But 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 EFA) or to mitigate some environmental bad outputs (e.g. capital in the form of manure cleaning-facilities, hence reducing GHG). If such goods are not accounted for in the technical efficiency calculation, a farm using more inputs to produce environmental good outputs or 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. Similarly, a farm using the subsidies received to implement actions to increase environmental good outputs or to reduce environmental bad outputs, may have a lower classic technical efficiency compared than a farm receiving the same level of subsidies but using them for producing marketed outputs. 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.

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 TF. For example, EFA may not be relevant for granivores farms since they are mostly off land and biodiversity may be worth considering in addition for crop farms. However, the limiting factor is the availability of information on environmental

outputs. Such information is generally complex to collect (e.g. the long list of information 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). Regarding the first three issues, one should thus be ready to rely on uncomplete data only, and to apply some specific treatment of missing data.

This relates to the second main conclusion of our analyses, namely regarding the way missing data were treated in our analyses. We used the general sample, for which data were missing for some technical efficiency calculations: the number of farms for calculating the classic technical efficiency was greater than the number of farms for calculating technical efficiency with GHG, which was also different than the number of farms for calculating technical efficiency with N balance. To test if the results would be different when the issue of missing data is addressed, we also used constant samples across the calculations of technical efficiencies: full samples, where missing data have been imputed by the means for the TF sample ('imputed samples'); and 'reduced samples', where one farm was full removed from all efficiency calculations as soon as it had missing information on some input or some output. Both treatments for missing data change the significance of some effects, in the way that some effects that were identified as significant with the general samples are not anymore significant with the imputed or reduced samples. This arises when there a lot of missing data: in this case, when imputing with the mean, a lot of farms have the same value and hence the variability in the sample is reduced; also, when we reduce the sample size (reduced sample), we create a sample bias (opposite to selection bias). Another finding is that some effects that were non significant with the general samples become significant for the reduced sample. The change in results between the general sample, the imputed sample and the reduced sample is mostly visible for granivores farms. Hence, the conclusion is that the treatment for missing data may bring changes in conclusions and policy recommandations, and that the sample considered for policy evaluation should be well thought when environmental outputs are collected.

Finally, one limit to our analyses in this paper is that the econometric analyses suffer from the fact that only one year is available. Hence, the effects of subsidies found here may be correlations rather than impacts, as endogeneity of subsidies with farmers' choices as well as the delay in the effect of policies could not be accounted for.

Acknowledgements

The authors thank the FLINT partners who contributed to collecting the data of the FLINT project, and for providing access to the data.

6 REFERENCES

Asmild, M., Hougaard, J.L. 2006. Economic versus environmental improvement potentials of Danish pig farms. *Agricultural Economics*, 35: 171-181.

Berre, D., Boussemart, J.-P., Leleu, H. Tillard, E. 2013. Economic value of greenhouse gases and nitrogen surpluses: Society vs farmers' valuation. *European Journal of Operational Research*, 226: 325-331.

Coelli, T., Rao, D., O'Donnell, C., Battese, G. 2005. *An Introduction to Efficiency and Productivity Analysis*. Second edition, Springer.

Coelli, T., Lauwers, L., Van Huylenbroeck, G. 2007. Environmental efficiency measurement and the materials balance condition. *Journal of Productivity Analysis*, 28: 3-12.

Dakpo, K.H. 2016. *On Modeling Pollution-Generating Technologies: A New Formulation of the By-Production Approach*. Working Paper SMART-LERECO n°16-06, Rennes, France.

Dakpo, K.H., Latruffe, L. 2016. *Agri-Environmental Subsidies and French Suckler Cow Farms' Technical Efficiency Accounting for GHGs*. Paper presented in the 90th annual Conference of the English Agricultural Economics Society (AES), University of Warwick, United Kingdom, 4-6 April.

Dakpo, K.H., Jeanneaux, P., Latruffe, L. 2016a. Modelling pollution-generating technologies in performance benchmarking: Recent developments, limits and future prospects in the nonparametric framework. *European Journal of Operational Research*, 250(2): 347-359.

Dakpo, K.H., Jeanneaux, P., Latruffe, L. 2016b. Greenhouse gas emissions and efficiency in French sheep meat farming: A non-parametric framework of pollution-adjusted technologies. *European Review of Agricultural Economics*, online first.

Latruffe, L. 2010. *Competitiveness, Productivity and Efficiency in the Agricultural and Agri-Food Sectors*. OECD Food, Agriculture and Fisheries Working Papers, No. 30, OECD Publishing, Paris, France.

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: 409-416.

Latruffe, L., Desjeux, Y. 2016. Common Agricultural Policy support, technical efficiency and productivity change in French agriculture. *Review of Agricultural, Food and Environmental Studies*, 97(1): 15-28.

Latruffe, L., Bravo-Ureta, B., Carpentier, A., Desjeux, Y., Moreira, V. 2016. Subsidies and technical efficiency in agriculture: Evidence from European dairy farms. *American Journal of Agricultural Economics*, online first.

Martin, J.P., Page, J.M. Jr. 1983. The impact of subsidies on X-efficiency in LDC industry: Theory and empirical test. *The Review of Economics and Statistics*, 64: 608-617.

Minviel, J. J., Latruffe, L. 2016. Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. *Applied Economics*, online first.

Njuki, E., Bravo-Ureta, B.E. 2015. The economic costs of environmental regulation in U.S. dairy farming: A directional distance function approach. *American Journal of Agricultural Economics*, 97(4): 1087-1106.

Oude Lansink, A., Reinhard, S. 2004. Investigating technical efficiency and potential technological change in Dutch pig farming. *Agricultural Systems*, 79: 353-367.

Piot-Lepetit, I., Le Moing, M. 2007. Productivity and environmental regulation: the effect of the nitrates directive in the French pig sector. *Environmental and Resource Economics*, 38: 433-446.

Serra, T., Zilberman, D., Gil, J.M. 2008. Farms' technical inefficiencies in the presence of government programs. *The Australian Journal of Agricultural and Resource Economics*, 52: 57-76.

Shortall, O., Barnes, A. 2013. Greenhouse gas emissions and the technical efficiency of dairy farmers. *Ecological Indicators*, 29: 478-488.

Toma, L., March, M., Stott, A.W., Roberts, D.J. 2013. Environmental efficiency of alternative dairy systems: A productive efficiency approach. *Journal of Dairy Science*, 96(11): 7014-7031.

Yang, C.C., Hsiao, C.K., Yu, M.M. 2008. Technical efficiency and impact of environmental regulations in farrow-to-finish swine production in Taiwan. *Agricultural Economics*, 39: 51-61.