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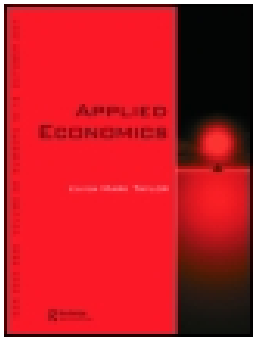
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Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results

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ABSTRACT

Investigating the impact of public subsidies on farm technical efficiency is becoming a critical issue in applied agricultural policy analysis. This article presents a meta-analysis of empirical results on this issue, based on data gathered from a systematic literature review. We find that, in the empirical literature, subsidies are commonly negatively associated with farm technical efficiency. Meta-regression estimation results show that the direction (significantly negative, significantly positive or non-significant) of the observed effects is sensitive to the way subsidies are modelled in the empirical studies.

KEYWORDS

Meta-analysis; technical efficiency; subsidies; farms

JEL CLASSIFICATION

C12; C83; Q12; Q18; D24

1. Introduction

Given successive reforms of agricultural policies and pressures on public budgets, investigating the link between public subsidies and farm technical efficiency has become a central research question in production economics. Technical efficiency refers to the capacity of a farm to make efficient use of the existing technology, that is, either to produce at the maximum level with a given set and level of inputs or to use the minimum level of inputs to produce a specific level of output. In general, public subsidies do not aim explicitly at improving technical efficiency but instead aim at increasing production, supporting farmers' income or favouring the production of specific outputs including environmental outputs. However, if subsidies have the side effect of decreasing farm technical efficiency, this may lead to the question of whether a more effective way of supporting farms might exist.

Theoretical results on this subsidy–efficiency link are ambiguous. On the one hand, subsidies may reduce farmers' effort (Martin and Page 1983) or change their risk attitudes (Serra, Zilberman, and Gil 2008), which might result in a reduction of technical efficiency. More generally, a negative impact of subsidization on technical efficiency may result from a wealth (income) effect, that is to say,

income stabilization resulting from subsidies may distort farmers' incentives to produce efficiently. Farmers' efforts in farming activities may be reduced if a larger part of their income is guaranteed by subsidization. Subsidization may enable farmers to smooth their wealth without adopting efficient production strategies. On the other hand, subsidies may help farmers overcome financial constraints that impede efficient restructuring or modernization, and thus may increase technical efficiency by improving the farm's productive capacity through replacement investment or net investment in advanced technologies (Zhu and Oude Lansink 2010). Also, one may expect no significant effect (i.e. null effect) of subsidies on technical efficiency, since this is not the primary aim of the subsidization policy. Consequently, several authors, such as Serra, Zilberman and Gil (2008), Kumbhakar and Lien (2010) and Zhu and Oude Lansink (2010), argue that investigating this issue is essentially empirical. However, findings from empirical studies also seem inconclusive. Significant effects, both positive and negative, of subsidies on farm technical efficiency may be found, as well as no significant effects. The empirical studies differ not only in the context of the study (e.g. country, period and types of farm considered) but also in the data used (e.g. number of

farms, cross-sectional or panel data) and in the methodology employed (e.g. parametric or non-parametric approach). Hence, one may wonder whether the direction of the subsidy–efficiency relationship found in the empirical literature is random or whether it is consistently related to the characteristics of the studies.

In this context, this article aims at shedding light on the relationship between public subsidies and farm technical efficiency by undertaking a meta-analysis of results obtained in existing empirical studies. The meta-analytical framework consists of a set of statistical and econometric methods which allow outcomes from empirical studies carried out on a particular research question to be synthesized and their heterogeneity to be investigated (Glass 1976; Stanley and Jarrell 1989). If there is a consistent link between the direction of the relationship found in the studies and certain characteristics of the studies, this may help draw methodological recommendations so that future research provides reliable findings for policy recommendations.

The article is organized as follows. In the second section, we present an overview of the possible ways of investigating the relationship between farm technical efficiency and subsidies which have been applied in the existing empirical literature. In the third and fourth sections, we present the data and methodology, respectively. In Section V, we describe and discuss the main results. In Section VI, we conclude.

II. Overview of the ways of estimating the link between farm technical efficiency and subsidies

Various estimation strategies can be found in the literature dealing with the efficiency–subsidy link. There are two main competing approaches: the non-parametric framework where the main method is Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis (SFA) which is a parametric framework. Both approaches allow farm-specific efficiency scores to be computed. These are strictly positive scalars bounded by one, with one being a fully efficient farm.

DEA, relying on Farrell's (1957) work and developed by Charnes, Cooper and Rhodes (1978) and Banker (1984), relies on programming methods to construct a linear frontier from the best performing farms in the sample at hand (introductory textbooks on DEA include Thanassoulis (2001) and Cooper, Seiford and Zhu (2011); for more advanced pictures on DEA, one can refer to Fried, Lovell and Schmidt (2008). The DEA model may have an output orientation, meaning that it is searched for the possible output increase that farmers could implement without changing the level of use of inputs. Researchers may prefer to assume an input orientation,¹ where the possible input decrease – keeping output the same – is searched for. The main advantages of DEA are that it can handle a multi-output multi-input context, and it does not necessitate specification assumptions. With DEA, the influence of subsidies is commonly investigated in two stages: in the first stage, technical efficiency is computed with DEA and in the second stage, a regression (Ordinary Least Squares, truncated, Tobit or quantile) is applied to the efficiency scores.

In contrast to DEA, SFA relies on econometrics and therefore necessitates specifications regarding the production function and the distribution of error terms (see Kumbhakar and Lovell 2000, Coelli et al. 2005 and Greene 2008, for a comprehensive view of SFA). However, one advantage of SFA is that it accounts for potential noise through its double-error term (random noise and inefficiency), while in the DEA case, any deviation from the efficient frontier is due to inefficiency. Bayesian methods can be used to provide more accurate inference results, for example accounting for regularity conditions (see van den Broeck et al. 1994, O'Donnell and Coelli 2005 and Griffin and Steel 2007). In the SFA case, the computation of efficiency and the effect of subsidies on efficiency are estimated in a single stage.

A further approach for investigating the efficiency–subsidy link relies on simple correlation analysis or on comparing the means of different subsamples on the basis of the farms' efficiency scores calculated with either DEA or SFA.

¹Note that there also exist non-oriented DEA models which do not choose between input- or output-orientation, but which scale inputs and outputs simultaneously. Such models include the hyperbolic DEA framework (Färe, Grosskopf, and Lovell 1985) and the nonparametric directional technology distance function approach (Chambers, Chung, and Färe 1998).

As mentioned above, different types of data may be used. One possibility is to use cross-sectional data, where farms are observed in one specific year. Panel data can also be used, where the same farms are observed in adjacent years. Some studies investigate the relationship between farm technical efficiency and subsidies in a specific year only, while other studies consider longer periods which, in some instances, enable any change in the way subsidies are allocated to farms to be captured. Although various levels of observations can be found in the efficiency literature, only studies using individual data, that is to say farm-level data, are found in the literature dealing with the subsidy–efficiency issue suggesting that such level is more appropriate than other levels (e.g. regional level) to study the issue.

Regarding subsidies, the subsidization policy depends on the context of the study. However, in general, one can observe that the total value of subsidies received by farms can be decomposed into several components, such as subsidies for implementing investment on the farm or subsidies for production activities. The latter can be disaggregated into several types, such as input subsidies, output subsidies also termed coupled subsidies (i.e. subsidies coupled with production), decoupled subsidies (i.e. lump-sum payments), environmental subsidies (i.e. subsidies favouring environmentally friendly practices such as organic farming) and subsidies provided to farms located in disadvantaged areas. An example of the latter is from the Common Agricultural Policy (CAP) of the European Union (EU) where farms located in the so-called less favoured areas (LFA) receive specific subsidies per hectare of farm area in LFA. Regarding coupled and decoupled subsidies, and taking again the example of the EU, over the past decades, the CAP has gradually moved from coupled subsidies to decoupled subsidies. In the mid-1990s, partially decoupled payments were introduced in the form of direct payments received per hectare of specific crop planted or per head of specific livestock bred. More recently, the decoupled Single Farm Payment has been implemented (see Silvis and Lapperre (2010) and Anania and Pupo D'Andrea (2015) for more details about the CAP and its evolution).

When investigating the relationship between farm technical efficiency and subsidies, the subsidies considered may be given as the total value received by

the farm. However, this might capture size effects. Some studies circumvent this issue by relating the subsidies considered to a size variable (such as the value of farm revenue, the farm area in hectares or the number of farm livestock units), or by using a share of the considered subsidies in all subsidies received by farms. A final point to note regarding the methodologies used in the empirical literature on the subsidy–efficiency link relates to the way in which subsidies are modelled. In general, subsidies are used as contextual factors, that is to say as explanatory variables of efficiency (e.g. Zhu and Oude Lansink 2010; Bojnec and Latruffe 2013; Kumbhakar, Lien and Hardaker 2014 and Sipiläinen, Kumbhakar and Lien 2014). In some papers, subsidies are also considered as an additional output to the traditional farm outputs used in the efficiency calculation (e.g. Silva, Arzubi and Berbel 2004; Hadley 2006; Rasmussen 2010; Silva and Marote 2013). The latter approach can however not accurately account for subsidies, since it implies that, for a similar input use, farms receiving subsidies produce more in value than farms not receiving subsidies. Thus, such an approach does not reflect the real production process of farms.

III. Data

The data used in our meta-analysis consist of 195 observations (i.e. 195 distinct results about the effect of subsidies) extracted from a set of 68 studies which were carried out during the period 1986–2014. The studies were collected in March 2014 from a systematic review of the existing empirical literature on the links between public subsidies and farm technical efficiency. The search for papers was conducted through the main scientific databases such as Econlit, Web of Science, Web of Knowledge, Journal Storage (JSTOR), Econpapers, Science Direct, RepEc (IDEAS) and Google Scholar, combining in several search formulae the following keywords: ‘subsidies’ or ‘support’, alone or with ‘public’, ‘government’, ‘CAP’, ‘Single Farm Payment’, ‘pillar 1’, ‘pillar 2’, ‘agricultural’, ‘EU’ or ‘farm bill’; together with ‘efficiency’, ‘technical efficiency’, ‘economic efficiency’, ‘farm efficiency’, ‘productive efficiency’, ‘farm performance’ or ‘economic performance’. The literature search was completed by exploring the reference lists of the papers obtained through the search of the databases.

One important potential bias in meta-analyses is publication bias, which refers to the fact that studies that are more likely to be submitted and published in journals, as well as cited, are those where results are significant and interesting (Coursol and Wagner 1986; Hedges 1992; Begg 1994; Sterne, Gavaghan, and Egger 2000; Dickersin 2005). In addition, it has been documented that certain studies remain unpublished because of theoretical or ideological divergences, or conflicts of interest between researchers (Sterling 1959; Mahoney 1977). There may also be a relatively long duration of the publishing process. Therefore, meta-analyses based only on literature published in journals may be biased. Given this, and as recommended (e.g. Cook et al. 1993; MacLean et al. 2003; Rothstein et al. 2005; Sterne, Gavaghan, and Egger 2000), we introduce some unpublished studies in our meta-analysis.

The online supplementary table provides an overview of the empirical studies on the relationship between public subsidies and farm technical efficiency. Various points should be noted. The first concerns the geographical coverage: developing and emerging countries are not widely covered by the existing literature. Only India (Charyulu and Biswas 2010; Dung et al. 2011), China (Thian and Wan 2000; Li, Nanseki, and Takeuchi 2012) and Brazil (Taylor, Drummond, and Gomes 1986) have been the focus of such an assessment. Within industrialized countries, it is worth noting that the majority of studies cover Europe. Despite some of the earliest studies being on Canada (Giannakas, Schoney, and Tzouvelekas 2001) and the United States (Lachaal 1994), there are only four more studies on the United States (Lambert and Bayda 2005; Serra, Zilberman, and Gil 2008; Chidmi, Solis, and Cabrera 2011; Zaeske 2012). In Europe, one publication has focused on Switzerland (Ferjani 2008), two on Norway (Kumbhakar and Lien 2010; Kumbhakar, Lien, and Hardaker 2014) and two on Russia (Sotnikov 1998; Sedik, Trueblood, and Arnade 2000). The EU appears to be largely covered but it is not covered in terms of the variety of authors. In fact, some authors have applied their model to several EU countries in a single publication (Latruffe et al. 2008; McCloud and Kumbhakar 2008; Fogarasi and Latruffe 2009; Zhu and Oude Lansink 2010; Latruffe et al. 2012; Zhu, Demeter, and Oude Lansink 2012) or to several production sectors in the same country (Karagiannis and Sarris 2002; Guyomard, Latruffe, and Le Mouél 2006; Hadley 2006;

Kleinhanss et al. 2007; Emvalomatis, Oude Lansink, and Stefanou 2008; Carroll et al. 2009; Fogarasi and Latruffe 2009; Desjeux and Latruffe 2010).

A second point concerns the production coverage. Most of the studies concentrate on the crop and dairy sectors, followed by beef cattle, sheep and pig. Some studies cover specific crops (cereals, oilseeds and proteinseeds [COP], cereals, wheat, corn, rice, alfalfa, tobacco, cotton, olive, fruits, vegetables and horticulture) and one study is applied to poultry. Crop production other than field crops is studied in countries with specific production conditions (rice in China; olives in Greece and Spain; alfalfa, tobacco and cotton in Greece).

A third point concerns the period covered. When looking at the dates of publications, the pioneer articles are by Taylor, Drummond and Gomes (1986) for Brazil, Lachaal (1994) for the United States and Sotnikov (1998) for Russia, who explicitly focussed on the effect of public support (credit subsidization, farm subsidies and output subsidies, respectively) on technical efficiency. A few papers followed in the early 2000s, namely Brümmer and Loy (2000); Sedik, Trueblood and Arnade (2000); Giannakas, Schoney and Tzouvelekas (2001) and Karagiannis and Sarris (2002), but most of the assessment started in the mid-2000s, and has increased in the past 10 years. Papers have mostly covered periods ranging from the early 1990s to the most recent data available in the 2010s. This corresponds to a period when microeconomic data became more widely available and when decision-makers increased their demand for policy evaluations.

A final point concerns the subsidy variables used. Various variables are used in the literature, dealing with total subsidies received by farms or specific subsidies such as production subsidies, investment subsidies, environmental subsidies, organic subsidies or output subsidies (i.e. subsidies coupled to output). The subsidies are proxied with either the total amount per farm; the average amount per hectare of land or per livestock head; a so-called subsidy rate, which is a ratio relating the subsidies considered to a farm financial performance indicator (output value, revenue or income) or a ratio of the subsidies considered to the total subsidies received by the farm (the payment ratio). In addition, a subsidy dummy may be used. This dummy captures whether the farm was beneficiary of subsidies or not. Alternatively, a dummy may capture whether there has been a change in policy or not.

Table 1. Share of observations depending on the sign of the estimated effect.

	Share (%) of the 195 observations reporting		
	Significantly negative estimated effect	Null (non-significant) estimated effect	Significantly positive estimated effect
All 195 observations	54	22	24
Observations depending on			
<i>The type of subsidies used</i>			
Total subsidies	29	6	7
Input subsidies	2	1	1
Environmental subsidies	6	3	4
LFA subsidies	4	2	1
Investment subsidies	1	2	4
Coupled subsidies	8	2	4
Decoupled subsidies (including direct payments and Single Farm Payment)	46	20	20
<i>The subsidy proxy used</i>			
Value of subsidies per farm	10	8	11
Subsidy rate	35	4	2
Subsidies per hectare	5	2	5
Subsidy dummy	4	8	6
<i>The type of farms considered</i>			
Crop farms	21	9	7
Dairy farms	18	7	12
Other livestock farms	7	6	6

The estimated effect refers to the effect of subsidies on technical efficiency found in the primary studies.

The last column of the online supplementary table shows that the most common finding on this issue is an inverse relationship. When non-significant relationships are not considered, the effect of subsidies on technical efficiency is significantly negative for 71% of the models and significantly positive for 29%. When taking into account the cases where subsidies have no significant effect, which is also a result in itself, then the effect is significantly negative for 60% of the models, significantly positive for 24% of the models and non-significant for 16%. At first sight, there is no obvious consistency in the results. For example, contradictory results are found for a given production sector with a similar subsidy variable (e.g. Hadley 2006; Iraizoz, Bardaji and Rapun 2005; for the beef production sector). Also, among studies in which the subsidy rate is, on average, similar, a significantly positive impact and a significantly negative impact of support on technical efficiency can be found; for example, Kumbhakar and Lien (2010) and Kumbhakar, Lien and Hardaker (2014), both for Norwegian cereal farms but using a different proxy for subsidies. Table 1 provides additional statistics regarding the estimated impact for the studies listed in the table in the online supplementary material. Table 1 shows that, among studies considering total subsidies (instead of various categories of subsidies), the share of observations reporting a significantly negative effect of subsidies on technical

efficiency is higher than the share reporting a significantly positive or a non-significant effect. The same finding is observed among studies modelling subsidies as a subsidy ratio per farm income.

IV. Empirical models

We explore here econometrically the heterogeneity of the direction of the subsidy effect in empirical studies by using categorical models. More precisely, we use probit models to investigate the determinants of the sign of the coefficient associated with the subsidy variable. First, we consider the three possible effects by estimating an ordered probit model with three categories ordered as follows: the first outcome of the ordinal-dependent variable has a significantly negative effect, the second outcome has a null (i.e. to say, non-significant) effect and the third outcome has a significantly positive effect. The dependent variable y_i for the i th study thus takes the value $j = 1, 2$ or 3 and is associated with an underlying latent variable² y_i^* , such that

$$y_i^* = x_i\beta + \xi_i$$

$$\text{and } y_i = \begin{cases} 1 & \text{if } y_i^* < \delta_1 \\ 2 & \text{if } \delta_1 < y_i^* < \delta_2 \\ 3 & \text{if } y_i^* > \delta_2 \end{cases} \quad (1)$$

²This variable does not have the traditional meaning of latent variables (as in biology or behavioural studies). Here, it only allows model the probability of observing a positive, negative or null effect, conditionally to the moderator variables.

where x_i is a $1 \times p$ vector of moderator variables explaining the observed effects, β is the parameters to be estimated and ξ_i is a standard normal shock. δ_1 and δ_2 are the cutpoints or threshold parameters to be estimated from the data. They enable matching the latent variable to the observed variable, and estimating the probability associated with each observed effect. Given the moderator variables, the probability that $y_i = j | j \in (1, 2, 3)$ is given by

$$\begin{aligned} \text{Prob}(y_i = 1) &= \phi(\delta_1 - x_i\beta) \\ \text{Prob}(y_i = 2) &= \phi(\delta_2 - x_i\beta) - \phi(\delta_1 - x_i\beta) \\ \text{Prob}(y_i = 3) &= 1 - \phi(\delta_2 - x_i\beta) \end{aligned} \quad (2)$$

where $\phi(\cdot)$ stands for the cumulative probability function of the standard normal distribution.

While the signs of the estimated parameters β can give an indication of whether the latent variable y_i^* increases from outcomes 1–3 when the determinant x_i increases (or takes the value one in the case of a dummy variable), marginal effects allow to compare the effect of a given determinant on the different alternatives (negative, null and positive outcome). More precisely, marginal effects, calculated for each determinant and each alternative k , show the change in the probability of the alternative k when the determinant increases by one unit (or takes the value one in the case of a dummy variable).

Second, although it is logical to order from a negative to a positive outcome, the ordering of the outcomes observed for the subsidy–efficiency nexus might not be quite natural from an applied policy perspective. For instance, for policymakers, it may be more meaningful to consider that the effects of subsidies on technical efficiency are either detrimental (negative) or non-detrimental (positive or null). For this reason, we also estimate binary probit models to confirm or disconfirm findings obtained with the ordered probit model. In the first binary probit model that we estimate, we assume that only significantly negative effects of subsidies on farms' technical efficiency are not considered desirable by policymakers, and thus, we group significantly positive effects and null effects together. Hence, the binary-dependent variable is equal to one for significantly positive or null effects and equal to zero for (undesirable) significantly negative effects (reference category). Finally, for comparison purposes, we also estimate a binary probit model in which the

dependent variable is equal to one for significantly positive effects and equal to zero for significantly negative effects (reference category). The full sample of 195 observations is here reduced to 153 observations (the observations with non-significant effects are excluded). The probability of obtaining the considered outcome with respect to the reference outcome is given by

$$\text{Prob}[y_i = 1 | x_i, \beta] = \int_{-\infty}^{-x_i\beta} \phi(z) dz \quad (3)$$

where $\phi(z)$ denotes the standard normal density.

For a given empirical study, the estimated models are assumed to be independent if they consist of estimations for different countries, different regions or different farming systems. However, in the estimation procedure, to control for intra-study autocorrelation arising from the fact that multiple observations may be drawn from a given paper, we use cluster-robust inferences. In this approach, which has been used in other meta-regressions (see Barrio and Loureiro 2010; Choumert, Motel and Dakpo 2013), the SEs are clustered by each primary study.

As explained above, we investigate whether the direction of the effect depends on the characteristics of the primary study, such as the analytical method employed to investigate the effect and the context of the study. More precisely, the following explanatory variables (x_i) are used in our three probit models (one ordered probit model and two binary probit models). (i) The way subsidies are modelled in the primary studies is included in our probit models by a dummy variable taking the value one if subsidies are treated as an additional output in the efficiency calculation (*Subsidies as output*). (ii) The type of subsidy considered in the primary studies is included via eight dummies: *Total subsidies*, *Input subsidies*, *Environmental subsidies*, *LFA subsidies*, *Investment subsidies*, *Coupled subsidies*, *Direct payments* and *Single Farm Payment*. (iii) Two dummies are included to capture which proxy of the subsidies is used in the primary studies, namely *Subsidy per revenue* and *Subsidy per hectare*. (iv) The estimation strategy followed in the primary studies is captured by five dummies in our probit models: a dummy taking the value one if SFA has been used to calculate technical efficiency in the primary studies and zero if not (*Parametric estimation*), a dummy

representing whether Bayesian techniques have been used for SFA estimation (*Bayesian estimator*), two dummies capturing the way the efficiency score calculated with DEA in the first stage is explained in the second stage (*Quantile regression; Tobit regression*) and a dummy representing whether the output-orientation (as opposed to input-orientation) is assumed for the calculation of technical efficiency with DEA (*DEA output-orientation*). (v) The type of data used is considered through the dummy *Panel data* taking the value one if panel data were used in the primary studies and the value zero if not. (vi) The geographical area of the farms considered in the primary studies is included in the meta-regression since it is expected that policy incentives and room for manoeuvre may differ depending on the farm location. This is done via the dummy *EU-area* equal to one for studies on EU countries and zero otherwise, and the dummy *North America* equal to one for studies on North American countries and zero otherwise. (vii) The influence of the publication date and of the publication status of the primary study is investigated through two dummies: *Publication date* and *Publication status*. The former takes the value

one for papers published in 2003 or before and zero after. This dummy is aimed at capturing scientific progress in the technical efficiency literature and investigates the potential effect on findings regarding the efficiency-subsidy relationship. The latter dummy captures whether the studies are articles published in academic journals.

As mentioned above, we believe that modelling subsidies as an additional output in the production process is not correct. For this reason, all three models (the ordered probit and the two binary probit models) are then re-estimated excluding the observations relying on such a modelling approach, thus reducing the full sample of 195 observations to a subsample of 150 observations (and in the case of the second probit model where observations reporting non-significant effects are excluded, the sample is reduced from 153 to 122 observations).

The definition and descriptive statistics for the moderator variables for both the full sample and the subsample are presented in Table 2. It can be noted that there is a large array of the types of subsidies considered but most of the models used total subsidies (44%). Regarding the modelling

Table 2. Meta-analysis moderator variables and descriptive statistics.

Variables	Description	Full sample		Subsample	
		Mean	SD	Mean	SD
Dependent variable	Effect of subsidies on technical efficiency in primary studies				
Significantly negative	=1 for significantly negative effect, 0 otherwise	0.54	0.49	0.62	0.49
Null (non-significant)	=1 for null effect, 0 otherwise	0.22	0.41	0.18	0.39
Significantly positive	=1 for significantly positive effect, 0 otherwise	0.24	0.43	0.2	0.40
Significantly positive or null	=1 for significantly positive or null effect, 0 otherwise	0.46	0.49	0.38	0.49
Moderator variables					
Subsidies as output	=1 if subsidies are modelled as output, 0 otherwise	0.23	0.42	0	
Total subsidies	=1 if the type of subsidies is total subsidies, 0 otherwise	0.44	0.49	0.46	0.50
Input subsidies	=1 if the type of subsidies is input subsidies, 0 otherwise	0.04	0.18	0.05	0.21
Environmental subsidies	=1 if the type of subsidies is environmental subsidies, 0 otherwise	0.12	0.33	0.09	0.29
LFA subsidies	=1 if the type of subsidies is LFA subsidies, 0 otherwise	0.05	0.22	0.03	0.18
Investment subsidies	=1 if the type of subsidies is investment subsidies, 0 otherwise	0.06	0.24	0.07	0.26
Coupled subsidies	=1 if the type of subsidies is coupled subsidies, 0 otherwise	0.13	0.34	0.14	0.35
Direct payments	=1 if the type of subsidies is direct payments, 0 otherwise	0.8	0.40	0.83	0.38
Single Farm Payment	=1 if the type of subsidies is Single Farm Payment, 0 otherwise	0.11	0.32	0.12	0.33
Subsidies per revenue	=1 if the subsidy proxy is the amount of subsidies per revenue, 0 otherwise	0.41	0.49	0.41	0.49
Subsidies per hectare	=1 if the subsidy proxy is the amount of subsidies per hectare of land, 0 otherwise	0.11	0.32	0.13	0.33
Parametric estimation	=1 for parametric estimation in the case of SFA, 0 otherwise	0.76	0.43	0.75	0.43
Bayesian estimator	=1 for Bayesian estimation in the case of SFA, 0 otherwise	0.05	0.21	0.06	0.24
Quantile regression	=1 for quantile estimation in the second stage following DEA, 0 otherwise	0.03	0.16	0.03	0.18
Tobit regression	=1 for Tobit estimation in the second stage following DEA, 0 otherwise	0.06	0.24	0.08	0.27
DEA output-orientation	=1 for DEA output-oriented model, 0 otherwise	0.11	0.31	0.13	0.33
Panel data	=1 for panel data, 0 otherwise	0.87	0.33	0.92	0.29
EU area	=1 for EU member states, 0 otherwise	0.82	0.38	0.78	0.41
North America	=1 for North American countries, 0 otherwise	0.03	0.17	0.04	0.19
Publication date	=1 for papers published in 2003 or before, 0 otherwise	0.11	0.31	0.13	0.34
Publication status	=1 for articles published in journals, 0 otherwise	0.51	0.50	0.48	0.50
Number of observations		195		150	

The subsample is the full sample without the observations where subsidies are treated as an additional output.
LFA: Less favoured areas; DEA: data envelopment analysis; SFA: stochastic frontier analysis.

strategy, almost one-quarter of the models (23%) include subsidies as additional output in the efficiency calculation, and most of the models (76%) use parametric estimation. Concerning the publication status, one-half of the models are in journal publications (51%).

V. Results and discussion

Estimation results for the ordered probit model and for the two binary probit models for the full sample are presented in Table 3. The results for the models for the subsample excluding observations modelling subsidies as output are not shown but are discussed below. The likelihood ratio and *R*-squared statistics in Table 3 indicate that all three models have a high goodness-of-fit. In addition, the percentages of correctly predicted observations for the two binary probit estimations suggest that both models are well behaved. However, in the estimation of the ordered probit model, the second threshold parameter (Cut2) is not statistically significant, suggesting that the second and the third categories (namely non-significant effects and significantly positive effects) could be collapsed into one single category, as in the case of our first binary probit model. In the estimation of the ordered probit model for the sample excluding observations treating subsidies as output (results not shown), none of the threshold parameters is statistically significant, suggesting that the ordered structure is not appropriate for this sample.

The estimates of the meta-regression analysis for the full sample in Table 3 highlight several main findings³ from the empirical literature on the relationship between public subsidies and farms' technical efficiency. First, when subsidies are modelled as an additional output in the calculation of technical efficiency, the probability of obtaining a significantly negative effect of subsidies on technical efficiency decreases, and the probability of obtaining a significantly positive effect increases. The intuition is that modelling subsidies as output tends to virtually inflate the output value, while there is no associated increase in input use. Hence, farms with larger subsidies are considered to be producing more output with the same level of inputs than farms with lower

subsidies. This meta-regression finding may explain some of the contrasting findings reported in the literature. For instance, using the classical SFA framework and modelling subsidies as output, Hadley (2006) found a significantly positive impact of subsidies on technical efficiency for beef farms in England and Wales, while using the same framework but considering subsidies as contextual variables only, Iraizoz, Bardaji and Rapun (2005) found a significantly negative impact for Spanish beef farms. Another example is the contrasting results reported by Areal et al. (2012) and Mamardashvili and Schmid (2013) for environmental subsidies and dairy farms. Areal et al. (2012) did not consider such subsidies as output and found that they impacted negatively farm technical efficiency. By contrast, Mamardashvili and Schmid (2013) modelled environmental subsidies as output and found a positive impact on farm technical efficiency.

As explained above, this approach is not a correct way of modelling a production process. A theoretical (economic) argument against the modelling of subsidies as output is that subsidies are not an output generated by the classic agricultural production technology. Intuitively, the effects of subsidies (coupled or decoupled) have to be evaluated through the variation that they induce in the output that is really produced by farmers but not by adding the subsidies to the real production. In addition, when using such approach, the effect of these subsidies on technical efficiency should be estimated with care as there may be some endogeneity problems.

Second, aggregating all subsidies received by farmers into a total subsidy variable may hide effects attributed to specific subsidies, while modelling each type of subsidy separately appears to be an appealing way to isolate their effect. For example, results of the ordered probit model in Table 3 show that in the literature, total subsidies are related in a non-significant way to farms' technical efficiency, while investment subsidies and coupled subsidies are significantly positively related to farms' technical efficiency (more precisely, both types of subsidies decrease the probability of obtaining a significant negative impact; in addition, coupled subsidies increase the probability of obtaining a significant positive impact). This latter finding is

³Note that many variables are non-significant. This suggests that the direction of the effect is not systematically influenced by these variables. In fact, we have re-estimated the models by permuting the variables using the method of 'ClustOfVar', a method allowing grouping together variables which are strongly related or variables which bring the same information (Chavent et al. 2012), but the significance of the variables remains unchanged.

Table 3. Ordered probit and binary probit estimates for the meta-regression on the full sample.

	Estimates	Ordered probit				Binary probit	
		Marginal effects		For significantly positive effect ($j = 3$)	Significantly positive or null effect versus negative effect	Significantly positive effect versus significantly negative effect	
		For significantly negative effect ($j = 1$)	For non-significant effect ($j = 2$)				
Intercept	0.94 (0.29)***	-0.36 (0.10)***	0.09 (0.03)***	0.26 (0.10)**	1.18 (0.77)	0.39 (1.38)	
Subsidies as output	0.25 (0.32)	-0.10 (0.13)	0.04 (0.05)	0.06 (0.07)	1.09 (0.31)***	1.98 (0.64)***	
Total subsidies	0.52 (0.69)	-0.20 (0.26)	0.05 (0.05)	0.14 (0.23)	0.21 (0.40)	0.61 (0.55)	
Input subsidies	-0.43 (0.45)	0.16 (0.16)	-0.06 (0.04)	-0.08 (0.07)	0.73 (0.73)	-1.43 (1.08)	
Environmental subsidies	-0.45 (0.51)	0.17 (0.17)	-0.08 (0.11)	-0.08 (0.06)	-0.61 (0.43)	-0.36 (0.71)	
LFA subsidies	1.10 (0.63)*	-0.39 (0.18)**	0.04 (0.08)	0.35 (0.25)	-0.28 (0.67)	0.43 (1.00)	
Investment subsidies	0.95 (0.42)**	-0.36 (0.14)**	0.07 (0.03)**	0.28 (0.15)*	1.14 (0.80)	1.95 (0.96)**	
Coupled subsidies	-0.58 (0.42)	0.23 (0.16)	-0.07 (0.04)*	-0.15 (0.12)	0.67 (0.45)	1.24 (0.48)**	
Direct payments	-0.25 (0.52)	0.09 (0.19)	-0.05 (0.10)	-0.05 (0.09)	-0.24 (0.41)	-0.11 (0.56)	
Single Farm Payment	-2.03 (0.42)***	0.66 (0.09)***	-0.27 (0.06)***	-0.39 (0.06)***	-0.16 (0.53)	0.11 (0.77)	
Subsidies per hectare	0.08 (0.44)	-0.03 (0.17)	0.01 (0.07)	0.02 (0.11)	-2.31 (0.47)***	-2.86 (0.73)***	
Parametric estimator	0.35 (0.36)	-0.13 (0.14)	0.06 (0.07)	0.07 (0.07)	0.05 (0.46)	0.66 (0.67)	
Bayesian estimator	0.56 (0.84)	-0.22 (0.31)	0.06 (0.03)**	0.16 (0.29)	0.71 (0.41)	1.88 (1.11)*	
Quantile regression	-0.86 (0.68)	0.26 (0.17)*	-0.17 (0.12)	-0.12 (0.05)**	-0.03 (0.64)	0.27 (0.90)	
Tobit regression	-0.46 (0.55)	0.17 (0.18)	-0.08 (0.11)	-0.08 (0.07)	-1.22 (0.61)	-0.78 (0.59)	
DEA output-orientation	-0.27 (0.53)	0.10 (0.19)	-0.05 (0.10)	-0.05 (0.10)	-0.20 (0.59)	0.89 (1.03)	
Panel data	-0.74 (0.35)**	0.28 (0.13)**	0.07 (0.03)**	-0.21 (0.12)*	-0.08 (0.53)	0.26 (0.77)	
EU area	-0.50 (0.35)	0.19 (0.13)	-0.06 (0.04)*	-0.13 (0.10)	-0.49 (0.40)	-1.75 (0.77)**	
North America	-0.03 (0.67)	0.02 (0.26)	0.007 (0.12)	0.01 (0.14)	-0.55 (0.33)	-1.18 (0.53)**	
Publication date	-1.26 (0.36)***	0.39 (0.07)***	-0.23 (0.07)***	-0.16 (0.03)***	-0.39 (0.71)	-0.48 (0.73)	
Publication status	-0.15 (0.24)	0.02 (0.09)	-0.02 (0.04)	-0.03 (0.05)	-1.53 (0.45)***	-1.72 (0.62)***	
Number of observations	1.1E - 05 (2E - 05)	-4E - 06 (10E - 05)	-1.2E - 06 (1.1E - 05)	-2E - 06 (1.1 - 05)	-0.06 (0.29)	0.06 (0.43)	
Cut1	-1.69 (0.70)**				4.2E - 06 (1.5E - 05)	2.9E - 05 (2.6E - 05)	
Cut2	-0.78 (0.63)						
Likelihood ratio	186.18***				111.42***	175.12***	
Pseudo R-squared	0.28				0.39	0.51	
Percentage of correctly predicted observations					80.00	87.58	
Number of observations	195				195	153	

Robust SEs are in brackets. The asterisks ***, ** and * indicate significance at the 1, 5 and 10% levels, respectively.

confirmed by the binary probit model where significantly positive effects are compared to the reference of significantly negative effects: in this model, investment subsidies and coupled subsidies both increase the probability of the probit model, that is to say the probability of obtaining positive effects.

Third, the subsidy proxy used influences the result. More precisely, all models (whether for the full sample or for the subsample excluding observations considering subsidies as output) consistently show that using the ratio of subsidies per farm revenue as the subsidy proxy increases the probability of obtaining a significantly negative effect and decreases the probability of obtaining a significantly positive or non-significant effect on farms' technical efficiency. This may be one of the reasons behind the discrepancy highlighted above regarding the findings by Kumbhakar and Lien (2010) and Kumbhakar, Lien and Hardaker (2014) for Norwegian cereal farms. While the former found a significantly positive impact using the amount of subsidies received by the farm, the latter found a significantly negative impact using the subsidy rate. It should however be noted that, in the literature on the subsidy–efficiency nexus, when the ratio of subsidies per farm revenue is used as the subsidy proxy, there may be a problem of endogeneity since revenue includes output, a variable that is used to calculate technical efficiency.

Fourth, in terms of methodologies, one finding in Table 3 is shown by the ordered probit model and the binary probit where significantly positive effects are compared to the reference of significantly negative effects: using panel data increases the probability of obtaining a significantly negative effect of subsidies on farms' technical efficiency and decreases the probability of obtaining a significant positive effect, compared to using cross-sectional data.

Fifth, results from all models for the full sample in Table 3 as well as results from binary probit models for the subsample excluding observations modelling subsidies as output show a negative effect of the dummy capturing the publication date. This indicates that studies published in 2003 or before were more likely to obtain a significantly negative effect of subsidies on farms' technical efficiency than later studies.

Finally, an additional result highlighted by our model estimates is that the dummy *EU area* has a negative effect on the probability of obtaining a significantly positive effect or a non-significant effect of subsidies

on farms' technical efficiency. This suggests that studies applied to EU member states are more likely to report a negative effect of subsidies on farms' technical efficiency compared to other regions in the world.

VI. Conclusion

Investigating the impact of public subsidies on farms' technical efficiency is becoming a critical issue in applied policy analysis. With respect to the fact that theoretical results on this issue are ambiguous and that empirical findings in the literature are inconclusive; the objective of this article is to identify factors that could explain the heterogeneity of the observed empirical results.

In the empirical literature, the overall effect of agricultural subsidies on farm technical efficiency is significantly negative, but for 46% of the results provided in the existing studies, the effect is null (non-significant) or even significantly positive.

The meta-analysis of the sign of the effect reveals that when subsidies are modelled as an additional output in the efficiency calculation, their effect on technical efficiency is commonly found to be positive. Using such a modelling approach may, however, give an erroneous view of subsidies' real influence on technical efficiency since there is no input increase associated with the additional output. Modelling subsidies as output in a study should thus be strongly substantiated, as it is clear from our meta-analysis results that it provides findings that are biased towards a positive effect of subsidies on technical efficiency. In addition, proxying the subsidies considered by the ratio of these subsidies to farm revenue increases the probability of obtaining a significantly negative effect of subsidies on farms' technical efficiency. A methodological recommendation is therefore that investigating the effect of subsidies on farms' technical efficiency should rely on a careful modelling of subsidies, and that, when possible, sensitivity analyses based on several modelling strategies should be carried out. In addition, from a methodological point of view, the endogeneity of the subsidy proxy should be considered in the two cases mentioned above: when subsidies are included as an additional output as well as a contextual variable and when the subsidy proxy is the subsidies related to the farm revenue as the latter is linked to the technical efficiency calculation.

The other main finding highlighted by our meta-regression is that the date of publication (whether in

journals or not) of the studies affects the direction of the subsidy–efficiency link obtained. More precisely, we find that studies published in 2003 or before are more likely to have reported a negative effect of subsidies on farms’ technical efficiency than more recent studies. One reason may be the policy periods considered in the studies: earlier studies have mechanically focussed on periods when decoupled subsidies were not fully on the governments’ agenda, and farms were under less pressure from macroeconomic conditions (such as price volatility). However, we have controlled for these two suggestions by testing in the meta-regression the effect of specific types of subsidies and by including several dummy variables capturing the periods covered by the studies (not shown in the final specification used here). Another reason may be scientific progress in terms of methodologies. We find that the direction of the subsidy–efficiency link is not affected by various methodological aspects that we have included in our meta-regression, but there may be other methodological advances that we have not been able to capture in our meta-regression. A recommendation is therefore to continue to investigate the impact of subsidies on farms’ technical efficiency using advanced techniques and multiple case studies so that policymakers are provided with tailored and more up-to-date findings.

In particular the two-stage approach in the case of DEA could be updated. The two-stage approach is widely used in the literature. However, according to Simar and Wilson (2007 and 2011), (i) this approach is meaningful only if a ‘separability condition’ between the input–output space and the contextual variables holds and (ii) in the second-stage regression, the traditional inference is flawed because the estimated efficiency scores used as dependent variables are serially correlated. Simar and Wilson (2007 and 2011) suggested the use of bootstrap methods for addressing the second issue, but stressed that the separability assumption may be unrealistic in many practical cases. For relaxing the (restrictive) separability assumption, Simar and Wilson (2015) argued that the safest approach is the conditional efficiency model developed by Cazals, Florens and Simar (2002); Daraio and Simar (2005, 2007) and De Witte and Kortelainen (2013).

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Overview of the empirical studies on the link between subsidies and farm technical efficiency

Overview of the empirical studies on the link between subsidies and farm technical efficiency							
Reference	Study period	Location of the sample	Production sector	Sample size	Type of subsidies	Impact variable used Subsidy proxy	Effect of the impact variable
Studies using DEA followed by a second-stage regression							
Bojnec and Latruffe (2013)	2004-2006	Slovenia	Crop, livestock	1,784	Total operational subsidies	Subsidy rate (subsidies to farm output value)	-
Boussemart et al. (2012)	2005-2008	France	Crop	3,337	Decoupled payment	Subsidies per hectare	+
Charyulu and Biswas (2010)	2009	India	Crop	46	Input and investment subsidies	Dummy	0
Desjeux and Latruffe (2010)	1990-2006	France	Crop	32,781	Investment subsidies	Subsidies per hectare	+
					Coupled subsidies	Subsidies per hectare	-
					Environmental subsidies	Subsidies per hectare	-
					Decoupled payment	Subsidies per hectare	-
Desjeux and Latruffe (2010)	1990-2006	France	Dairy	20,410	Investment subsidies	Subsidies per livestock unit	+
					Coupled subsidies	Subsidies per livestock unit	+/-
					Environmental subsidies	Subsidies per livestock unit	+
					Decoupled payment	Subsidies per livestock unit	+
Desjeux and Latruffe (2010)	1990-2006	France	Beef cattle	10,003	Investment subsidies	Subsidies per livestock unit	0
					Coupled subsidies	Subsidies per livestock unit	-
					Environmental subsidies	Subsidies per livestock unit	-
Ferjani (2008)	1990-2001	Switzerland (valley)	Crop, livestock	12,426	Direct payments	Subsidy rate (subsidies to gross margin)	-

Ferjani (2008)	1990-2001	Switzerland (hill)	Crop, livestock	6,968	Direct payments	Subsidy rate (subsidies to gross margin)	-
Ferjani (2008)	1990-2001	Switzerland (mountains)	Crop, livestock	3,713	Direct payments	Subsidy rate (subsidies to gross margin)	-
Fogarasi and Latruffe (2009)	2001-2004	France	Dairy	2,716	Total subsidies	Subsidy rate (subsidies to output value)	-
Fogarasi and Latruffe (2009)	2001-2004	Hungary	Dairy	128	Total subsidies	Subsidy rate (subsidies to output) value	-
Fogarasi and Latruffe (2009)	2001-2004	France	Crop	3,644	Total subsidies	Subsidy rate (subsidies to output) value	-
Fogarasi and Latruffe (2009)	2001-2004	Hungary	Crop	1,112	Total subsidies	Subsidy rate (subsidies to output) value	-
Fousekis et al. (2001)	2009	Greece	Sheep	101	Not indicated	Subsidy rate (subsidies to total farm income)	-
Gaspar et al. (2007)	2004-2005	Spain	Crop, livestock	69	Total subsidies	Subsidy rate (subsidies to income)	-
Guyomard et al. (2006)	1995-2002	France	Crop	5,800	CAP direct payments	Subsidy rate (subsidies to farm revenue)	-
Guyomard et al. (2006)	1995-2002	France	Beef cattle	816	CAP direct payments	Subsidy rate (subsidies to farm revenue)	-
Guyomard et al. (2006)	1995-2002	France	Dairy	2,144	CAP direct payments	Subsidy rate (subsidies to farm revenue)	-
Lambert and Bayda (2005)	1995-2001	United States	Crop	378	Total subsidies	Value per farm	0
Latruffe et al. (2013)	2001	Hungary	Livestock	192	Not indicated	Subsidy rate (subsidies to farm revenue)	-
Latruffe et al. (2008)	2005	Romania	Crop	319	Subsidies for crop output	Subsidies per hectare	+

					Subsidies for seeds and pesticides purchase	Subsidies per hectare	-
Li et al. (2012)	2010	China	Crop	99	Public agricultural subsidies	Subsidies per hectare	-
					Investment subsidies	Dummy	+
Nastis et al. (2012)	2008	Greece	Alfalfa	40	CAP subsidies	Subsidy rate (subsidies to output value)	-
Sedik et al. (2000)	1991-1995	Russia	Crop	350	Total subsidies	Subsidy rate (subsidies to farm revenue)	-
Skevas et al. (2012)	2003-2007	The Netherlands	Crop	703	Crop subsidies	Value per farm	-
Studies using parametric (SFA) estimation							
Areal et al. (2012)	2000-2005	England	Dairy	25,000	Environmental payment	Dummy	-
					Set-aside payment	Dummy	+
Bakucs et al. (2010)	2001-2005	Hungary	Crop, livestock	3,210	Total subsidies	Subsidy rate (subsidies to output value)	-
Barnes et al. (2010)	1989-2008	England, Wales	Crop, dairy, livestock		Total subsidies	Subsidy rate (subsidies to gross margin)	-/0
Bojnec and Ferto (2011)	2004-2008	Slovenia	Crop, livestock	3,353	Total subsidies	Value per farm	-
Bojnec and Ferto (2013)	2004-2008	Slovenia	Crop, livestock	1,451	Total subsidies	Value per farm	-
Bojnec and Latruffe (2009)	1994-2003	Slovenia	Crop, livestock	130	Production subsidies	Subsidy rate (subsidies to revenue)	-
Brümmer and Loy (2000)	19987-1994	Germany	Dairy	5,093	Farm credit program as investment subsidies	Dummy	-
Caroll et al. (2009)	1996-2006	Ireland	Dairy	3,593	Decoupled subsidies	Dummy	-
Caroll et al. (2009)	1996-2006	Ireland	Cattle rearing	2,087	Decoupled subsidies	Dummy	0
Caroll et al. (2009)	1996-2006	Ireland	Cattle finishing	2,164	Decoupled subsidies	Dummy	0

Caroll et al. (2009)	1996-2006	Ireland	Sheep	890	Decoupled subsidies	Dummy	0
Caroll et al. (2009)	1996-2006	Ireland	Cereals	1,016	Decoupled subsidies	Dummy	0
Chidmi et al. (2011)	2004-2008	United States	Dairy	1,151	Total subsidies	Value per farm	+
Dinar et al. (2007)	1996	Greece	Crop, livestock	265	Total subsidies	Value per farm	0
Dung et al. (2011)	2009-2010	India	Crop	362	Total subsidies	Value per farm	-
Emvalomatis et al. (2008)	1996-2000	Greece	Crop	3,614	Compensatory payments	Value per farm	-
Emvalomatis et al. (2008)	1996-2000	Greece	Cotton	1,117	Compensatory payments	Value per farm	-
Giannakas et al. (2001)	1987-1995	Canada	Wheat	100	Government income transfer	Subsidy rate (subsidies to total farm income)	-
Hadley (2006)	1982-2002	England	Dairy	10,597	Total subsidies	Subsidy rate (subsidies to gross margin)	+
Hadley (2006)	1982-2002	England	Sheep	4,765	Total subsidies	Subsidy rate (subsidies to gross margin)	-
Hadley (2006)	1982-2002	England	Beef cattle	2,846	Total subsidies	Subsidy rate (subsidies to gross margin)	+
Hadley (2006)	1982-2002	England	Poultry	578	Total subsidies	Subsidy rate (subsidies to gross margin)	0
Hadley (2006)	1982-2002	England	Pig	1,459	Total subsidies	Subsidy rate (subsidies to gross margin)	0
Hadley (2006)	1982-2002	England	Cereals	4,772	Total subsidies	Subsidy rate (subsidies to gross margin)	-
Hadley (2006)	1982-2002	England	Other crops	6,461	Total subsidies	Subsidy rate (subsidies to gross margin)	-
Hadley (2006)	1982-2002	England	Mixed farming	7,435	Total subsidies	Subsidy rate (subsidies to gross margin)	-
Iraizoz and Muniz (2004)	1989-1999	Spain	Livestock	398	Total subsidies	Subsidy rate (subsidies to	-

						farm revenue)	
Iraizoz et al. (2005)	1989-1999	Spain	Beef cattle	2,594	Total subsidies	Subsidy rate (subsidies to farm revenue)	-
Karagiannis and Sarris (2005)	1991-1995	Greece	Tobacco	1,481	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Wheat	1,480	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Mixed crops	1,485	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Cotton	1,475	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Olive	1,481	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Fruits	1,470	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Vegetables	1,400	Total subsidies	Value per farm	-
Karagiannis and Sarris (2002)	1991-1995	Greece	Horticulture	1,400	Total subsidies	Value per farm	-
Karagiannis and Tzouvelekas (2005)	1989-1992	Greece	Sheep	178	Total subsidies	Value per farm	0
Kroupová and Malý (2010)	2004-2008	Czech Republic	Crop	715	Total subsidies	Subsidies per hectare	-
Kumbhakar and Lien (2010)	1991-2006	Norway	Cereals	1,512	Total subsidies	Value per farm	+
Kumbhakar et al. (2012)	2004-2008	Norway	Cereals	687	Coupled subsidies	Subsidy rate (subsidies to total farm net income)	-
				687	Environmental payments	Subsidy rate (subsidies to total farm net income)	-
Lachaal (1994)	1972-1992	United States	Dairy	/	Total subsidies	Value per farm	-
Lakner (2009)	1995-2005	Germany	Dairy	1,348	Agri-environmental subsidies	Value per farm	-
Lambarraa and Kallas (2009)	2000-2004	Spain	Olive	315	LFA subsidies	Payment ratio (subsidies to total subsidies)	-
Lambarraa et al. (2009)	1995-2003	Spain	COP	9,852	Policy reform (Agenda 2000)	Dummy	-

Latruffe et al. (2008)	2000-2004	Czech Republic	Dairy	431	Operational and investment subsidies	Value per farm	-
Latruffe et al. (2008)	2000-2004	Hungary	Crop, livestock	3,210	Operational subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2008)	2000-2004	Slovenia	Crop	130	Production subsidies	Subsidy rate (subsidies to farm revenue)	-
Latruffe et al. (2012)	1990-2007	Belgium	Dairy	5,017	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Denmark	Dairy	8,004	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	France	Dairy	21,514	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Germany	Dairy	30,085	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Ireland	Dairy	7,578	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Italy	Dairy	32,120	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Luxembourg	Dairy	3,821	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	The Netherlands	Dairy	5,017	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Portugal	Dairy	9,040	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Spain	Dairy	22,642	Total subsidies	Subsidy rate (subsidies to output value)	-

Latruffe et al. (2012)	1990-2007	United Kingdom	Dairy	13,119	Total subsidies	Subsidy rate (subsidies to output value)	-
Latruffe et al. (2012)	1990-2007	Belgium	Dairy	5,017	Decoupled subsidies	Dummy	0
Latruffe et al. (2012)	1990-2007	Denmark	Dairy	8,004	Decoupled subsidies	Dummy	-
Latruffe et al. (2012)	1990-2007	France	Dairy	21,514	Decoupled subsidies	Dummy	+
Latruffe et al. (2012)	1990-2007	Germany	Dairy	30,085	Decoupled subsidies	Dummy	+
Latruffe et al. (2012)	1990-2007	Ireland	Dairy	7,578	Decoupled subsidies	Dummy	0
Latruffe et al. (2012)	1990-2007	Italy	Dairy	32,120	Decoupled subsidies	Dummy	+
Latruffe et al. (2012)	1990-2007	Luxembourg	Dairy	3,821	Decoupled subsidies	Dummy	0
Latruffe et al. (2012)	1990-2007	The Netherlands	Dairy	5,017	Decoupled subsidies	Dummy	0
Latruffe et al. (2012)	1990-2007	Portugal	Dairy	9,040	Decoupled subsidies	Dummy	0
Latruffe et al. (2012)	1990-2007	Spain	Dairy	22,642	Decoupled subsidies	Dummy	+
Latruffe et al. (2012)	1990-2007	United Kingdom	Dairy	13,119	Decoupled subsidies	Dummy	+
Malá (2011)	2004-2008	Czech Republic	Crop	390	Environmental subsidies	Subsidies per hectare	-
Malá (2011)	2004-2008	Czech Republic	Crop	390	Other subsidies	Subsidies per hectare	0
Mamardashvili and Schmid (2013)		Switzerland (plain)	Dairy	1,362	Environmental subsidies	Subsidies per animal	+
Mamardashvili and Schmid (2013)		Switzerland (hill)	Dairy	2,504	Environmental subsidies	Subsidies per animal	+
Mamardashvili and Schmid (2013)		Switzerland (mountain)	Dairy	1,958	Environmental subsidies	Subsidies per animal	+
Manevska-Tasevska et al. (2013)		Sweden				Subsidy rate (subsidies to farm revenue)	-
	1998-2008		COP	309	Total subsidies		
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	COP	309	Coupled subsidies	Value per farm	-
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	COP	309	Environmental subsidies	Value per farm	0
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	COP	309	LFA subsidies	Value per farm	0
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Dairy	3,879	Total subsidies	Value per farm	-

Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Dairy	3,879	Coupled subsidies	Value per farm	+
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Dairy	3,879	Environmental subsidies	Value per farm	+
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Dairy	3,879	LFA subsidies	Value per farm	-
		Sweden				Subsidy rate (subsidies to	-
Manevska-Tasevska et al. (2013)	1998-2008		Beef cattle	806	Total subsidies	farm revenue)	
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Beef cattle	806	Coupled subsidies	Value per farm	-
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Beef cattle	806	Environmental subsidies	Value per farm	+
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Beef cattle	806	LFA subsidies	Value per farm	0
		Sweden				Subsidy rate (subsidies to	-
Manevska-Tasevska et al. (2013)	1998-2008		Pig	1,487	Total subsidies	farm revenue)	
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Pig	1,487	Coupled subsidies	Value per farm	-
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Pig	1,487	Environmental subsidies	Value per farm	+
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Pig	1,487	LFA subsidies	Value per farm	0
Manevska-Tasevska et al. (2013)	1998-2008	Sweden	Pig	1,487	Investment subsidies	Value per farm	0
McCloud and Kumbhakar (2008)	1997-2003	Denmark	Dairy	2,709	Total subsidies	Value per farm	+
McCloud and Kumbhakar (2008)	1997-2003	Finland	Dairy	1,844	Total subsidies	Value per farm	+
McCloud and Kumbhakar (2008)	1997-2003	Sweden	Dairy	2,053	Total subsidies	Value per farm	+
Piesse and Thirtle (2000)	1985-1991	Hungary	Cereals	819	Total subsidies	Value per farm	-
Rasmussen (2010)	1985-2006	Denmark	Crop, livestock	41,926	Total subsidies	Value per farm	0
Rezitis et al. (2003)	1993-1997	Greece	Crop, livestock	482	Total subsidies	Value per farm	-
Sauer and Park (2009)	2002-2004	Denmark	Dairy	168	Organic subsidies	Value per farm	+
Serra et al. (2008)	1998-2001	United States	Crop	2,196	Total subsidies	Value per farm	-
Sipiläinen et al. (2014)	1998-2001	Finland	Dairy	6,341	Policy change	Dummy	0
Sipiläinen et al. (2014)	1998-2001	Norway	Dairy	5,926	Policy change	Dummy	0
Sotnikov (1998)	1990-1995	Russia	Crop, livestock	450	Output subsidy	Value per farm	-
Thian and Wan (2000)	1983-1996	China	Indica rice	346	Investment subsidies	Value per farm	+

Thian and Wan (2000)	1983-1996	China	Japonica rice	224	Investment subsidies	Value per farm	0
Thian and Wan (2000)	1983-1996	China	Wheat	335	Investment subsidies	Value per farm	+
Thian and Wan (2000)	1983-1996	China	Corn	288	Investment subsidies	Value per farm	+
Zaeske (2012)	1985-2005	United States	Crop	240	Total subsidies	Value per farm	+
Zhu et al. (2012)	1995-2004	Germany	Dairy	12,458	Coupled subsidies	Subsidy rate (subsidies to total income)	-
Zhu et al. (2012)	1995-2004	The Netherlands	Dairy	3,223	Coupled subsidies	Subsidy rate (subsidies to total income)	-
Zhu et al. (2012)	1995-2004	Sweden	Dairy	3,341	Coupled subsidies	Subsidy rate (subsidies to total income)	-
Zhu et al. (2012)	1995-2004	Germany	Dairy	12,458	Livestock subsidies	Payment ratio (subsidies to total subsidies)	-
Zhu et al. (2012)	1995-2004	The Netherlands	Dairy	3,223	Livestock subsidies	Payment ratio (subsidies to total subsidies)	-
Zhu et al. (2012)	1995-2004	Sweden	Dairy	3,341	Livestock subsidies	Payment ratio (subsidies to total subsidies)	-
Zhu et al. (2012)	1995-2004	Germany	Dairy	12,458	Input subsidies	Payment ratio (subsidies to total subsidies)	-
Zhu et al. (2012)	1995-2004	The Netherlands	Dairy	3,223	Input subsidies	Payment ratio (subsidies to total subsidies)	-
Zhu et al. (2012)	1995-2004	Sweden	Dairy	3,341	Input subsidies	Payment ratio (subsidies to total subsidies)	-
Zhu and Oude Lansink (2010)	1995-2004	Germany	COP	4,755	Total subsidies	Subsidy rate (subsidies to farm revenue)	-
Zhu and Oude Lansink (2010)	1995-2004	The Netherlands	COP	1,966	Total subsidies	Subsidy rate (subsidies to farm revenue)	-

Zhu and Oude Lansink (2010)	1995-2004	Sweden	COP	1,009	Total subsidies	Subsidy rate (subsidies to farm revenue)	-
Zhu et al. (2011)	1995-2004	Greece	Olive	2,492	Total subsidies	Subsidy rate (subsidies to farm revenue)	-
Zhu and Oude Lansink (2010)	1995-2004	Germany	COP	4,755	Crop subsidies	Payment ratio (subsidies to total subsidies)	
Zhu and Oude Lansink (2010)	1995-2004	The Netherlands	COP	1,966	Crop subsidies	Payment ratio (subsidies to total subsidies)	
Zhu and Oude Lansink (2010)	1995-2004	Sweden	COP	1,009	Crop subsidies	Payment ratio (subsidies to total subsidies)	
Studies using correlation or comparative analysis							
Douarin and Latruffe (2011)	2001-2002	Lithuania	Crop	147	Total subsidies	Subsidies per hectare	-
Galanopoulos et al. (2011)	2011	Greece	Sheep, goats	106	Total subsidies	Value per farm	+
Gaspar et al. (2009)	2004-2005	Spain	Livestock	69	Total subsidies	Value per farm	-
Kleinhanss et al. (2007)	1999; 2000	Spain	Pig	255; 249	Total subsidies	Value per farm	+
Kleinhanss et al. (2007)	1999; 2000	Spain	Beef cattle	1,435; 1,543	Total subsidies	Value per farm	+
Kleinhanss et al. (2007)	1999; 2000	Spain	Sheep and goats	553; 679	Total subsidies	Value per farm	+
Kleinhanss et al. (2007)	1999; 2000	Germany	Pig	355; 355	Total subsidies	Value per farm	+
Kleinhanss et al. (2007)	1999; 2000	Germany	Beef cattle	604; 604	Total subsidies	Value per farm	+
Quero (2006)	2002	Spain	Beef cattle	50	Livestock premium	Subsidy rate (subsidies to farm revenue)	-
Soares et al. (2001)	1996	Spain	Dairy	122	Coupled subsidies	Value per farm	+
Taylor et al. (1986)	1982	Brazil	Crop	433	Credit subsidies	Value per farm	0
Theodoridis et al. (2012)	2007-2010	Greece	Sheep	58	Total subsidies	Value per farm	+

Notes: COP: cereal, oilseeds and proteinseeds. Dummy: the impact variable is a dummy equal to one if the farm receives some subsidies and zero if not. The effect of the impact variable is noted + when the effect is significant and positive, - if the effect is significant and negative, and 0 if the effect is not significant

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