Meta-regression analysis of the impact of agricultural subsidies on farm technical efficiency

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Abstract

Predicting and investigating the impact of subsidisation on farm technical efficiency are becoming critical issues in applied policy analysis. This paper presents a meta-regression analysis of empirical results on this issue, based on logistic regressions and data gathered from a systematic literature review from 1972 to 2014. The review reveals that subsidisation is commonly negatively associated with farm technical efficiency. Estimation results show that the direction (negative, positive or null) of the observed effects is sensitive to the way subsidies are modelled in the empirical studies, but robust to farming systems studied, estimation methods used, and geographical areas considered.

Keywords

technical efficiency; subsidies; farms; meta-regression analysis; multinomial probit model

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1. Introduction

This paper aims to shed light on the relationship between public subsidies and farm technical efficiency by meta-analysing results from related empirical studies. It questions whether there is unambiguous evidence in the existing empirical literature on the subsidy-farm efficiency link. One of the main goals of agricultural policies is to support farms' productive efficiency through subsidisation (Kleinhanß et al., 2007; OECD, 2012; European Council, 2013). From this regard and given successive reforms of agricultural policies, predicting and investigating the subsidy-farm efficiency link are becoming central research questions in production economics. Notwithstanding, theoretical results on this issue are ambiguous (see for example, Martin and Page, 1983; Serra et al., 2008; Zhu and Oude Lansink, 2010). Consequently, Serra et al. (2008), Kumbhakar and Lien (2010), and Zhu and Oude Lansink (2010) argue that investigating this issue is essentially empirical. However, findings from empirical studies on this issue also seem inconclusive (Zhu et al., 2011; Rizov et al., 2013). In such cases, it is widespread to meta-analyse empirical studies in order to reach sound conclusions (Cooper and Hegdes, 1994; Cucherat, 1997).

The meta-analytical framework consists in a set of statistical and econometric methods which allows synthesising outcomes from empirical studies carried out on a particular research question and investigating their heterogeneity (Glass, 1976; Stanley and Jarrell, 1989). The basic meta-analytical metric, namely the effect size, indicates the magnitude and the direction of the relationship between two variables. However, the issue of the non equivalence of the effect sizes may arise (Becker and Wu, 2007), resulting from disparities in empirical specifications. Due to this, and in order to keep a large number of observations for our analysis, in the present paper we do not consider the magnitude of the effect in the meta-analysis, but only its direction. In the economic literature, such meta-analytical approach based on qualitative effect instead of quantitative effect, has been recently used for example by Schläpfer (2006), Kiel and Williams (2007), Jacobsen and Hanley (2008), and Choumert et al. (2013). Given that the observed effect of the subsidy-efficiency link may be positive, negative, or null, the present study explores the heterogeneity of empirical studies using firstly a multinomial probit (MNP) meta-regression framework.

In the next section, we underline some theoretical arguments and prior evidences on the relationship between public subsidies and farms' technical efficiency. The third section presents the meta-analytical process. In the fourth section, we describe and discuss the main results. The last section draws some concluding remarks.

2. Theoretical arguments and prior evidence of the subsidy-efficiency link in agriculture

Theoretical arguments support that subsidisation may either positively or negatively impact farms' technical efficiency (Zhu and Oude Lansink, 2010; Kumbhakar and Lien, 2010). Positive relationship may be explained through investment decisions triggered by subsidisation. That is, public subsidies may improve technical efficiency if they are used to update the farm's productive capacity through replacement investment or net investment in advanced technologies. Public subsidies may enable farmers to keep on or to achieve scale economies through investments. A negative impact of subsidisation on technical efficiency may result from a non-stochastic wealth (income) effect (Zhu et al., 2012). Subsidies may result in income stabilisation and thus distort farmers' incentive to produce efficiently. Farmers' effort in farming activities may be reduced if a larger part of their income is guaranteed by subsidisation. In order words, subsidisation may enable farmers to smooth their wealth without adopting efficient production strategies.

In the existing literature the general finding is a negative influence of subsidisation. This may be due to the fact that investment decisions are related to the replacement of capital stock rather than to implementing more efficient technologies. This means that wealth and insurance effects prevail on investment effects. However, agricultural policies rely on different support programs, and the effect on efficiency may vary across subsidies. Total farm subsidies can be divided into six categories: (i) coupled production subsidies, made of coupled subsidies including crop and livestock payments, and of set-aside premiums; (ii) input subsidies, namely coupled subsidies on intermediate consumption; (iii) environmental subsidies provided when implementing environmental-friendly practices; (iv) subsidies received by farms located in less favoured area (LFA); (v) decoupled subsidies, that is Single Farm Payment which decouples direct payments from production; and (vi) investment subsidies. Hence, the impact of public subsidies on farms' technical efficiency should be discussed in light of the objective and modalities of the support program. For instance, environmental payments may lead to negative influence on technical efficiency, because they aim at producing environmental goods and services which are not taken into account in the traditional efficiency calculation.

Given the theoretical ambiguity of the impact of subsidisation on technical efficiency, empirical choices should be carefully made in modelling subsidies to avoid spurious results. As pointed out by McCloud and Kumbhakar (2008), almost all empirical studies model subsidies *ad hoc*. In the literature, subsidies are modelled as inputs (McCloud and Kumbhakar, 2008), as facilitating inputs (McCloud and Kumbhakar, 2008), as outputs (Kleinhanß et al., 2007; Rasmussen, 2010), as neutral contextual drivers (Bojnec and Latruffe, 2013), or as non-neutral contextual drivers (Latruffe et al., 2012; Kumbhakar and Lien, 2010). Furthermore, many empirical studies also suffer from simultaneity bias, as some subsidy payments are potentially endogenous (Kumbhakar and Lien, 2010). Hence, in the stochastic frontier analysis (SFA) framework, Kumbhakar and Lien (2010) advocate a triangular system to model subsidies. That is, to include subsidies in the production function as well as in the inefficiency function, and to consider subsidies as endogenous if it is believed that farmers can manipulate the amount they receive. This enables accounting for the fact that subsidisation may influence production decisions (i.e. productivity) as well as technical efficiency, and for the consideration of simultaneity between production and subsidy payments. In the case of non-parametric efficiency calculation, the conditional efficiency measurement (Daraio and Simar, 2007; De Witte and Kortelainen, 2012) seems to correspond to the same intuitions.

3. Meta-analytical process: data and methodology

3.1 Data collection

The data used in the subsequent analysis consists of 195 observations (i.e. 195 distinct results about effect of subsidies), extracted from a set of 68 studies carried out on periods from 1972 to 2014. The studies are collected from a systematic review of the existing empirical literature on the links between public subsidies and farm technical efficiency. The search of papers on this issue was conducted through the main scientific databases such as Econlit, Web of Science (WoS), Web of Knowledge (WoK), JSTOR, Econpapers, Science Direct, RepEc (IDEAS) and Google Scholar, combining in several search formulae the following keywords: on the one hand ‘subsidies’ or ‘support’, alone or with ‘public’, ‘government’, ‘CAP’ for Common Agricultural Policy, ‘Single Farm Payment’, ‘pillar 1’, ‘pillar 2’, ‘agricultural’, ‘EU’ for European Union, ‘farm bill’, and on the other hand ‘efficiency’, technical efficiency’, ‘economic efficiency’, ‘farm efficiency’, ‘productive efficiency’, ‘farm performance’ or ‘economic performance’. This literature search was completed by exploring the reference lists of the papers obtained through the databases’ search. To avoid publication bias (Sterne et al., 2008), unpublished studies are also included in the meta-analysis if they provide sufficient information on the data used, the estimated effect, and their analytical method. For a given empirical study, the estimated models are assumed to be independent if they consist of estimations for different countries, or different regions or different farming systems. The papers included in the meta-analysis are indicated with two stars (**) in the reference list.

3.2 Empirical models and moderator variables

We use a logistic meta-regression framework to explain consistently empirical results found on the relationship between public subsidies and farm technical efficiency. First, we consider the negative and positive effects with respect to the null effect by estimating a multinomial probit model (MNP)[1] using the simulated maximum likelihood method. More precisely, for the three observed effects, we specify three binary variables y_{ik}, with $k = 1,2,3$ which stand for positive, negative, and null effect, respectively. These binary variables are associated with latent variables y_{ik}^*, such as $y_{ik}^* = X_{ik}\beta + \xi_{ik}$ with $y_{ik} = 1$ if $y_{ik}^* > 0$, and 0 otherwise. X_{ik} is a $1 \times p$ vector of moderator variables explaining the observed effects; β are parameters to be estimated; and $\xi_i = (\xi_{i1}, \xi_{i2}, \xi_{i3}) \sim MNV(0, \Omega)$.The probability of alternative k for the i-th observation is given by:

$$Prob\left[y_{ik} = k | X_{ik}, \beta_k, \Omega_{(\mathrm{k})}\right] = \int_{-\infty}^{-X_{i1}\beta_1} \int_{-\infty}^{-X_{i2}\beta_2} \mathcal{N}_{(\mathrm{k})}\left(\xi_{ik}; 0, \Omega_{(\mathrm{k})}\right) d\xi_{ik} \tag{1}$$

where $\mathcal{N}_{(\mathrm{k})}\left(\xi_{ik}; 0, \Omega_{(\mathrm{k})}\right)$ is the density of a k-variate Gaussian distribution.

The MNP model allows the separation in more than two categories but often leads to convergence problems when the number of moderator variables increases. For this reason, assuming that only negative effects of subsidies on farms’ technical efficiency are not desirable by policy-makers, and thus grouping positive and null effects together, we estimate in addition to the MNP a binary probit model, where the dependant variable is equal to 1 for positive or null effects and 0 for (undesirable) negative effects:

[1] The MNP model is used with multivariate dependent variables which do not have natural ordering. In contrast to the multinomial logit and conditional logit models, the MNP model does not impose the restrictive property of the independence of irrelevant alternatives (IIA).

$$Prob[y_i = 1|X_i, \beta, \Omega] = \int_{-\infty}^{-X_i\beta} \phi(z)dz \tag{2}$$

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

The definition and descriptive statistics for the moderator variables are presented in Table 1, revealing three interesting features. Firstly, the most common finding on the subsidy-efficiency link is that public subsidies are negatively related to farms' technical efficiency. Secondly, empirical studies commonly model subsidies as contextual drivers. That is, subsidies are usually assumed to influence only the distribution of the efficiency scores, while there is strong theoretical evidence that subsidies may influence the input marginal product (Hennessy, 1998; Serra al., 2008). Finally, the existing literature on the subsidy-efficiency association relies broadly on the impact of total subsidy received by farmers. This suggests that research on this issue is usually focused on the wealth effect of subsidies. In order words, few studies have explored the impact of different types of subsidies on farms' efficiency.

4. Results and discussion

Estimation results for the MNP specified in equation (1) and for the binary probit model specified in equation (2) are presented in Table 2. For the MNP model the omitted alternative is the null effect and for the binary model the omitted alternative is the negative effect. Results from both models are quite similar. The likelihood ratio (LR) statistics indicate that both models have a high goodness-of-fit. In addition, the LR statistic for the correlation matrix (Ω) for the MNP estimation and the percentages of correctly predicted observations for the binary probit estimation suggest that both models are well behaved.

The estimates of the meta-regression analysis highlight three findings from the empirical literature on the relationship between public subsidies and farms' technical efficiency. Firstly, when subsidies are modelled as output they decrease the probability to obtain a negative effect of subsidies on efficiency, and increase the probability of obtaining of a positive effect. This is an expected result because modelling subsidies as output tends to virtually inflate the output value, while there is no associated increase in input use. This result is likely one explanation for many contrasted findings reported in the literature. For instance, using the classical SFA framework and modelling subsidies as output, Hadley (2006) found a positive impact of subsidies on technical efficiency for beef farms in England and Wales, while using the same framework and considering subsidies as contextual variables only, Iraizoz et al. (2005) found a negative impact for Spanish beef farms. Similar explanations are plausible for the contrasted results reported by Areal et al. (2012) and Mamardashvili and Schmid (2013) for environmental subsidies.

Secondly, aggregating all subsidies received by farmers into total subsidies increases the probability of a negative effect of subsidies on farms' technical efficiency. Such negative effect may be explained by the non-stochastic wealth (or income stability) effect of subsidies (Zhu et al., 2012). This implies that under subsidisation, as argued in Karagiannis and Sarris (2005), farmers usually tend to substitute subsidy income with production income, and to put less effort into farming activities. In contrast to this, modelling each type of subsidy separately appears to be an appealing way to isolate their effect. For example, Table 2 shows clearly that investment subsidy is positively related to farms' technical efficiency.

Finally, results in Table 2 show that farming systems, estimation methods (parametric, semi-parametric) and geographical area do not influence the direction of the effect of public subsidies on farms' technical efficiency. This suggests that the direction of the effect is robust to these drivers. In addition, our probit results appear to be robust against publication bias, indicating that the file-drawer problem highlighted by Duval and Tweedie (2000)[2] may be ignored. Indeed, results in Table 2 show that there is no systematic difference between published and unpublished studies in terms of direction of the observed effects.

Table 1. Meta-analysis variables and descriptive statics

Variable	Description	Mean	Standard deviation
Dependent variable of the multinomial probit model			
Positive	=1 if positive effect, 0 otherwise	0.25	0.43
Negative	=1 if negative effect, 0 otherwise	0.54	0.49
Null	=1 if null effect, 0 otherwise	0.21	0.41
Dependent variable of the binomial probit model			
Positive	=1 if positive or null effect, 0 otherwise	0.46	0.49
Moderator variables			
Subsidy modelling			
As output	= 1 if subsidies are modelled as output, 0 otherwise	0.23	0.42
As contextual	= 1 if subsidies are modelled as contextual variables, 0 otherwise	0.63	0.48
As non-neutral	= 1 if subsidies are modelled as influencing input productivity or output, 0 otherwise	0.18	0.38
Subsidy type			
Total subsidy received	= 1 for total subsidy received, 0 otherwise	0.44	0.49
Coupled subsidy	= 1 for coupled output subsidy, 0 otherwise	0.13	0.34
Input subsidy	= 1 for input subsidy, 0 otherwise	0.04	0.18
Environmental subsidy	= 1 for environmental subsidy, 0 otherwise	0.12	0.33
LFA subsidy	= 1 for LFA subsidy, 0 otherwise	0.05	0.22
Investment subsidy	= 1 for investment subsidy, 0 otherwise	0.06	0.24
Farming system			
Crop farming	= 1 for crop farms, 0 otherwise	0.38	0.48
Dairy farming	= 1 for dairy farms, 0 otherwise	0.38	0.48
Livestock farming	= 1 for livestock farms (excluding dairy), 0 otherwise	0.18	0.39
Mixed farming	= 1 for mixed farms, 0 otherwise	0.08	0.28
Estimation strategy			
Parametric estimation	= 1 for parametric estimation, 0 otherwise	0.76	0.43
Semi-parametric estimation	= 1 for two-stage DEA estimation, 0 otherwise	0.18	0.38
Balanced panel	= 1 for balanced panel data, 0 otherwise	0.08	0.28
Time varying	= 1 for time varying efficiency specification, 0 otherwise	0.82	0.39
Heterosc. frontier	= 1 for time heteroscedastic frontier specification, 0 otherwise	0.17	0.38
Bayesian estimator	= 1 for Bayesian estimation, 0 otherwise	0.05	0.21
Quantile regression	= 1 for quantile estimation, 0 otherwise	0.03	0.16
Tobit regression	= 1 for Tobit estimation in the second stage, 0 otherwise	0.06	0.24
Output orientation	=1 for output-oriented technical efficiency, 0 otherwise	0.11	0.31
Geographical area			
EU-area	= 1 for EU member countries, 0 otherwise	0.82	0.38
North America	= 1 for north American countries, 0 otherwise	0.03	0.17
Control variable			
Varsize	Ratio of the number of regressors on the number of observations in the primary studies used.	0.02	0.03
Publication status	= 1 for published papers, 0 otherwise	0.51	0.50

[2] The file drawer-problem refers to the fact that studies with significant and interesting results are more likely to be submitted, published and cited.

Table 2. Multinomial Probit and binary Probit estimates for the meta-regressions

	Multinomial Probit (MNP)		Binary Probit
	Negative effect	Positive effect	Positive of null effect
Intercept	0.23 (0.53)	-0.26 (0.48)	-0.41 (0.94)
As output	-1.03 (0.37) ***	0.94 (0 .39) **	1.37 (0 .67) **
As contextual	/	/	0.23 (0.71)
As non-neutral	-0.08 (0.31)	0.20 (0.35)	0.72 (0.60)
Total subsidy received	0.64 (0.24) ***	-0.34 (0.28)	-0.75 (0.28) ***
Coupled subsidy	/		-0.38 (032)
Input subsidy	-0.23 (0.51)	0.46 (0.60)	0.14 (0.58)
Environmental subsidy	0.31 (0.35)	0.07 (0.38)	-0.44 (0.41)
LFA subsidy	0.11 (0.41)	-0.09 (0.59)	0.04 (0.49)
Investment subsidy	-0.99 (0.47)**	0.58 (0.47)	1.22 (0.51) **
Crop farming	/	/	0.49 (0.42)
Dairy farming	/	/	0.49 (0.46)
Livestock farming	/	/	0.58 (0.50)
Mixed farming	0.62 (0.47)	-0.65 (0.60)	/
Parametric estimation	-0.44 (0.40)	-0.30 (0.41)	0.52 (0.65)
Semi-parametric estimation	/	/	-0.35 (0.74)
Balanced panel	0.46 (0.53)	-0.10 (0.45)	-0.24 (0.48)
Time varying	/	/	-0.43 (0.46)
Heterosc. frontier	0.77 (0.39) **	-1.09 (0.55)**	-0.73 (0.43) *
Bayesian estimator	-0.95 (0.51) *	1.55 (0.57) ***	0.79 (0.57)
Quantile regression	0.56 (0.87)	0.14 (0.89)	-0.68 (0.92)
Tobit regression	0.06 (0.66)	-0.40 (0.57)	0.26 (0.65)
Output orientation	-0.22 (0.43)	0.10 (0.43)	0.55 (0.45)
EU-area	0.23 (0.35)	-0.50 (0.35)	-0.38 (0.32)
North America	-0.34 (0.65)	0.01 (0.63)	0.28 (0.69)
Varsize	-8.59 (3.56) **	2.20 (2.68)	7.50 (4.32)*
Publication status	0.14 (0.28)	-0.04 (0.31)	-0.32 (0.32)
LR statistic	121.1***		69.04 ***
LR statistic for Ω	48.3***		
% correctly predicted			73.85
Pseudo R-squared			0.23
Number of observations	195		195

Note: Robust standard errors are in parentheses; *** p<0.01, ** p<0.05, * p<0.1

5. Concluding remarks

Predicting and investigating the impact of public subsidies on farms' technical efficiency are becoming critical issues in applied policy analysis. With respect to the fact that theoretical results on this issue are quite ambiguous and that empirical findings in the literature are likely inconclusive, the objective of this paper was to identify factors that could explain the heterogeneity of the observed empirical results.

Results from a multinomial probit model and a binary probit model reveal several interesting features. First, when subsidies are modelled as output in efficiency calculation, their effect on technical efficiency is commonly found to be positive. Using such modelling approach may provide an erroneous view of their real influence on efficiency since there is no input increase associated. Second, empirical studies using total subsidies received by farms and not specific types of subsidies, usually find a negative effect of subsidisation on farms' technical efficiency. By contrast, investment subsidies are positively related to farms' technical efficiency. These results provide strong empirical evidence that each type of subsidies have to be treated separately in empirical analysis. Lastly, the direction of the observed effects on the subsidy-efficiency association is robust to farming systems, estimation methods, and geographical areas. It should also be kept in mind that, even though modelling subsidies as non-neutral drivers does not show any systematic effect in our probit results, this approach is theoretically consistent (Sipiläinen and Kumbhakar, 2010).

In conclusion, our meta-analysis results suggest that investigating the effect of subsidies on farms' technical efficiency should rely on a careful modelling of subsidies.

References

**Areal, F.G., Tiffin, R. and Balcombe, K. (2012). Farm technical efficiency under a tradable milk quota system. *Journal of Dairy Sciences* 95: 50-62.

** Barnes, A.P., Revoredo-Giha, C., Sauer, J., Elliott, J. and Jones, G. (2010). A report on technical efficiency at the farm level 1989 to 2008. Final Report to Defra. London.

**Bakucs, L.Z., Latruffe, L., Ferto, I. and Fogarasi, J. (2010). The impact of EU accession on farms' technical efficiency in Hungary. *Post-Communist Economies* 22(2): 165-175.

Becker, B.J. and Wu, M.-J. (2007).The synthesis of regression slopes in meta-analysis. *Statistical Science* 22(3): 414-429.

**Bojnec, S. and Ferto, I. (2011). Impact of off-farms income on farm efficiency in Slovenia. Paper presented at the Congress of the European Association of Agricultural Economists. Zurich, Switzerland.

**Bojnec, S. and Ferto, I. (2013). Farms income sources, farm size and farm technical efficiency in Slovenia. *Post Communist Economies* 25(3): 343-356.

**Bojnec, S. and Latruffe, L. (2009). Determinants of technical efficiency of Slovenian farms. *Post Communist Economies* 21(1): 117-124.

**Bojnec, S. and Latruffe, L. (2013). Farm size, agricultural subsidies and farm performance in Slovenia. *Land Use Policy* 32: 207-217.

**Boussemart, J.-P., Kassoum, A. and Vigeant, S. (2012). Impact de l'Introduction des DPU sur l'Efficacité Technique des Exploitations Agricoles d'Eure-et-Loir. Paper presented at the 29th French Conference on Applied Microeconomics. Brest, France.

**Brümmer, B. and Loy, J.-P. (2000). The technical efficiency impact of farm credit programmes: a case study of Northern Germany. *Journal of Agricultural Economics* 51(3): 405-418.

**Caroll, J., Greene, S., O'Donoghue, C., Newman, C. and Torne, F. (2009). Productivity and the Determinants of Efficiency in Irish Agriculture (1996-2006). Paper presented at the 83rd Annual Conference of the Agricultural Economics Society. Dublin, Ireland.

**Charyulu, D.K. and Biswas, S. (2010). Efficiency of Organic Input Units Under UNPOF Scheme in India. Working Paper, Indian Institute of Management, No 210-04-01. Ahmedabad, India.

**Chidmi, B., Solis, D. and Cabrera, V.E. (2011). Analyzing the sources of technical efficiency among heterogeneous dairy farms: a quantile regression approach. *Journal of Development and Agricultural Economics* 3(7): 318-324.

Choumert, J., Motel, P.C. and Dakpo, H.K. (2013). Is the Environmental kuznets Curve for deforestation a threatened theory? A meta-analysis of literature. *Ecological Economics* 90: 19-28.

Cooper, H. and Hedges, L.V. (1994). *Handbook of Research Synthesis*. New York: Russell Sage Foundation.

Cucherat, M. (1997). *Méta-Analyse des Essais Thérapeutiques*. Paris: Masson.

Daraio, C. and Simar, L. (2007). *Advanced Robust and Nonparametric Methods in Efficiency Analysis: Methodology and Applications*. New York, NY: Springer.

**Desjeux, Y. and Latruffe, L. (2010). Influence of Agricultural Policy Support on Farmers' Technical Efficiency: An Application to France. Paper presented at the Asia-Pacific Productivity Conference. Academia Sinica, Taiwan.

De Witte, K. and Kortelainen, M. (2012). What explains the performance of students in a heterogeneous environment? Conditional efficiency estimation with continuous and discrete environmental variables. *Applied Economics* 45 (17): 2404-2412.

**Dinar, A., Karagianis, G. and Tzouvelekas, V. (2007). Evaluating the impact of agricultural extension on farms' performance in Crete: a nonneutral stochastic frontier approach. *Agricultural Economics* 36: 135-146.

**Douarin, E., and Latruffe, L. (2011). Potential impact of the EU Single Area Payment on farm restructuring and efficiency in Lithuania. *Post-Communist Economies* 23(1): 87-103.

**Dung, K.T., Sumalde, Z.M., Pede, V.O., McKinley, J.D., Garcia, Y.T. and Bello, A.L. (2011). Technical efficiency of resource-conserving technologies in rice-Wheat systems: the case of Behar and Eastern Uttar Pradesh in India. *Agricultural Economics Research Review* 24: 201-210.

Duval, S.J. and Tweedie, R.L. (2000). A non-parametric trim-and-fill method of accounting for publication bias in meta-analysis. *Journal of the American Statistical Association* 95: 89-98.

**Emvalomatis, G., Oude Lansink, A. and Stefanou, S. (2008). An Examination of the Relationship Between Subsidies on Production and Technical Efficiency in Agriculture: The Case of Cotton Producers in Greece. Paper presented at the 107th Seminar of the European Association of Agricultural Economists. Sevilla, Spain.

European Council, (2013). Conclusions: Multiannual financial framework, EUCO 37/13. Brussels, Belgium.

**Ferjani, A. (2008). The relationship between direct payments and efficiency in Swiss farms. *Agricultural Economics Review* 9(1): 93-102.

**Fogarasi, J. and Latruffe, L. (2009). Farm Performance and Support in Central and Western Europe: A Comparison of Hungary and France. Paper presented at the 83rd Annual Conference of the Agricultural Economics Society. Dublin, Ireland.

**Fousekis, P., Spathis, P. and Tsimboukas, K. (2001). Assessing efficiency of sheep farming in mountainous area of Greece. A nonparametric approach. *Agricultural Economics Review* 2 (2): 5-15.

**Galanopoulos, K., Abas, Z., Laga, V., Hatziminaoglou, I. and Boyazoglu, J. (2011). Technical efficiency of transhumance sheep and goat farms and the effect of EU subsidies: do small farms benefit more than large farms? *Small Ruminant Research* 100: 1-7.

**Gaspar, P., Escribano, M., Mesias, M.J., Pulido, F. and Martinez-Carrasco, F. (2007). La efficiencia in explotaciones granaderas de dehesa : un approximacion DEA al papel de la sostenibilidad y de las subvenciones comunitarias. *Revista Española de Estudios Agrosociales y Presqueros* 215-216: 185-209.

**Gaspar, P., Mesias, M.J., Escribano, M. and Pulido, F. (2009). Assessing the technical efficiency of exensive livestock farming systems in Extremadura, Spain. *Livestock Science* 121: 7-14.

**Giannakas, K., Schoney, R. and Tzouvelekas, V. (2001). Technical efficiency, technological change and output growth of wheat farms in Saskatchewan. *Canadian Journal of Agricultural Economics* 49: 135-152.

Glass, G. (1976). Primary, secondary and meta-analysis of research. *Educational Researcher* 5: 3-8.

**Guyomard, H., Latruffe, L. and Le Mouël, C. (2006). Technical Efficiency, Technical Progress, and Productivity Change in French Agriculture: Do Subsidies and Farms' Size Matters? Paper presented at the 96th Seminar of the European Association of Agricultural Economists. Tänikon, Switzerland.

**Hadley, D. (2006). Patterns in technical efficiency and technical change at the farm-level in England and Wales, 1982-2005. *Journal of Agricultural Economics* 57: 81-100.

Hennessy, D.A. (1998). The production effects of agricultural income support policies under uncertainty. *American Journal of Agricultural Economics* 80 (1): 46-57.

**Iraizoz, B. and Muniz, I.A. (2004). Análisis de la efficiencia técnica en explotaciones ganaderas de vacuno de carne en España. *Revista Española de Estudios Agrosociales y Presqueros* 204 :67-93.

**Iraizoz, B., Bardaji, I. and Rapun, M. (2005). The Spanish beef sector in the 1990s: impact of the BSE crisis on efficiency and profitability. *Applied Economics* 37: 473-484.

Jacobsen, J.B. and Handley, N. (2008). Are there income effects on global willingness to pay for biodiversity conservation? *Environmental and Research Economics* 43 (2): 137-160.

**Karagiannis, G. and Sarris, A. (2002). Direct Subsidies and Technical Efficiency in Greek Agriculture. Paper presented at the 10th Congress of the European Association of Agricultural Economists. Zaragoza, Spain.

**Karagiannis, G. and Sarris, A. (2005). Measuring and explaining scale efficiency with the parametric approach: the case of Greek tobacco growers. *Agricultural Economics* 33: 441-451.

**Karagiannis, G. and Tzouvelekas, V. (2005). Explaining output growth with a heteroscedastic non-neutral production frontier: the case of farms in Greece. *European Review of Agricultural Economics* 32(1): 51-74.

Kiel, K.A. and Williams, L. (2007). The impact of superfund sites on local property values: are all sites the same? *Journal of Urban Economics* 61(1): 170-192.

**Kleinhanß, W., Murillo, C., San Juan, C. and Sperlich, S. (2007). Efficiency, subsidies, and environmental adaptation of animal farming under CAP. *Agricultural Economics* 36: 49-65.

**Kroupová, Z. and Malý, M. (2010). Analysis of agriculture subsidy policy tools: application of production function. *Politiká Ekonomie* 6: 774-794.

**Kumbhakar, S.C. and Lien, G. (2010). Impact of subsidies on farm productivity and efficiency. In Ball, V.E., Fanfani, R. and Gutierez, L. (eds), *The Economic Impact of Public Support to Agriculture, Studies in Productivity and Efficiency*. New York, NY: Springer, 109-124.

**Kumbhakar, S.C., Lien, G. and Hardaker, J.B. (2012). Technical efficiency in competing panel data models: a study of Norwegian grain farming. *Journal of Productivity Analysis* DOI: 10.1007/s11123-012-0303-1.

**Lachaal, L. (1994). Subsidies, endogenous technical efficiency and the measurement of productivity growth. *Journal of Agricultural and Applied Economics* 26(1): 299-310.

**Lakner, S. (2009). Technical Efficiency of Organic Milk-Farms in Germany: The Role of Subsidies and of Regional Factors. Paper presented at the Conference of the International Association of Agricultural Economists. Beijing, China.

**Lambarraa, F. and Kallas, Z. (2009). Subsidies and Technical Efficiency: An Application of Stochastic Frontier and Random Effect Tobit Models to LFA Spanish Olive Farms. Paper presented at the 113th Seminar of the European Association of Agricultural Economists. Chania, Crete, Greece.

**Lambarraa, F., Stefanou, S., Serra, T. and Gil, J.M. (2009). The impact of the 1999 CAP reforms on the efficiency of COP sector in Spain. *Agricultural Economics* 40: 355-364.

**Lambert, D.K. and Bayda, V.V. (2005). The impact of farm financial structure on production efficiency. *Journal of Agricultural and Applied Economics* 37(1): 277-289.

**Latruffe, L., Bakucs, L.Z., Bojnec, S., Ferto, I., Fogarasi, J., Gavrilescu, J., Jelinec, L., Luca, L., Medonos, T. and Toma, C. (2008). Impact of Public Subsidies on Farms' Technical Efficiency in New Member States Before and After EU Accession. Paper presented at the 12th Congress of the European Association of Agricultural Economists. Gent, Belgium.

**Latruffe, L., Bravo-Ureta, B., Moreira, V., Desjeux, Y. and Dupraz, P. (2012). Productivity and Subsidies in European Union Countries: An Analysis for Dairy Farms Using Input Distance Frontiers. Paper presented at the Conference of the International Association of Agricultural Economists. Foz Do Iguaçu, Brazil.

**Latruffe, L., Desjeux, Y., Bakucs, L.Z., Ferto, I. and Fogarasi, J. (2013). Environmental pressure and technical efficiency of pig farms in Hungary. *Managerial and Decision Economics* DOI: 10.1002/mde.2600.

**Li, D., Nanseki, T. and Takeuchi, S. (2012). Measurement of agricultural production efficiency and the determinants in China based on DEA approach: a case study of 99 farms from Habei province. *Journal of the Faculty of Agriculture, Kyushu University* 57(1): 235-244.

**Malá, Z. (2011). Efficiency analysis of Czech organic agriculture. *Ekonomie a management* 1: 14-28.

**Mamardashvili, Ph. and Schmid, D. (2013). Performance of Swiss Dairy farms under provision and public goods. *Agricultural Economics-Czech* 59(7): 300-314.

**Manevska-Tasevska, G., Rabinowicz, E. and Surry, Y. (2013). Policy impact on farm efficiency in Sweden: 1998-2008. Agrifood Economics Center, Working paper, N0.6. Scheelevägen, Sweden.

Martin, J.P. and 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.

**McCloud, N. and Kumbhakar, S.C. (2008). Do subsidies drive productivity? A cross-country analysis of Nordic dairy farms. In Chib, S., Griffiths, W., Koop, G. and Terrel, D. (eds), *Bayesian Econometrics, Advances in Econometrics*. Bingley, UK: Howard House, Wagon Lane, 245-274.

**Nastis, S.A., Papanagiotou, E. and Zamanidis, S. (2012). Producctive efficiency of subsidized organic alfalfa farms. *Journal of Agricultural and Resource Economics* 37(2): 282-288.

OECD, (2012). Agricultural policy monitoring and evaluation 2012: OECD countries, OECD publishing. http://dx.doi.org/10.1787/agr_pol-2012-en

**Piesse, J. and Thirle, C. (2000). A stochastic frontier approach to firm level efficiency, technical change, and productivity during the early transition in Hungary. *Journal of Comparative Economics* 28: 473-501.

**Quero, M.C. (2006). Efficiencia téchnica de la producción de vacuno de carne en la dehesa. *Revista Española de Estudios Agrosociales y Presqueros* 212: 139-154.

**Rasmussen, S. (2010). Scale efficiency in Danish agriculture: an input distance-function approach. *European Review of Agricultural Economics* 37 (3): 335-367.

**Rezitis, A.N., Tsiboukas, K. and Tsoukalas, S. (2003). Investigation of factors influencing the technical efficiency of agricultural producers participating in farm credit programs: the case of Greece. *Journal of Agricultural and Applied Economics* 35(3): 529-541.

Rizov, M., Pokrivcak, J. and Ciaian, P. (2013). CAP subsidies and productivity of the EU farms. *Journal of Agricultural Economics* 64(3): 537-557.

**Sauer, J. and Park, T. (2009). Organic farming in Scandinavia: productivity and market exit. *Ecological Economics* 68: 2243-2254.

Schläpfer, F. (2006). Survey protocol and income effects in the contingent valuation of public goods: a meta-analysis. *Ecological Economics* 57 (3): 415-429.

**Sedik, D.J., Trueblood, M.A. and Arnade, C. (2000). Agricultural restructuring in Russia, 1991-1995: a technical efficiency analysis. In Wehrheims, P., Serova, E.V., Frohberg, K. and Von Braun, J. (eds), *Russia's Agro-Food Sector: Towards Truly Functioning Markets*. Boston: Kluvert Academic Publishers, 495-512.

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

Sipiläenen, T. and Kumbhakar, S.C. (2010). Effects of direct payments on farm performance: the case of dairy farms in Northern EU countries. University of Helsinki, Discussion papers No 43. Helsinki, Finland.

**Sipiläenen, T., Kumbhakar, S.C. and Lien, G. (2014). Performance of dairy farms in Finland and Norway from from 1991 to 2008. *European Review of Agricultural Economics* 41 (1): 63-86.

**Skevas, T., Oude Lansink, A. and Stefanou, S.E. (2012). Measuring technical efficiency of pesticides spillovers and production uncertainty: the case of Dutch arable farms. *European Journal of Operational Research* 223: 550-559.

**Soares, E., Berbel, J. and Arzubi, A. (2001). Análisis No paramétrico de efficiencia en las explotaciones lecheras de las Azores a partir de datos RICA-A. Proceedings of the IV Congreso National de Economía Agraria. Pamplona, Spain.

**Sotnikov, S. (1998). Evaluating the effects of price and trade liberalization on the technical efficiency of agricultural production in transition economy: the case of Russia. *European Review of Agricultural Economics* 25: 412-431.

Stanley, T.D. and Jarrell, S.B. (1989) Meta-regression analysis: a quantitative method of literature surveys. *Journal of Economic Surveys* 3: 54-67.

Sterne, J.A.C., Egger, M. and Moher, D. (2008). Addressing reporting bias. In Higgins, J.T. and Green, S. (eds), *Cochrane Handbook for Systematic Review of Interventions*. Chichester, UK: Wiley, 297-333.

**Taylor, T.G., Drummond, H.E. and Gomes, A.T. (1986). Agricultural credit programs and production efficiency: an analysis of traditional farming in Southeastern Minas Gerais, Brazil. *American Journal of Agricultural Economics* 68(1): 110-119.

**Theodoridis, A., Ragkos, A., Roustemis, D., Galanopoulos, K., Abas, Z. and Sinapis, E. (2012). Assessing technical efficiency of Chios sheep farms with Data Envelopment Analysis. *Small Ruminant Research* 107: 85-91.

**Thian, W. and Wan, G.H. (2000). Technical efficiency and its determinants in China's grain production. *Journal of Productivity Analysis* 13: 159-174.

**Zaeske, A.L. (2012). Aggregate Technical Efficiency and Water Use in U.S. Agriculture. CERE working paper, No 11. Umea, Sweden.

**Zhu, X. and Oude Lansink, A. (2010). Impact of CAP subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden. *Journal of Agricultural Economic,* 61(3): 545-564.

**Zhu, X., Karagiannis, G. and Oude Lansink, A. (2011). The impact of direct income transfers of CAP on Greek olive farms' performance: Using a non-monotonic inefficiency effects model. *Journal of Agricultural Economics* 62(3): 630-638.

**Zhu, X., Demeter, R.M. and Oude Lansink, A. (2012). Technical efficiency and productivity differentials of dairy farms in three EU countries: the role of CAP subsidies. *Agricultural Economics Review* 13(1): 66-92.