Extended Abstract
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Paper/Poster Title	A Meta-Analysis of the Environmental Efficiency of Agricultural Production in Europe

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	***200 words max***
"Environmental pressures associated with agricultural production remain pressing issues that require policy attention. In this study, we use meta-regression analysis to examine the variation in environmental performance of farms, proxied by environmental efficiency (EE), based on 49 eligible research papers published between 1991 and 2022, resulting in 150 observations. We also analyse the factors influencing environmental efficiency. A key result from the analysis is that the average EE reported across these studies is 65.4%. Our results reveal significant factors influencing the EE score across different farms. Education, investment per cow, and participation in agri-environmental schemes have significantly positive effects on EE scores across all farms, while concentrate feeds per hectare have a negative effect on the environmental efficiency of livestock production farms. We conclude that investment in environmentally friendly technology and practices, as well as farmers' skills and knowledge of the use of these technologies, are key.	

Keywords	Environmental Efficiency, farming, meta-regression analysis
JEL Code	Q12, Q57 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

Agriculture is changing global natural ecosystems and degrading the environment at unprecedented rates. As a key driver of global environmental change, agriculture is responsible for a substantial share of global carbon emissions, massive losses of biodiversity, and degradation of land, soil, and freshwater systems. With a growing world population and increasing food consumption, pressures will rise further, threatening the resilience of agro-ecological systems. Addressing these challenges requires policy support aimed at reconciling production and the environmental sustainability of the agricultural sector.

In the present study, we contribute to the understanding of environmental performance estimates of agricultural production in Europe and associated driving factors, filling important gaps in the literature. Firstly, no comprehensive systematic review exists on the environmental efficiency of agricultural production. Secondly, existing studies often debate the best way to treat undesirable factors (either as ‘bad’ output or ‘bad’ input). Our meta-analysis allows us to holistically analyse changes in environmental efficiency scores, accounting for all possible ways undesirable factors are treated.

We conduct a meta-regression analysis to synthesize existing empirical studies on the environmental efficiencies of European farms and the factors influencing them. Our dependent variable is based on the environmental efficiency measure of farms reported in existing studies. The variation in environmental efficiency scores across and within studies is explained using several specific methods and case study differences.

The findings from this study will assist policymakers in understanding the factors that influence environmental performance. This understanding is crucial for devising balanced policies required to enhance the sustainability of production systems and will shape future agri-environmental schemes.

Methodology	***100 – 250 words***

Our analysis comprises three main parts. First, we conduct a systematic literature review based on the PRISMA framework to identify studies estimating environmental efficiency and associated influencing factors (Moher et al., 2015). Second, we transfer eco-efficiency score estimates, along with explanatory variables, into a meta-database. Third, we use fractional regression analysis to estimate the factors influencing environmental efficiency while accounting for study characteristics.

To explain the variation in environmental efficiency as a function of key study attributes, meta-regressions were estimated. This process requires addressing the fact that the dependent variable, EE scores, ranges between 0 and 1. Following Ogundari (2021), we utilized the Fractional Regression Model (FRM) as a suitable framework for variables defined on the unit interval, regardless of whether boundary values are observed or not. The employed FRM is estimated using a Quasi Maximum Likelihood Estimator (QMLE) characterized by consistent and asymptotically normally distributed standard errors (Davidson and Mackinnon, 2004).

Collinearity problems were identified by analysing correlations between variables. Variance inflation factors of the selected model were estimated to test for any remaining potential multicollinearity problems (Fox and Monette, 1992). Variables with potential multicollinearity issues were excluded.

The independent variables were categorized into three groups: (i) direction of socioeconomic and structural variables, (ii) methodological design, and (iii) case study characteristics.

In total, 49 eligible papers published between 1991 and 2022 were analysed, resulting in 150 observations.

Results	***100 – 250 words***

Our analysis shows that the average EE is 65.4%, with a range from 45.1% (observed in Hungary) to the highest estimate of 94.2% (observed in Dutch farms). This kind of variation across studies is typical for efficiency studies and is an important motivation for meta-analysis (Bravo-Ureta et al., 2015).

We use three variables to capture the effect of the methodology: parametric stochastic frontier, parametric deterministic frontiers, and the omitted category is the non-parametric studies. The results show that the latter category exhibits a significantly higher mean EE than the deterministic parametric approach.

Furthermore, factors including forage per hectare (*p<0.01)*, education (*p<0.01)*, investment per cow (*p<0.05)*, and participation in agri-environmental schemes (*p<0.10)* have significantly positive effects on environmental efficiency. More specifically, concentrate feeds per hectare ((*p<0.01)* have a negative effect on the environmental efficiency of livestock production.

Discussion and Conclusion	***100 – 250 words***

This study analysed the environmental efficiency and associated driving factors, providing empirical evidence to inform the formulation of policies related to the improvement of environmental performance in agricultural production. The results of the study indicate that the environmental efficiency of farms in the study area is approximately 65.4%, suggesting that there is more room for improvement in terms of increasing productivity and reducing undesirable environmental impacts.

Considering the significance of investment per cow, which is statistically significant, it is suggested that policy support to enhance capital investment in innovations is essential. Given that the education variable is significant, it is also recommended that investment in environmentally friendly techniques and practices should be complemented with appropriate farmers' skills and knowledge of their use. With a particular emphasis on livestock production, efficient nutrient management is necessary to improve environmental performance. For example, given the significance of forage grazed per hectare, it is important to place more emphasis on increased incorporation of grass-based feeding systems and better inputs management. Another way to ensure improved nutrient management is to implement agri-environmental schemes more broadly and practically, ensuring compliance.