Extended Abstract
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Paper/Poster Title	Water in pesticide application and rational inefficiency: The case of Spanish crop producers

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Abstract	*200 words max*

Agricultural activities can be characterized by inefficient use of production factors, including water. This study assesses to what extent this inefficient use of water and pesticide can be attributed to farmers' rational decisions and whether these rational decisions could lead to water externalities from pesticide pollution. The empirical application covers 148 arable crop producers in Spain using a Data Envelopment Analysis (DEA) model accounting for production risk through a state-contingent approach. The results reveal that technical inefficiency could be attributed to the crop producers' rational decisions, which can be consequently associated with environmental risks due water pollution from pesticide run-off.

Keywords	Rational behaviour, technical efficiency, water, pesticide run-off, production risk
JEL Code	D24, Q12, Q15, Q25

Introduction	*100 – 250 words*

Overuse of water resources for economic purposes (mainly from the agricultural sector), drought and socioeconomic barriers have aggravated the water scarcity. However, water scarcity can also caused from deterioration of water quality that can be induced either from physical or human related activities. Some of the sources of water quality degradation can be sediment loads from soil erosion, salinization, use of (obsolete) chemicals and water scarcity. The 2030 Agenda for Sustainable Development acknowledges the importance of water quality and includes a specific water quality target in Sustainable Development Goal (SDG). Target 6.3: "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally".

While intensive use of chemical fertilizers and pesticides along with the expansion of irrigated land has contributed to increasing agricultural productivity, at the same time they are transferring agricultural pollution to water bodies. Water pollution from agriculture is a more insidious threat, being quite diffuse and hard to measure, and affecting agricultural productivity (and consequently farmers' incomes) every year. Deficits in water supply and degradation of the ecological status of water are two of the issues that particularly affect food production

sectors and environmental sustainability, which sometimes can be exacerbated by the irrational decisions that farmers make regarding input use.

Methodology *100 – 250 words*

In this study, we adopt the production function approach where each arable crop producer uses a vector of inputs, including water for pesticide application, to produce a single output, which is an aggregate output index of cereal, oilseed and protein crops. Each producer's technical efficiency score is then estimated using the Data Envelopment Analysis (DEA) model which also accounts for production risk through a state-contingent approach (bad, normal and ideal states of nature). The application focuses on a sample of 148 Spanish arable crop producers in Catalonia.

For the rational inefficiency hypothesis to be tested, we developed and assessed 4 assumption groups regarding the magnitude of inefficiencies and the amount of water used for pesticide application (measured in liters/ha). Crop producers with water use for pesticide application and efficiency scores below the median were categorized as the *rational inefficient* group. The producers who applied relatively low levels of water for pesticide use but attained high levels of efficiency form the *multi-efficient* group. Crop producers with low efficiency and high levels of water use for pesticide application appear to adopt a *technical inefficient* behavior. Finally, producers with both high efficiency and high water application for pesticide use were viewed as being *technical efficient*.

Results *100 – 250 words*

The efficiency scores were derived using the General Algebraic Modeling system (GAMs) software. The efficiency estimates obtained imply statistically significant heterogeneity in farm performance in the four sub-groups considered. The total number of Catalan crop producers are proportionally distributed among the four groups introduced in this study. To assess the hypothesis of rational inefficiency among the Catalan arable crop producers, a comparison between the *rational inefficient* group and the *technical efficient* group needs to be performed. The *rational inefficient* group on average had lower values of technical efficiency scores and lower amounts of water used for pesticide application compared to the *technical efficient* group. This pattern also holds under the three different states of nature, where the *technical efficient* group performs better than the *rational inefficient* group, while using more water for pesticide application. In addition, our results reveal that the producers belonging to the *rational inefficient* group had significantly higher values of pesticide pollution compared to the other three groups. These high levels of pesticide pollution in the *rational inefficient* group indicate that these producers are choosing to use less water for pesticide application, but they also exhibit elevated levels of pollution from pesticide application. This can be interpreted as a potential situation of rational inefficiency among crop producers associated with environmental externalities.

Discussion and Conclusion *100 – 250 words*

Water pollution from agriculture is a more insidious threat, being quite diffuse and hard to measure, and affecting agricultural performance and productivity (and consequently farmers' incomes). Deficits in irrigation water supply and degradation of the ecological status of water

are two of the issues that particularly affect food production sectors and environmental sustainability. Improper application of fertilizers, pesticides or even irrigation water can lead to agricultural water impairments and generate non-market externalities that are borne by the society as a whole.

Based on the results of this study, some of the crop producers may experience lower efficiency scores due to the limited use of water for pesticide application, which could be further associated with higher levels of pesticide pollution. Given that all producers are profit-maximizing oriented, the low performance of the *rational inefficient* producers in comparison to the *technically efficient* producers may not only be attributed to poor production decisions (limited use of water), but also to diminished land and water quality (or even ecosystem degradation) due to pesticide pollution on their fields over the years.

Improving water quality in the agricultural sector has been the priority at the nation level worldwide. Many countries have introduced or revised already existing water quality targets, objectives and plans in regulation or other policies. Most countries respond with a combination of policy instruments that combine regulatory frameworks with economic instruments and restrictions to agricultural activities, to better control water quantity and quality in agriculture and further promote healthy ecosystems.