Extended Abstract
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Paper/Poster Title	**Assessing eco-efficiency to provide guidance on how to reach a regional Safe and Just Operating Space**

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***
The Safe and Just Operating Space (SJOS) concept enables us to assess how regions perform regarding multiple environmental and social dimensions. It defines environmental boundaries that should not be exceeded, the "safe operating space", and social dimensions that should be reached, the "just operating space". If regions are not in the SJOS, a crucial question is whether they can reach it through efficiency improvements or if a system transformation is required. We aim to consider the SJOS concept for the agricultural sector and propose using eco-efficiency assessment to provide insights into potential pathways towards reaching the SJOS. Eco-efficiency results can improve the understanding of where increases in efficiency can improve sustainability and where a system transformation is required. Knowledge of the potential to increase efficiency can guide policy and steer the development and implementation of novel technology towards either increasing the efficiency of a current system or motivating shifts towards new production systems. In this paper, we assess the eco-efficiency of agricultural production on a regional level in the EU. Our results show in which EU regions there is potential for efficiency improvements and what absolute changes improving efficiency would correspond to.	

Keywords	Eco-efficiency, sustainability, EU agriculture, nuts2 regions
JEL Code	Q15, Q16, Q18 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

The SJOS is a global framework defining targets for human operations. However, it does not specify how to reach these targets. On the contrary, Eco-efficiency provides insights into what changes are possible regarding efficiency improvements and identifies a region's ability to create relatively less environmental damage for a given production level. By evaluating eco-efficiency considering the SJOS for indicator selection and when analysing the results, we can identify how dimensions of the SJOS are affected by improving eco-efficiency. Thus, we enable insights into how eco-efficiency improvements could bring inefficient regions which are operating outside the SJOS closer to the targets.

We aim to answer the question: How much can environmental and social sustainability improve by increasing regional eco-efficiency? By answering this question, we can provide insights into whether improved eco-efficiency is a potential pathway towards bringing operations to within the SJOS. This knowledge can help

target policy interventions such as steering the development and adoption of novel technology towards the potential for efficiency improvements.

We evaluate the eco-efficiency of agricultural production on a regional level in the EU (NUTS2), considering social and environmental dimensions of the SJOS to select indicators. By evaluating eco-efficiency on a regional level, we can provide policy-relevant insights regarding which regions can improve efficiency and which are already operating eco-efficiently. If regions already operate efficiently but still do not operate in the SJOS, we require other actions to increase sustainability than targeting efficiency improvements.

Methodology	***100 – 250 words***

To evaluate eco-efficiency, we use data envelopment analysis (DEA) analogously to an input-oriented efficiency measure assuming constant returns to scale. Eco-efficiency is formulated as a ratio of weighted produced value to weighted environmental pressures. Weights are generated such that higher weights are given to outputs and sources of environmental damage where a region performs well relative to other regions. A unit is inefficient if weights cannot be determined for the other units such that the ratio of value over environmental damage is at least as high as for the unit under evaluation.

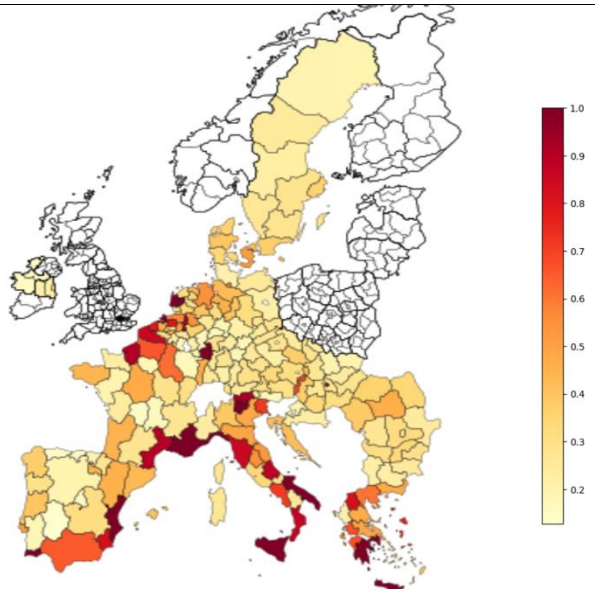
To compute eco-efficiencies, we consider economic indicators from Eurostat and GHG emissions from the EDGAR-database. All indicators are for the year 2020. We include seven indicators for value produced representing the production of seven types of goods: crops, animal production, potatoes, wine, fruit, olive oil and other. As environmental pressures, we consider indicators for GHG emissions from agricultural soils, manure and enteric fermentation from nitrous oxide and methane expressed in CO2 equivalents.

This approach is preliminary as we do not yet include all dimensions of the SJOS. We aim to develop the model considering sub-technologies, i.e. separating processes relating to the production of different environmental and social outcomes, which can be aggregated to total eco-efficiency scores. This approach enables us to include more indicators without decreasing the discriminating power of the model. Furthermore, we want to account for heterogeneities between regions which can affect eco-efficiency by controlling for e.g. geographical location or institutional differences.

Results	***100 – 250 words***

Removing outliers and observations where data is missing, we have a dataset consisting of 191 regions used for the analysis. Preliminary results show that mean eco-efficiency across regions is 0.41. Fifteen regions obtain eco-efficiency scores of 1, indicating full efficiency. The regions classed as fully efficient are heterogenous and distributed across several countries, which indicates the ability for different types of regions to operate fully efficient. Figure 1 displays preliminary results of the spatial distribution of the eco-efficiency scores.

Figure 1: Spatial distribution of eco-efficiency scores



We explore the relation between the eco-efficiency scores and other indicators such as the degree of specialisation in crop or animal production respectively, and do not find any strong associations. This speaks for that different types of regions have potential to operate efficiently.

Ultimately, we want to interpret the eco-efficiency scores as potentials for absolute improvements of the SJOS dimensions. Therefore, it is crucial that each region is evaluated accurately. By adding more dimensions to the model and accounting for heterogeneities between regions, we want to provide reliable estimates of the absolute changes associated with eco-efficiency improvements.

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

In this paper, we assess the eco-efficiency of NUTS2 regions in the EU in the light of the SJOS. Novelties are that we establish a connection between the eco-efficiency concept and the SJOS framework and that we derive what absolute changes are associated with improvements in eco-efficiency. We highlight the usefulness of this connection in order to evaluate to what extent efficiency improvements are sufficient to reach the SJOS and where system transformation is necessary. While the results in this paper do not provide insights into what system changes are required, the results provide useful insights on where to target efforts to improve eco-efficiency and which regions' eco-efficiency increases might not be sufficient for sustainable production.

In our preliminary assessment of EU agriculture, we find room for improvement in the evaluated regions regarding GHG emission efficiency, and we see that fully efficient regions are identified in different countries all over the EU, as seen in Figure 1. This result would imply that there is room for policy and technology which increase production efficiency by decreasing GHG emissions while maintaining value added.

In future versions of this study, we aim to compute absolute changes based on the efficiency scores to provide insights into how improving efficiency can affect sustainability, for example how much GHG emissions can decrease by improving eco-efficiency.