Extended Abstract
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Paper/Poster Title	A comparison of animal and plant-based proteins from an economic, environmental, and nutritional perspective in the Republic of Ireland

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Abstract	***200 words max***

Protein is a central component of human health and nutrition. The current animal protein production systems might not be able meet the growing global demand for food and protein while also meeting climate change policy commitments. Therefore, alternative sources of protein must be considered. This study uniquely compares animal-based protein sources (milk, beef, sheep) to plant-based protein (wheat, barley, oats) across a suite of economic, environmental, and nutritional metrics. Economic performance is measured through the gross margin earned by the farmer, environmental performance through the farm-level CO_2 emissions, and the nutritional performance through the gross protein yield and the protein yield corrected for digestibility using the Digestible Indispensable Amino Acid Score (DIAAS). Findings indicate that cereal crops perform better in terms of environmental and nutritional aspects but lag significantly behind the best economically performing livestock-based system, dairying. Moreover, dairy farms produce less gross protein than crop-specialized farms, but they produce a similar amount of available protein on a per hectare basis, i.e., protein that can be utilized by the body after digestion. The results do not allow for a definitive answer as to which protein source is the most holistically sustainable as the relative efficiency depends on the metric considered.

Keywords	plant-based proteins; animal proteins; protein economic efficiency; food policy
JEL Code	Q18 Agricultural Policy; Food Policy; Animal Welfare Policy

Introduction ***100 – 250 words***

The world's population is expected to reach between 8.5 and 8.6 billion people by 2030 (UN, 2019). As a result, the global demand for food is expected to grow by 1.3% per annum by 2030 (OECD/FAO, 2021). On average, more than half of all protein consumed in the world is derived from animal products, and animals are a major contributor to global warming. This puts protein production at the centre of the challenge that is sustainably feeding the world's growing population (OECD/FAO, 2021).

While many studies focus on the impact of agriculture, especially livestock, on environmental outcomes (Detzel et al., 2022; Mosnier et al., 2021), fewer studies focus on the combined economic (Watson et al., 2017), nutritional (Gorissen et al., 2018) and environmental impacts of the production of various protein sources. This study aims to compare several types of proteins using economic, environmental and nutritional metrics. More specifically, this paper examines the following research questions: how do plant-based proteins compare with animal on a suite of economic, environmental, and nutritional metrics? Furthermore, if plant-based proteins are more environmentally sustainable and are nutritionally equivalent or superior to animal proteins, what policy or market levers are required to incentivise farmers to shift production away from livestock systems?

Methodology

100 – 250 words

The economic aspect is measured by the gross margin in euros. The environmental impact is measured by the total GHG emissions in kg of CO_2 equivalent. The GHG emissions are calculated according to the IPCC methodology, as previously published by Buckley and Donnellan (2022). The nutritional aspect is evaluated using the gross protein yield and the protein yield corrected for digestibility using the DIAAS value of each protein source, as suggested by Moughan (2021).

Indicators are expressed per hectare, per 100 g of gross protein, and per 100g of digestible protein, to present the efficiency of the different protein sources considered. Results are derived by unit of product (e.g., kg). The types of livestock protein sources considered are beef, lowland sheep meat and milk. The plant-based protein sources examined are winter oats, spring oats, winter wheat, winter barley and spring barley.

The economic and environmental indicators are developed using data from the Teagasc National Farm Survey 2020 (NFS). Data for protein yields come from the existing literature (ANSES, 2020; Teagasc Animal and Grassland Research and Innovation Programme, 2015; Schweihofer, 2011; NFS, 2021; Ertl et al. (2016)).

Results

100 – 250 words

Dairy farms generate the highest economic returns per hectare (€2,538), while cattle and sheep farms have lower economic performance per hectare than all other farm systems (€400 and €431 against more than €640). Livestock production generate higher levels of GHG emissions per hectare compared to crop production (4,414 kgs for beef and 9,839 kgs for milk compared to less than 3,000 kgs), except for lowland sheep which generates a similar amount of CO_2 per hectare.

When looking at protein yields, livestock-based products have lower gross protein yields than cereal-based products (between 31 kgs and 411 kgs per hectare against more than 720 kgs per hectare for cereals). However, when considering available protein production, the gap between milk and crop-based products narrows significantly. Milk produces 411 kgs of available protein per hectare against between 330 kgs and 642 kgs per hectare for cereals.

When considering protein efficiency, i.e., the gross margin and GHG emissions per 100g of protein, sheep and beef meat generate more euros per 100 g of gross and available protein produced but they also generate more CO_2 compared to crops. This might be due to the overall low protein yields observed for those two production systems.
Milk production is less environmentally sustainable than cereals when looking at results per 100g of gross protein, but when looking at results per 100g of available protein, the gap narrows. Dairy farms also are more economically profitable with €0.62 per 100g of available protein against between €0.11 and €0.40 for crops.

Discussion and Conclusion

100 – 250 words

Overall, crops are more environmentally efficient than livestock, both per hectare and per 100 g of protein. Economically, shifting production away from beef and sheep would give the opportunity of a gross margin increase, a so-called win-win scenario. However, shifting production away from dairy towards crops would cause a considerable reduction in gross margin for farmers. This suggests that policy makers need to consider both non-monetary and monetary incentives to promote such land use changes. Monetary incentives could be used to favour crop production and compensate the loss of gross margin for dairy farmers who would decide to change production. Changing production systems also requires skills and capital which might not be available to farmers. Technological improvement, both to limit livestock farms pollution as well as to increase the profitability of crops exist and could be supported by public authorities. Market opportunities also must be developed for farmers to be able to sell their crop production. However, some barriers exist that could prevent land use change and an increase in crop production, such as land suitability or tight European regulations when it comes to chemical uses or production standards for crops.