Extended Abstract
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Paper Title	CAP reform and GHG emissions: policy assessment using a PMP agent-based model.

Abstract prepared for presentation at the 97th Annual Conference of the Agricultural Economics Society, The University of Warwick, United Kingdom

27th – 29th March 2023

Abstract	***200 words max***
The European agricultural sector is responsible for 13% of the region's total greenhouse gas emissions due to enteric fermentation, agricultural soils, and fertilization. Eco-schemes and Agriculture Environmental Schemes have been introduced with the post 2020 CAP reform to mitigate the impact of agricultural sector on the environment. The aim of this research work is to assess the likelihood of dairy farmers of Emilia Romagna region (Italy) to accept predefined policy scenarios that implies different level of CO_2 taxation on GHG emissions produced by the livestock sector. It uses an agent-based model (ABM) and it follows the positive mathematical programming (PMP) approach. ABMs allow to evaluate agricultural policies and farmers' level of acceptance simulating interaction between farmers, taking territorial specificity and farm heterogeneity into account. The PMP methodology enables to add social and cultural perspective to the economical drivers. The Least Square method used allows to overcome shortage in data availability. Results show that farmers take decisions based on economic profitability but also on their social and cultural background. Farmers opt for more efficient agricultural management practices if it is economically convenient, but the possibility to exchange production factors can contribute to the optimisation of their utility function.	

Keywords	GHG, ABMs, PMP, CAP
JEL Code	Agriculture Q1; Agriculture and environment: Q15; Agricultural Policy: Q18; see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

The livestock sector, including production, transport and feed processing, contributes with 81-86% to the GHG emissions produced by the European agriculture (EU, 2020). The European Common Agricultural Policy is progressively evolving to foster more sustainable agricultural practices, by introducing new policy tools, such as the eco-schemes, to align to Farm to Fork and Biodiversity Strategy objectives. Agro-ecological practices, relying more on biological cycles and less on external chemical inputs could significantly reduce the ecological footprint of agriculture but could also have negative impacts on agricultural producers' incomes (EC, 2022). This effect could however be mitigated through measures that stimulate the reduction of inefficiencies through interactions between farmers. It is therefore of particular interest to assess how farmers could react when faced with the possibility of using

eco-schemes to make up for lost revenue from the reduction in basic payments, in an environment where they can exchange production factors such as land and pollution quota. In this context, farm models, and more specifically ABMs, are better suited to fulfill the challenge of developing holistic farm models for policy impact assessment, while delivering substantial innovations to mathematical programming models (Kremmydas et al, 2018; Reidsma et al., 2018; Berger and Troost, 2014).

Methodology	***100 – 250 words***

This work uses a two-step PMP approach agent-based model applied to dairy farms. The ABM simulate agents' behavior in deciding what production plan and what technologies to adopt. Capturing interactions among farms in the use of scarce resources the ABM evaluates structural changes under the assumption of non-full rational production choices due to the maximisation of the utility function rather than the profit function (Kremmydas et al, 2018; Nolan et al, 2009). PMP farm models, widely used for agricultural policy assessment, assume that the observed production level, reproduced in the calibration phase, is the optimal agent's choice (Paris and Howitt 1998). Estimation of the cost function, represented through the Cholesky decomposition, is obtained using the Least Square (LS) method. LS allows to estimate the variable costs per activity, not available in FADN. In addition, it allows to differentiate between the variable costs, linked to the technology, and the transaction costs linked to the agent's choice of what to produce and how (Marongiu et al., 2012). The 'normative' phase that follows reproduces the farms' behavior when market shocks or agricultural policy scenarios occur. Estimating an unambiguous cost function for each agent allows the representation of farms' heterogeneity from economic and technological perspective. This work focuses on Emilia Romagna region where agriculture and livestock activities are responsible for 17.9% of national CO_2 emission (82,020 tons), 9.3% of CH_4 (1,767,000 t CO_2 eq) and 12.1% of N_2O (1,421,303 t CO_2 eq) (ISPRA, 2015).

Results	***100 – 250 words***

Results refer to an agricultural policy scenario that considers scenarios of increasing taxation on CO_2 emissions: 20, 50, 100 and 150 euro per ton CO_2-equivalent. Manure spreading in non nitrate-vulnerable zones is also simulated, with the possibility to rent land from non-livestock farms, in order to respect the Council Directive 91/676/CEE against nitrate pollution. Each scenario is assessed on: (i) economic optimization resulting from changes in farms gross margins; (ii) changes of production plans and land usage; (iii) structural changes in terms of farms sizes in hectares due to land rented in or out and (iv) environmental impact measured in GHG emission, water consumption and nitrate level as result of the simulated CAP measures adoption. Results indicate that livestock farmers are responsive to CO_2 taxation policies. They tend to adopt strategies that involve production and structural reorganisation. On the production side, the number of animals reared decreases, while the possibility of leasing rights to pollute leads farmers to relocate nitrogen surplus to non-livestock neighbouring farms. Another effect of taxation on production plans is the substitution of fodder production generating high level of CO_2 emission with less impactful ones. Finally, taxation policies impact farms' gross margin, which

shrinks, pushing inefficient farms out of the market and causing structural reorganisation.

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

The environmental policy tools, developed through the post 2020 reform, represent a new phase of the European Communitarian Agricultural policy. The repercussion of their application on farm structure and agrarian regions will considerable. If output prices are assumed to remain unvaried, CO_2 taxation will influence livestock farms' production strategy to become more environmentally sustainable. Increased environmental sustainability is due to pressure reduction on soil (fewer animals per hectare), use of more sustainable fodder and the possibility of redistributing nitrate quotas to non-livestock farms. However, the possibility of exchanging land favours the most economically efficient farms, which increase their size at detriment of inefficient farms, with consequent economic and social impact. The case of the Emilia Romagna region is emblematic, as wealth and welfare generated by PDO (protected designation of origin) cheeses such as Parmigiano Reggiano, led over time to increasing environmental pollution and creeping structural reform pushing small scale farms to leave the market. While environmental pollution can be countered with targeted policies, such as effluent taxation, the effect on the socio-economic structure requires the use of more complex set of interventions that the Rural Development Plan must address.