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THE IMPACT OF AGRICULTURE ON CLIMATE CHANGE: A REVIEW OF APPROACHES TO MODELLING AGRICULTURAL EMISSIONS

Luca Salvatici,
Marco Sforza,
Cristina Vaquero Piñeiro

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The impact of agriculture on climate change: a review of approaches to modelling agricultural emissions

Luca Salvatici, Marco Sforza, Cristina Vaquero Piñeiro*

Department of Economics and Rossi-Doria Centre, Roma Tre University

Abstract

The paper aims to examine how the existing economic simulation models have addressed environmental and emission issues in agriculture. From a modelling perspective, assessing the impacts of agricultural emissions is bound to be complex, and currently, we are far from reaching a consensus on which modelling approaches are more effective and why. This lack of agreement can be partly explained by a severe data constraint at detailed levels, different theoretical modelling foundations, and institutional aspects, such as model maintenance and dissemination of results. We select eight general and partial equilibrium models, which include the agriculture sector, to provide a comparative assessment of alternative modelling approaches for agricultural emissions. Specifically, the review intends to: i) contribute to the taxonomy of simulation models, including the agrifood sector and the status of current research at the global level; ii) identify factors influencing the quality of the results in terms of opportunities for decarbonizing agriculture, reducing net emissions related to land use, and mitigating non-CO2 greenhouse gases; and iii) present how the models in the literature deal with mitigation potential, cost-benefits and side effects, and cost-effectiveness of selected technologies.

JEL Codes: Q530, D580, Q110, C680
Keywords: Economic models; Ex-ante simulation models; GHG emissions; Agricultural economics

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(*) Corresponding author: cristina.vaqueropineiro@uniroma3.it

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1. Introduction

Agricultural systems are a core part of the environmental sustainability challenge and green transition promoted by national and international institutions for the next decades (European Commission, 2020a; UN, 2015). The environmental sustainability of this sector will play a crucial role, and among environmental issues, greenhouse gas (GHG) emissions will be a significant determinant in the future. As recently reported by the FAO (2024), at the global level, agriculture's GHG emissions have, in fact, nearly doubled over the past 50 years and may increase by another 30% by 2050. From a production perspective, agriculture is, in fact, one of the economic sectors most affected by the negative impacts of emission-related climate change (FAO, 2024). This sector is, in fact, responsible not only for non-CO2 emissions generated within the farm gate by crops and livestock activities (e.g., CH4 and N2O) but also for CO2 emissions caused by the conversion of natural ecosystems, mostly forest land and natural peatlands, to agricultural land use (Tubiello, 2021).

To bolster the sustainability of agrifood systems[1], the EU has recognized the reduction of GHG emissions as instrumental and necessary, although not entirely sufficient. Within the European Green Deal, which aims to reach the climate-neutral objective by 2050, the EU Farm to Fork strategy is one of the rare exceptions of food policies that accounts for food-related emissions, aiming to cut them by 50% by 2030 (European Commission, 2020b; European Commission, 2020c). However, despite the clear mention, agricultural GHG emissions are not directly targeted, leaving politicians and practitioners without an optimal strategy to address GHG emissions challenges. At the same time, despite its centrality in political agendas, agriculture is one of the few industries not covered by the EU's emissions trading system, although proposals are currently under discussion (European Commission et al., 2023). To continue, it may not come as a surprise that the agricultural sector is not included in the Carbon Border Adjustment Mechanism (CBAM), even if the inclusion of fertilizer in CBAM addresses both the direct emissions from fertilizer manufacturing as well as indirect emissions and pass-through effects from reduced agricultural nutrient application because of higher fertilizer prices. As far as climate change is concerned, the measurement of emissions is not clear-cut, which complicates the implementation and management of measures that could generate distortive

[1] FAO defined sustainable food system (SFS) as a food system capable of delivering food security and nutrition for all people in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised (FAO, 2018).

incentives. In this context, ex-ante simulation analysis provides quantitative assessments that highlight synergies and trade-offs across different possible economic, environmental, and social sustainability goals and policies targeted to achieve them (Dorfman et al., 2024).

The objective of this paper is to examine the primary simulation economic models and review how existing approaches have addressed environmental and emission issues. Specifically, the paper intends to: i) contribute to the taxonomy of simulation models including the agrifood sector and the status of current research at the global level; ii) identify factors influencing the quality of the results in terms of opportunities for decarbonizing agriculture, reducing net emissions related to land use, and mitigating non-CO2 greenhouse gases; and iii) present how the models in the literature deal with mitigation potential, cost-benefits and side effects, and cost-effectiveness of selected technologies.

There exist many models that inform society and policymakers regarding future developments at the national and global level, as well as strategies to influence them (Ronzhyn and Wimmer, 2018). These models differ not only in their underlying assumptions and theories but also in their varying adaptability to model increasingly complex, interconnected, and sustainability-oriented development pathways, as recently outlined. In this context, decision-making models should be crafted to consider, and model, the diverse sustainable dimensions of development comprehensively and harmoniously. From the modelling perspective, the assessment of agricultural emission impacts is bound to be complex, and at present, academic and policy debates are far from a consensus on which are and why the modelling approaches are more effective. This lack of agreement can be partly explained by a severe data constraint at detailed levels, different theoretical modelling foundations, and institutional aspects, such as model maintenance and dissemination of results.

Today, the issue is like never before relevant given: (i) the puzzling future of globalization; (ii) the institutional debate on the world beyond the Sustainable Development Goals (post-2030 Agenda); (ii) the diffusion of the sustainability agrifood systems also concerning at lower levels, i.e. urban food policies (Warren et al., 2015).

In this scenario, ex-ante economic analysis helps design more sustainable agrifood policies accounting for their effects on food security, safety, and environmental sustainability. A general problem associated with implementing transboundary measures is that countries have varying

levels of participation in global value chains. In this respect, global models are necessary to anticipate the friction encountered when agricultural sectors become part of the discussion for potential inclusion in climate change policies.

This paper focuses on equilibrium models, both general and partial, and examines their supply-side aspects, specifically how input-related emissions are incorporated into these models. The decision to select only general and partial equilibrium models stems from their widespread use in policy analysis (Borges, 1986) through ex-ante simulations, which are crucial for evaluating trade, agricultural, and environmental policies.[2] Moreover, equilibrium models, unlike other modelling approaches (e.g., Input-Output Models), include behavioral equations and rely on shared, detailed, and comparable data sources. Finally, partial equilibrium models are included because they provide a deeper understanding of sectoral specifics, which is essential when evaluating agricultural or trade policies related to particular inputs or characteristics of the agricultural sector (e.g., policies targeting livestock or place-based farm policies).

We aim to inform scientific community and policy practitioners on how literature studied climate and environmental-related impacts in key sectors like agriculture and livestock, including links to regional land use change, water resources and differences in agricultural production techniques worldwide. To the best of our knowledge this is the first overview of the approaches adopted in modelling agricultural GHG emissions. The comparative analysis allows to highlight the heterogeneity of the strategies implemented.

The rest of the paper is organized as follows. Section 2 summaries the theoretical debate around the use of equilibrium models in policy analysis. Section 3 presents the research setting, while Section 4 reports the results with information on input-related emissions. Section 5 concludes.

2. Environmental and agrifood issues in simulation models

As noted by Tonurist and Hanson (2020, p. 43), "*embedding the future in the present is no easy task*," and many existing macroeconomic models lack the features that agrifood systems' sustainability should ensure. The macro-level modelling approach has been the base of the

[2] For a review of macroeconomics approaches to modelling sustainability see Wiebe et al. (2023).

implementation of different frameworks. Over the years, computable equilibrium models have been increasingly used by researchers and practitioners. These models offer a robust framework for understanding the environmental impacts of agriculture, and they have been recognized as crucial for evaluating the validity of policies aimed at reducing emissions while maintaining agricultural productivity and quality standards.

Computable General Equilibrium (CGE) Models are extensions of the classical equilibrium analytic model and are mainly based on the formalization of the Arrow-Debreu model.[3] CGE models exist for almost all countries in the world and, substantial number of them have been developed to examine a wide range of policies, such as and global value chains (Cui et al., 2024). Over the years these models have been extended to address new challenges, such as the implementation of environmental and social policies, at both national and regional levels (Nordhaus and Yang, 1996). They represent, in fact, a flexible analytical and simulation device capable of capturing the multiple effects that the implementation of a set of combined policy issues could produce on the whole economy. In these models, the environmental context can be included as production inputs like capital and labor.

Partial Equilibrium Models (PEM), instead, imply that the analysis of the effects of a policy is focused only on specific sectors or markets. The influence of the rest of the economy on that sector remains constant by omitting interactions with other markets. While CGE models analyze the whole economic system, the PEM focus on a specific sector and the rest of the economy remain unchanged. The strength of PEM is, therefore, the possibility to delve into one specific sector, allowing for more specific modelling.

Although several of these models have been adapted to incorporate environmental and sustainability elements, their primary focus is not mainly geared toward assessing the sustainability aspects (Berthet and Fusacchia, 2024). In both approaches, the most common environmental measures are emissions and energy use. The strength of these models lies in their ability to integrate economic, energy, and environmental factors to assess the impact of agricultural activities on environmental emissions. These models are, therefore, instrumental in exploring the connection between agricultural practices and emissions, aiding in the development of strategies and policies to reduce environmental impacts. For example, Komen and Peerlings (2001)

[3] They are based on social accounting matrices and usually use nested constant-elasticities of substitution production functions. The objective is to find the optima allocation of resources available in economic systems.

employed CGE models to assess the welfare effects of introducing higher levels of milk quotas while maintaining constant agricultural nitrate emissions in the Netherlands. By using the GTAP-E model, Clora et al. (2021) simulated the emission effects of dietary transitions in the EU, and the impacts of different related policy strategies.

Partial equilibrium models have been employed to examine the impact of climate change and mitigation strategies on agriculture, as demonstrated by Meijl et al. (2018). Only some exceptions include a specific modelling of other environmental sustainability dimensions such as land-changes and waste management in general equilibrium MAGNET (Woltier and Kuiper, 2014), while water use in partial equilibrium SIMPLE and SIMPLE-G models (Baldos et al., 2020).

3. Research design

This paper reviews general and partial equilibrium models, with a focus on the supply side, specifically examining how input-related emissions are incorporated into these models.

The aim of reviewing how input-related emissions is incorporated into the models includes examining the functional form of the equations and the updating of emissions coefficients. We refer to these features as the "*technological modeling*" of emissions. Reflecting on the upstream and downstream transmission channels that might affect carbon and non-carbon emissions in agriculture, this paper identifies the following four key channels: (i) land; (ii) capital; (iii) intermediates; and (iv) technology. They correspond to the four main production inputs. Conversely, the output refers to the GHG emissions generated by the production process.

3.1 Models selected

We have selected eight equilibrium models, including general and partial. These models encompass the agricultural sector, including its output and inputs, and therefore, there is an associated representation of agriculture-related emissions. The models selected, along with the type of equilibrium and the main reference, are shown in Table 1.

The models selected for this review are among the most widely used by researchers and policymakers. They are maintained by public institutions—such as the OECD for METRO-PEM, the EC-JRC for AGLINK-COSIMO, and CAPRI—by consortia (e.g., GTAP-type models),

or by universities (e.g., COFFEE-TEA, GLOBIOM). This institutional backing enhances the reliability of the models, partly due to network effects arising from their user base, which contributes through feedback, technical support, and continuous improvements.

Among the models are five general equilibrium models—EUcalc, GTAP-AEZ-GHG, TEA, EC-MS-MR, and METRO—and five partial equilibrium models (i.e., COFFEE, PEM, GLOBIOM, AGLINK-COSIMO, and CAPRI). Two of these combine a general equilibrium and a partial equilibrium: the TEA-COFFEE and the METRO-PEM models.

Table 1: Models considered in the analysis

Model	Equilibrium	Main reference	Developed by
EUcalc	General	Clora and Yu (2022)	Potsdam Institute for Climate Impact Research; EC-JRC; IIASA
GTAP-AEZ-GHG	General	Golub et al. (2009)	Center for Global Trade Analysis – Purdue University
TEA-COFFEE	General/Partial	Rochedo (2016); Cunha (2019); Cunha et al. (2020)	COPPE/UFRJ-Cenergia
EC-MS-MR	General	Ghosh et al. (2012)	Environment Canada
METRO-PEM	General/Partial	Valin et al. (2023)	OECD
GLOBIOM	Partial	Havlík et al. (2014)	IIASA
AGLINK-COSIMO	Partial	Harvey and Pilgrim (2011); Araujo Enciso et al. (2015)	EC-JRC
CAPRI	Partial	Britz and Witzke (2014)	EC-JRC

Source: Authors' elaboration

4. Models' overview

4.1 Agricultural production function and input-related emissions

This review examines how inputs are incorporated into models and the implications for accounting for emissions, aiming to identify the most effective perspective for modelling agricultural emissions within economic equilibrium models.

As discussed in the previous section, this paper focuses on the technological modelling of emissions in the supply-side equations of the models. Let us consider a general functional form for the agricultural production function. The production output, in terms of physical output, is directly linked to a quantity of emissions (i.e., GHGs in terms of CO2 equivalents) and is

determined by applying an emission factor to the quantity of output. Agricultural systems can be characterized by diverse intensities of land use, energy, and chemical inputs, and consequently, the associated emission intensities (Stehfest et al., 2019).[4]

Next, there is the technological factor that shapes the relationship between inputs. This factor allows for the consideration of how mitigation techniques are (potentially) incorporated, which may involve an increase in production efficiency (i.e., higher output with the same emissions) or a reduction in emissions (i.e., the same level of output with lower emissions).

Finally, when considering the inputs to the production function, their main effects on emissions can be summarized as follows. Land is primarily associated with CO2-related emissions, which can exert both positive and negative effects. Capital is linked to livestock activities, which are primarily associated with methane emissions. Intermediate goods are incorporated into the models primarily in relation to energy use and fertilizer application.

The following sections will discuss each input-related issue in more detail.

4.2 Land

Land is a crucial element in the agricultural production process and represents a significant asset in mitigating both the direct and indirect impacts of climate change through CO2 emissions (Harvey and Pilgrim, 2011).

The impact of land on emissions is twofold. On the one hand, land use can explicitly reduce CO2 emissions through carbon sequestration and afforestation. On the other hand, land-use change (e.g., converting tropical forests to agricultural land) contributes to an increase in the net carbon dioxide (CO2) stock. Many of the models analyzed explicitly account for this dual effect of land.

The level of detail in the modelling varies across the models considered. Some models provide spatial detail (i.e., they are spatial models), such as COFFEE and GLOBIOM, while others

[4] The discussion of emission-related effects on output, as well as the total stock of pollutants, is outside the scope of this review.

allocate land based on the number of land types considered (ranging from seven in COFFEE to two in METRO).

Moving from simpler to more detailed models, the METRO-PEM model assumes a fixed amount of land allocated in the PEM module (partial equilibrium) between two agricultural uses: pastures and crops, excluding unmodeled commodities. The partial equilibrium COFFEE model employs a Leontief-type production function to allocate land across various possible uses, including crop-vegetation, forest, forage grass, grassland, flooded land, and non-suited land. Among the more detailed models, the GTAP-AEZ-GHG model explicitly accounts for both forestry extensification (i.e., expansion of forested areas) and intensification (i.e., increased biomass on existing forest land) and allocates land according to its productivity. Among those with spatial detail, GLOBIOM offers a disaggregated supply-side model, where land is divided into spatial clusters (5-arcminute pixels) grouped by country, altitude, slope, and soil class. Finally, the AGLINK-COSIMO model employs a dual approach to land modelling, allowing for the evaluation of land use, incorporating physical land constraints, and accounting for the carbon sink, thereby enabling the assessment of net forest emissions.

4.3 Capital

In the equilibrium models analyzed, capital goods are primarily linked to livestock and are homogeneous. Specifically, the only capital good considered is livestock, which is associated with the primary source of non-CO2 emissions in these models—namely, methane from enteric fermentation and manure management.

In these models, the profit-maximizing farmer chooses the quantity of livestock, and the emissions from the capital are determined by applying emission coefficients.

The modelling of capital in these frameworks involves two main issues: i) the limitation in the types of capital considered and ii) the measurement of emissions.

Regarding the first issue, some models present a limited representation of capital types. For example, the METRO-PEM model only includes dairy cows and other cattle, excluding other types of livestock. This choice is driven by the model's focus on evaluating agricultural policies

related to these specific goods. Similarly, GLOBIOM also presents this limitation but allows capital to be determined by future demand, which is influenced by population growth.

Measuring emissions is another common issue across the models, particularly using emission coefficients to convert output into emission stock. A key challenge here is updating emissions coefficients, as these values are typically exogenous in most of the models considered. However, a few models in our selection—such as GTAP-AEZ-GHG, EC-MS-MR, and CAPRI—allow emissions associated with livestock to grow at an endogenous rate. This mechanism, related to the introduction of mitigation technologies, will be further discussed in the section on technology.

4.4 Intermediate goods

The intermediate goods considered in the agricultural production function are generally energy and fertilizers. While fertilizers are by far the most important industry-specific intermediate goods, energy is the most relevant in the models analyzed, as it is the good with the greatest level of detail.

Regarding fertilizers and pesticides, the primary source of pollution is nitrous oxide. In the models considered, emissions are accounted for by applying an emission factor to the output produced, with the quantity of fertilizers and pesticides required by the crops being fixed. In one model (METRO-PEM), emissions from intermediates are also linked to the consumption of nutrients for capital stock (e.g., livestock).

All other models provide a more detailed representation of emissions related to energy consumption, including the production of biofuels, another energy source—along with its associated GHG emissions—directly linked to agriculture. The models that include this level of detail are: EUcalc, GTAP-AEZ-GHG, COFFEE, AGLINK-COSIMO, and CAPRI.

Notably, EUcalc is the most detailed of these, as it is an energy general equilibrium (GE) model based on the GTAP framework. It includes a comprehensive energy consumption model that accounts for energy use beyond agri-food goods and considers the share of e-fuels and biofuels. In the TEA-COFFEE model, the GE module (i.e., TEA) identifies the impact of emissions, while the energy module (i.e., COFFEE) is responsible for assessing the impacts of

emissions. Among partial equilibrium models, both AGLINK-COSIMO and CAPRI also consider energy, with AGLINK-COSIMO placing particular emphasis on biofuels.

When considering these factors, it is important to note that their impact on emissions is multifaceted. On the one hand, the use of biofuels has a positive impact on emissions through crop production, which requires fertilizers; however, it also has a negative impact through land use, as it is associated with a reduction in the carbon sink.

4.5 Technology

There are two key elements to consider when examining the technological modelling of emissions in the production function: i) the update of emission coefficients and ii) the adoption of mitigation techniques.

The update of emission coefficients, the factor that converts output into associated GHG emissions, is largely exogenous in the models considered. It can be either constant, as in TEA-COFFEE or GLOBIOM, or a linear function that decreases over time at a fixed rate due to technical progress (e.g., METRO-PEM).

The introduction of mitigation techniques is a critical distinguishing factor. It appears as a feature in only three models: GTAP-AEZ-GHG, EC-MS-MR, and CAPRI. The GTAP-AEZ-GHG model incorporates an abatement cost curve for mitigating key agricultural non-CO2 emissions, with the cost structure calibrated from the literature. In the EC-MS-MR model, the abatement cost curve is introduced through a carbon price, which incentivizes technological improvements and the adoption of cleaner technologies. Finally, the CAPRI model treats technology as an endogenous variable, determined by factors such as mitigation costs, farmer revenues, cost-saving behavior, and the presence of incentives or subsidies.

5. Conclusion: challenges in modelling emissions

The objective of this review was to analyze and assess various approaches for modelling GHG emissions from the agricultural sector in economic equilibrium models, both general and partial. The analysis reveals that there is still a long way to go in terms of modelling

emissions in these models due to the heterogeneity of the approaches adopted. However, some relevant insights for scholarly and political debate arise from it.

Our first contribution relates to the classification of emissions' sources, which stems from the analysis of the choices of modelling of agricultural production function in the models under review. Here we have identified four upstream and downstream channels of emissions, which are linked to the inputs of the production function. Each choice of modelling the specific input may impact the extent to which the emissions related to that input enter in the total stock of pollutants resulting as the output of the process. Therefore, from a taxonomic perspective, we propose an analysis based on i) land, ii) capital, iii) intermediates, and iv) technology.

From the models' perspective, we identify three main issues which appear to be most impactful, that is our second contribution. The first one pertains to land modelling. Many of the models reviewed provide specific details about land, as their dual impact on GHG emissions (e.g., positive due to carbon sink, or negative due to land use change) makes it essential for accurately modelling environmental impacts. In some models, the allocation rules are straightforward. For instance, in METRO-PEM, the amount of land is an exogenous input that can be allocated between pastures and crops *versus* non-modelled commodities. Conversely, in other models, such as GLOBIOM, the allocation is modelled according to its heterogeneous features (i.e., country, altitude, slope, and soil class), which eventually improves the model's reliability. Therefore, modelers should reflect on how to introduce allocation and differentiation rules to better account for the related emissions.

A second issue concerns the measurement of emissions, particularly those from livestock. The variety of livestock considered in the models is often limited. Since livestock are directly linked to both food consumption choices and methane emissions, it is crucial to account for a broad range of livestock types. Additionally, emission coefficients in the models are typically exogenous. Incorporating a costly mitigation technology into the models could help endogenize the dynamics of emissions. Finally, when energy and agriculture are jointly modelled, biofuels must be properly accounted for, as their emissions impacts are multifaceted: through fuel combustion, crop cultivation, fertilizer use, and the reduction of carbon sinks. Failing to consider these factors would exclude important agriculture-related impacts and potentially bias policy simulations. Finally, our last contribution relates to how the selected models deal with the adoption of mitigation technologies. We have highlighted that the modeling choices related to

technology adoption are even more heterogeneous than other inputs due to the various possible interventions, both from a modeler's perspective and a policy standpoint. Only a limited number of models considered, in fact, the mitigation choices. In this case, the approach mainly adopted is through the profit maximizing behavior or the cost channel related to the carbon pricing.

The limited representation of other environmental aspects of these models (e.g., land use) is a common characteristic mainly explained by the difficulty of linking environmental aspects to the aggregated economic flows. However, there are other macro-economic modelling approaches, which are beyond the scope of this review, that may help to cover some aspects not addressed by the models analyzed. For instance, input-output models, emissions, and environmental impacts in general (e.g., land use), are linked to production at the industry level and the inter-industry linkages are visible. These models include not only GHG emission, but also other local pollutants that can be estimated if those can be linked to industrial production. Dynamic system models are more flexible, given that modelers can include additional modules in the main models to account for environmental and sustainability issues. At the same time, socio-economic linkages can be better represented in an integrated assessment model (IAM) framework, which includes biological and social features into the modelling framework leaving modellers free of choosing of which socio-economic variables of interest include within the model.

From a policy perspective, the review highlights the importance of considering the complexity of economic systems at an appropriate level of detail. This is, in fact, crucial for offering consistent policy simulations that can be used to implement more effective political measures in the future (Tonurist and Hanson, 2020). First, a comprehensive and sound data source allowing them to delve into the specificity of the agricultural sector is needed. In particular, non-CO2 emissions should be addressed with a higher detail, to capture the multifaceted aspects concerning agricultural processes. In this light, an example is represented by the GTAP non-CO2 database (Rose and Lee, 2009), which maps non-CO2 gas emissions by emissions drivers (i.e., output-, or endowment-related emissions).

A political framework capable of perceiving changes before they occur, in fact, reducing risks, and seizing the opportunities that arise from them is what national and international institutions are facing (Barbero-Vignola et al., 2020; OECD, 2019). In the future, climate

change mitigation strategies will be the core strategies of political agendas, and different measures will be proposed to reduce agricultural emissions. For instance, the EU is following an extensification practice, based on the increasing of organic production as a channel to increase the environmental sustainability of the agrifood systems.[5] The Farm to Fork strategy fixed the 25% target of EU agricultural land under organic farming by 2030. While intensification measures result in improving yields, technical efficiencies, and land and chemical inputs use, negatively affecting agrobiodiversity (Henke and Vaquero-Piñeiro, 2023) and natural resources quality, extensive ones (e.g., organic agriculture) support the reduction of synthetic fertilizers and pesticides as well as agroforestry interventions. However, the adoption of extensification practices, if limited at specific areas (e.g., the EU) may induce some spillover effects at the global level shaping a reorganization of the agricultural production among countries. For instance, assuming the need in the future to produce the same agricultural outputs, if not even more, the lower crop yield driven by the increase of organic farming in some countries, should be compensate by the increase in other countries, where environmental sustainability restrictions are not in force. This complexity suggests the validity of adopting ex-ante simulation models to address sustainability issues in policy designing and targeting.

Several factors that make this study not conclusive. The first one concerns the list of the models considered, which can be extended. The second one is the focus of the review that, so far, regards only equilibrium models. More comprehensive research should include also other types of models (e.g., Input Output and Agent based models). The last one refers to the supply-side perspective adopted, which can be completed by looking at the demand-side. All these aspects are in our future research agenda.

[5] Organic agriculture is defined as: *"an overall system of farm management and food production that combines best environmental and climate action practices, a high level of biodiversity, the preservation of natural resources and the application of high animal welfare standards and high production standards…"* (Regulation (EU) 2018/848, p.1)

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