

# A scoping review of the impact of agricultural, food and environmental policies on the transition toward a Safe and Just Operating Space for EU agri-food systems

Linda Arata<sup>1</sup>, Anwesha Chakrabarti<sup>2</sup>, Silvia Coderoni<sup>3</sup>, Anne-Célia Disdier<sup>4</sup>, Tamás Krisztin<sup>5</sup>, Bettina Meinhardt<sup>5</sup>, Till Kuhn<sup>6</sup>, Margherita Muzzillo<sup>1</sup>, Ana I. Sanjuán<sup>7</sup>, Paolo Sckokai<sup>\*1</sup>, Alessandro Varacca<sup>1</sup>

<sup>1</sup>Department of Agricultural and Food Economics, Università Cattolica del Sacro Cuore, Piacenza, Italy

<sup>2</sup>Krea University, Andra Pradesh, India

<sup>3</sup>Department of Biosciences, Agro-Food and Environmental Technologies, Università degli Studi di Teramo, Italy

<sup>4</sup>Paris School of Economics, France

<sup>5</sup>International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

<sup>6</sup>Institute for Food and Resource Economics (ILR), University of Bonn, Germany

<sup>7</sup>Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Zaragoza, Spain

\*Corresponding author: [paolo.sckokai@unicatt.it](mailto:paolo.sckokai@unicatt.it)

## Abstract

The transition of agri-food systems toward a Safe and Just Operating Space (SJOS) is a complex phenomenon, which implies finding proper pathways for satisfying human needs and social justice for all, while staying within the limits of the planet's natural resources. In this context, public policies can play a key role in driving the transition. Thus, in this paper, we have carried out a scoping review of the literature on the relationships between some key public policies affecting agricultural and food and the SJOS dimensions, with the purpose of identifying the most important knowledge gaps. Following the most recent protocols proposed by the literature, we have reviewed papers published in the 2000-23 period using the Web of Science database as main reference. Our results show that the available evidence is somehow scattered across the SJOS thematic areas, with a clear prevalence of the environmental (SOS) with respect to the social (JOS) ones. Thus, there is clear research gap in exploring the impact of public policies on JOS issues such as social equity, health and nutrition security. Moreover, very few studies explore synergies and trade-offs between different SJOS dimensions. This is especially relevant in evaluating a complex policy mix such as the Green Deal of the EU. Finally, from a methodological perspective, the available studies provide some interesting hints for extending the available toolkit for ex-ante policy modelling, which deserve further research.

**Keywords:** Safe and Just Operating Space; Common Agricultural Policy; Non-Tariff Measures; Climate and nutrient policies

**JEL Codes:** Q18, Q17

## 1. Introduction

The most recent European Union (EU) policy developments, which are at the core of the so-called Green Deal, require strong transformations of the EU agri-food systems, in order to improve their environmental and social performances. EU policies targeted to the agricultural sector, such as the Common Agricultural Policy (CAP), but also other policies that have an impact on agriculture and food, can play a key role in driving these transformations, as long as they are properly designed in terms of coherence between objectives and tools. However, to design the future of EU policies for agriculture and food systems, a reference conceptual framework is needed, in order to properly identify all the dimensions involved in this transition process. In fact, the structure of the Green Deal, which is designed as a set of strategies addressing the main challenges for reaching climate neutrality by 2050, require further efforts in conceiving proper pathways for reaching the Green Deal objectives in agriculture and food systems (Boix-Fayos & de Vente 2023; Guyomard et al. 2020).

In this context, the Safe and Just Operating Space (SJOS) concept (Raworth. 2012) is a promising potential unifying framework, since it integrates two critical issues of global sustainability - planetary boundaries and social foundations - to ensure that natural resources are used within safe environmental limits while meeting human needs and social justice. In a recent paper, Muller et al (2024) refine the SJOS concept providing a set of thematic areas and a corresponding set of indicators that define the main environmental (*Safe*) and social (*Just*) outcomes that are relevant for EU agriculture. A graphical representation of this approach is provided in Figure 1.

This paper proposes a comprehensive scoping review of the literature on the impact of some key agricultural, food and environmental policies on the transition toward a SJOS for EU agri-food systems, with the objective of identifying the main knowledge/research gaps.

We have reviewed three key policy areas that explicitly target some of the SJOS dimensions: (a) a selection of CAP policy tools, with a special focus on the Agri-Environmental and Climate Measures (AECMs); (2) a selection of EU trade policies, with a special focus on Non-Tariff Measures (NTMs); and (3) a selection of EU climate- and nutrient-related policies tightly connected to the agri-food systems. In carrying out this scoping review, we focus on both the theoretical and empirical evidence on the impact of existing policies (i.e., ex-post evaluation), while surveying, at the same time, some key methodological and empirical issues, such as the data and indicator needs, the modelling approaches and the econometric and/or simulation strategies adopted in the studies. In particular, we focus on methods with potential relevance for the ex-ante policy evaluation tools via bespoke modelling approaches. In fact, as long as the transition toward a SJOS implies exploring new dimensions and new indicators, proper ex-post impact analysis of policies may provide new methodological insights for policy-making support in the area of agriculture and food systems.

The remainder of the paper is structured as follows. In section 2 we present the methodology of our scoping review, while in sections 3, 4 and 5 we present the literature review on the relationships between the three categories of policies discussed above and the SJOS dimensions. In section 6 we discuss the main results of the study, including the main research gaps, and we draw implications for policy modelling. In section 7 we conclude our analysis.

## 2. Methods

We systematically analysed the literature on the impacts of key public agriculture and food policies on the main SJOS dimensions through a scoping review. Following Munn et al (2018), the objective of a scoping review is to determine the nature, size and extent of the literature related to a given topic as well as to identify possible knowledge gaps in that literature. This approach contrasts with that of systematic reviews,

which focus on answering specific and well-defined research questions. As our aim is to provide an overview of the evidence emerging from some rather heterogeneous research areas, the scoping review method seemed the most appropriate for our purposes (Tricco et al, 2018; Munn et al, 2018).

In carrying out our review, we have followed the PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews) guidelines proposed by Tricco et al (2018) as well as the procedure proposed by Peters et al. (2015). Our scoping review protocol involved five phases (see Online Appendix 1 for details): (1) definition of a research questionnaire for the analysis of the selected studies; (2) definition of the search strategy and exclusion criteria; (3) search for relevant studies; (4) screening and selection of studies; (5) data extraction and analysis.

The research team participating to the review was divided into three groups, each covering one of the three EU policy areas scrutinised in this paper: (a) CAP agri-environmental and climate policies; (b) non-tariff trade measures; (c) climate and nutrient policies. Each team identified the relevant keywords to be searched on Web-of-Science (WOS), starting from some fundamental papers selected drawing on the expertise of the team members. The keywords were further carefully reviewed by each team, in order to identify the final set of search terms.

Our scoping review covered the period 2000-2023 and was carried out using the WOS database as the main reference. The specific search queries and the corresponding results are reported in Online Appendix 2. We also reviewed other studies that, although not indexed in WOS, the three research teams deemed particularly relevant for the analysis.

The results of the queries were next screened for both manageability (the ideal number of returned articles is less than 200) and consistency (the search results should include the key papers initially identified by the research team). We then performed a further screening based on a two-step procedure. First, potentially interesting papers were identified based on their title and abstract. Second, the papers included in the review were eventually selected based on the analysis of the full text, which was carried out following the review questionnaire provided in Online Appendix 1. A total of 57, 43 and 109 studies pertaining to each of the three policy categories identified in the introductory section, respectively, were finally included in the review.

### **3. Ex post impact of the Common Agricultural Policy tools**

In this section, we focus on the studies addressing the ex-post evaluation of the CAP policy instruments relevant to achieving a SJOS for European agriculture.

The goals of the CAP, through its Pillar I and Pillar II, span across different priorities, including environmental and climate care, biodiversity conservation, and ensuring fair income for farmers. Pillar I consists of direct payments and market measures. The main goal of direct payments is to provide income support to farmers while incentivizing environmental and animal welfare standards. Market measures aim to address challenges in the agri-food sector (e.g., price volatility) through regulations such as the common market organisations (CMOs). Finally, Pillar II comprises rural development policies. The main tools of rural development are organic farming and the agri-environmental climate measures (AECMs), which hold a crucial role in the CAP's contribution to the European Green Deal.

The reviewed papers were organized into two main groups: (1) studies aimed at addressing the Safe Operating Space (SOS) outcomes (e.g., biodiversity, land use, water use, nutrient flows, chemical pollution, greenhouse gases-GHG-emissions), (2) papers aimed at evaluating the Just Operating Space (JOS) outcomes (e.g., nutrition security, health, labour fairness, social equity, farm resilience). The review begins by identifying the main papers belonging to the first group, emphasizing the most important methodological differences as well as the SOS outcomes analysed and the main implications of the results. A different logic



and Weiss, 2009), by including the pre-treatment land management measures as covariates, face a bias risk: farms might exhibit lower land management intensity before entering a program due to factors unrelated to participation. To address this issue, some studies employed more advanced matching procedures, such as a combination of Mahalanobis distance, exact matching on entry years, and Kernel matching (Uehleke et al., 2022) or coarsened exact matching (Bertoni et al., 2020). However, such impact identification only compares the average differences between participants and matched non-participants. This means that only the ATE or ATT (average treatment effect or average treatment effect on the treated) can be measured. To overcome this issue, a very recent stream of literature is employing Machine Learning (ML) techniques to ex-post evaluate the heterogeneous effect of CAP's tools on both environmental and economic indicators. These studies include Coderoni et al. (2024a); Uehleke et al. (2023); Stetter et al. (2022); and Bertoni et al. (2021).

This body of literature can be further classified according to the different SOS outcomes analysed: biodiversity, nitrogen and phosphorus loading, land conversion, and climate change.

In the early literature reviews and metaanalyses, biodiversity levels have been primarily measured through species richness and abundance (Kleijn and Sutherland, 2003; Batáry et al. 2011; Scheper et al., 2013; Tuck et al., 2014; Batáry et al., 2015). Most of the studies employing standard econometric techniques also used animal and plant species as indicators, as in Calvi et al., 2018; Fuentes-Montemayor et al., 2011; Armsworth et al., 2012; Kleijn et al., 2006, and Primdahl et al., 2003, or composite nature value indicators, as computed by Desjeux et al., 2015. Among these studies, the biodiversity impact of AECMs has yielded mixed findings. For example, Primdahl et al. (2003); Fuentes-Montemayor et al. (2012); Batáry et al. (2015); and Desjeux et al. (2015) report beneficial effects of AECMs on biodiversity indicators, while negligible or even detrimental effects emerge in Kleijn and Sutherland (2003), Granlund et al. (2005), Bellebaum and Koffijberg (2018), Kaligarič et al. (2019) and Calvi et al. (2018). Greater details are provided by Kleijn et al. (2006), who found a more positive impact on the abundance of common species rather than on endangered ones. Relatedly, Armsworth et al. (2012) highlighted the potential threat to biodiversity under overly simplified policy schemes, suggesting that a more complex measure design might result in better environmental outcomes. Conversely, studies using more advanced econometric approaches concentrated on indicators such as livestock numbers (Cisilino et al., 2019) and density (Pufahl and Weiss, 2009) and, foremost, crop heterogeneity (Cisilino et al., 2019; Arata and Sckokai, 2016; Chabé-Ferret and Subervie, 2013; Bertoni et al., 2020). Most of these studies proved that the analysed measures were at least partly effective in improving biodiversity indicators.

In the evaluation of nitrogen and phosphorus loading, researchers have mainly focused on the use of pesticides and fertilizers, as done by Varacca et al. (2023); Uehleke et al. (2023, 2022); Stetter et al. (2022); Kuhfuss and Subervie (2018); Arata and Sckokai (2016); Cisilino et al., 2019; and Pufahl and Weiss (2009). Among these, the studies by Kuhfuss and Subervie (2018) and Cisilino et al. (2019) have been the only ones to directly quantify herbicide and pesticide use respectively, while the rest have primarily employed expenditure data as indirect measures. Furthermore, other papers analysed the area allocated to cover crops for soil nitrate recovery and the length of fertilizer-free grass buffer strips (Chabé-Ferret and Subervie, 2013; Fugazza et al., 2022) or the presence of nitrogen-fixing crops (Bertoni et al., 2021; Fugazza et al., 2022). Also in this case, findings vary across studies. Uehleke et al. (2022) and Uehleke et al. (2023) found that CAP's tools resulted in a moderate decrease in fertilizer expenditures. Similarly, Pufahl and Weiss (2009); Arata and Sckokai (2016), and Kuhfuss and Subervie (2018) showed a positive impact. On the contrary, Bertoni et al. (2021) detected an increase in nitrogen-fixing crops, while Chabé-Ferret and Subervie (2013) found effectiveness for buffer strips but no effects for cover crops. Finally, recent studies from Varacca et al. (2023) and Stetter et al. (2022) found no significant effects.

Great attention has also been dedicated to the effects of CAP on reducing land conversion. This has been measured in different ways. For example, Primdahl et al. (2003) used the share of permanent grassland, abandoned land, and hedges per utilized agricultural area. Similarly, Uehleke et al. (2022); Bertoni et al.



(2022) also accounted for other socioeconomic indicators, such as gender equality (in terms of the impact on women's participation in the agricultural sector), which, however, was found to be modest.

Setting aside these differences, all three review papers aimed at assessing the heterogeneity of the effects across the two CAP Pillars. Lillemets et al. (2022) found that Pillar I has been more effective in decreasing the labour outflow from agriculture than Pillar II. Using static and dynamic panel data estimators, Olper et al. (2014a) also showed the benefits of Pillar I in maintaining labour in agriculture. However, Schuh et al. (2016) and Vigani et al. (2019) suggested that the positive effects differ among Member States (MS) and regions. Thus, the impact of CAP tools on agricultural employment seem to largely depend on different market and production structures. This was also suggested by other papers that employed standard econometric approaches (Garrone et al., 2019; Tocco et al., 2013; Psaltopoulos et al., 2006). Notably, Tocco et al. (2013) found a difference in policy response across new and old MS; in the new countries, both pillars had a positive effect on preventing the exit of labour from agriculture, while in the old ones, no impact was detected. Different results were obtained by Petrick and Zier (2011), who, applying a DID-matching technique, found that investment aids and transfers to less-favoured areas had a zero marginal employment effect in Germany.

Most of Pillar I's direct payments have, among others, the objective of income redistribution. Studies aimed at assessing the effects of direct payments on income disparity are mixed, as some found them to be positive (Keeney, 2000; Severini and Tantari, 2015; Piet and Desjeux, 2021), negligible (Ciliberti et al., 2022), or even negative, as they increase income concentration (Allanson, 2006; Schmid et al., 2006; El Benni and Finger, 2012).

In general, however, a severe data availability problem still emerges. Given the heavy reliance of most studies on FADN information, their limited scope and capacity to capture social themes constrains the evaluation of the CAP's impacts on several dimensions of the JOS. This data gap, especially regarding indicators such as health, nutrition security, and farm resilience has already been acknowledged by the literature and is most likely related to both the difficulty in collecting relevant social variables, and the CAP's longstanding focus on economic objectives. As a result, existing studies tend to concentrate on rural employment and income distribution, potentially leaving out other crucial aspects of social well-being. The few attempts to include additional socioeconomic factors such as gender equality have not been extensively explored and often reveal only modest impacts.

#### **4. Ex post impact of the EU trade policies**

This section focuses on the ex-post impact evaluation of non-tariff measures (NTMs) on SJOS-related issues, as NTMs have gained prominence as a trade policy instrument, not only in the EU but also globally. The relevance of NTMs has increased, firstly, because of substantial tariff cuts following multilateral and bilateral trade agreements. Secondly, regional trade and investment agreements, in particular, those prompted by the EU, make an increasing use of provisions on harmonisation or mutual recognition of NTMs targeted to working conditions, environmental and food safety standards. And thirdly, sustainability and food standards are promoted under the auspices of the EU Green Deal. Thus, the EU trade policy aims at improving sustainability globally by leveraging access to the EU market and ensuring EU producers level play field (i.e. mirror clauses).

Some NTMs, as standards on sanitary and phytosanitary (SPS) or technical barriers to trade (TBT), are policy instruments targeted to SJOS outcomes such as nutrition, health, food quality, sustainable production and the protection of environment. But NTMs can also affect SJOS outcomes indirectly through their influence on trade. It is a common view that compliance costs with NTMs may reduce trade, compromising

the potential economic growth, and consequently affecting food security, employment, poverty and disproportionately affect small and medium sized enterprises and women (UNCTAD, 2018; USCAP, 2019). These social as well as some environmental (i.e. CO<sub>2</sub> emissions) impacts of trade policies have been more studied in the context of trade liberalization, through tariff reduction and free trade agreements (see Barros and Martínez-Zarzoso (2022) for a literature review). Most of the empirical literature on NTMs delves into the trade implications of NTMs (Ghodsai et al., 2017), and therefore, the impacts of NTMs on SJOS indicators are only implied indirectly. This section focuses on a limited number of SJOS outcomes focusing on NTMs (where possible), complemented by the impact of trade liberalization policies. The objective of this review is to cover some stylized patterns found in the empirical literature on trade policy, not necessarily constrained to the EU geographical area or policy. In fact, much of the literature is concerned about SJOS impacts in less developed countries. From a methodological perspective, much of the empirical evidence linking NTMs and trade relies on the gravity equation, and panel data econometric techniques are widely used also for SJOS direct impact assessments.

#### *4.1. SOS outcomes*

EU trade policies, especially non-tariff measures have a significant impact on global and European land conversion (Janssens et al., 2021). Williams and Kerr (2016) discuss how the EU's environmental standards for biodiesel imports can reduce land conversion in developing countries by enforcing strict sustainability and land use criteria. This approach can limit these countries' biodiesel exports to the EU, potentially decreasing land use for biofuel production and highlighting the environmental influence of EU trade policies.

Trabelsi (2013) investigates the impact of non-tariff measures in the Euro-Mediterranean area on agricultural trade. The findings suggest these barriers create considerable trade restrictiveness, indirectly affecting land conversion through trade flow changes and economic incentives.

Finally, Mao et al. (2023) explore the economic and environmental consequences of agricultural non-tariff measures. They observe these measures support domestic agriculture in importing countries while weakening it in exporting nations, leading to welfare distortions and increased carbon emissions from the food processing industry. This underscores the need for policy reforms to promote sustainable agri-food systems.

The relationship between trade liberalization and climate change policy has significant implications for GHG emissions, especially in agriculture. Himics et al. (2018) focus on the European Union's trade liberalization agenda, using the CAPRI model to demonstrate that while trade liberalization alone has modest effects on agricultural GHG emissions by 2030, it substantially undermines global GHG mitigation efforts when combined with carbon pricing. This is mainly due to increased emission leakage, where emission reductions within the EU are offset by increases in less emission-efficient regions. This finding highlights the complexity of formulating trade policies that balance economic and environmental sustainability, stressing the need for trade agreements to consider emission leakage to support global GHG mitigation.

Environmental provisions in Preferential Trade Agreements (PTAs) are a policy instrument that has a direct impact on environment outcomes. Several studies suggest that these provisions have been associated with lower CO<sub>2</sub> emissions, as shown by Francois et al. (2023) and Martínez-Zarzoso & Oueslati (2018). In addition, research by Baghdadi et al. (2013) and Zhou et al. (2017) suggests a reduction in air pollution associated with the inclusion of environmental provisions in trade agreements. While trade liberalization adds to the environmental challenges arising from trade liberalization, such as increasing deforestation (Abman & Lundberg, 2020), the inclusion of specific provisions to protect forests and biodiversity appears to offset the net increase in forest loss (Abman et al., 2021).

Pothen and Hübner (2018) and Allevi et al. (2018) show that trade policies can interact positively with environmental policies. For example, tariff removal leads to a lesser increase in emissions due to substitution and composition effects. Additionally, environmental regulations in closed-loop supply chain networks, as

studied by Allevi et al. (2018), can incur additional costs for producers but ultimately reduce carbon emissions, indicating the potential for positive environmental outcomes through well-designed policies. This situation necessitates these firms' adoption of emissions reduction technologies to bridge the cost gap with developed-country firms.

The interaction between international trade policies and nutrient flows, particularly nitrogen and phosphorus, is a burgeoning area of research. However, no literature explicitly addresses the link between non-tariff measures and phosphorous/nitrate flows. Consequently, we rely on studies examining the broader impacts of trade policies. Shi et al. (2016) reveal how China's food importation, primarily from America and Asia, influences its nitrogen cycle. Nesme et al. (2016) focus on the EU's dependency on imported agricultural products and its phosphorus fertilizer footprint. Yao et al. (2021) investigate the environmental effects of US-China trade tensions on nutrient pollution.

Recent literature indicates a nuanced relationship between non-tariff measures, European trade policies, and global freshwater use and eutrophication. Hamilton et al. (2018) highlight the significant role of non-food commodities in global marine and freshwater eutrophication, influenced by income elasticity and the trade-driven nature of these impacts. This suggests the importance of expanding the focus of trade agreements and policies beyond food commodities, particularly as economies develop and consumption patterns evolve. Baylis, Nogueira, and Pace (2022) note that as tariff rates decline under WTO commitments, non-tariff measures, particularly food safety standards, emerge as significant trade impediments, as seen in the EU seafood trade where these barriers nearly offset a quarter of the gains from tariff reductions.

European Union policy initiatives such as the Green Deal (Bieroza, Bol, & Glendell, 2021) and preferential trade policies (Cipollina, et al., 2014; Borchert et al., 2020) play a crucial role in shaping water use and quality. Bieroza et al. (2021) critically assess the EU Green Deal, noting its potential but emphasizing the challenges in relying on the reform of the CAP for mitigating agricultural pollution. Cipollina et al. (2014) and Borchert et al. (2020) provide insights into the EU's preferential trade policies, highlighting their significant but varied impact on trade volumes across sectors and their ability to promote trade in compliance with non-trade policy objectives. However, the limited number of studies directly linking non-tariff measures and European trade policies with freshwater use suggests an area ripe for further research. In this respect, Hirsch et al. (2020) find that water resources play a crucial role in shaping foreign direct investments in land, especially in the context of rainfed crops, contributing to the phenomenon of large-scale Foreign Land Acquisition (FLA).

#### 4.2. *JOS outcomes*

The impact of NTMs is not necessarily gender neutral in terms of compliance with costs and benefits from protection, and UNCTAD (2022) provides a systematic review of empirical evidence, mainly based on case studies and anecdotal evidence. As entrepreneurs, compliance with NTMs requires access to financial resources and technical skills that women lack due to education, training, time and mobility constraints rooted in social norms. Furthermore, NTMs can be particularly burdensome for SMEs and are more prevalent in the agri-food and textile sectors, where women are more likely to be employed or run businesses. Kareem (2017) provides quantitative evidence on the widening of the gender employment gap in agriculture induced by EU SPS and TBT measures. On the other hand, inadequate protection through inappropriate technical regulations that do not take into account anatomical and physiological gender differences may also disproportionately affect women engaged in high-risk production activities or as consumers of cosmetics or pharmaceutical products (UNCTAD, 2022).

The gender impact of trade policies has been more investigated in the context of trade liberalisation, with a focus on developing countries. To the extent that women are more engaged in food sectors, which have experienced price declines due to competition from increased imports, and less engaged in cash crops, which benefit from greater access to international markets, the gender gap in employment and wages has widened

(IANWGE, 2011; Balamoune-Lutz, 2007). Using microdata, Zaki (2014) finds empirical support for the contribution of tariffs and procedural obstacles to the gender wage gap in Egypt.

There is an abundant literature on the impact of trade liberalisation (through trade openness and trade and investment agreement indicators) and globalisation (economic, social and cultural, through the KOF index) on nutrition and health, mainly focused on low- and middle-income regions, while there is a paucity of equivalent research on the direct effect of NTMs. The review by Cuevas García-Dorado et al. (2019) points to foreign direct investment and socio-cultural aspects of globalisation as the most influential on overnutrition and prevalence of non-communicable diseases (NCDs) (e.g. obesity), due to dietary shifts towards unhealthier diets. Some empirical evidence supports the positive impact of trade liberalisation on reducing undernutrition by increasing the availability of affordable healthy foods, while the association with NCD prevalence or overweight is not clear.

Nutrition labelling falls within the spectrum of NTMs that promote healthy food choices by consumers, and a large body of consumer research literature supports this view (Cecchini and Warin, 2016). Similarly, Maximum Residue Levels (MRLs) requirements directly target the protection of human health (and the environment, for instance, through limits and bans on pesticides), but the lack of international harmonisation can create costly trade barriers that reduce opportunities for socio-economic development, especially in low-income countries (Curzi et al., 2018).

Some empirical evidence suggests that the adaptation of exporters to more stringent food standards stimulates investment and quality upgrading (Olper, Curzi and Pacca, 2014b) and alters domestic supply chains (Swinnen, 2016). However, convergence to stricter standards may divert trade away from destination markets with lower purchasing power (Disdier, Fontagné and Cadot, 2015) and may force some firms to specialise in less regulated export markets (Essaji, 2008), reducing product and market diversification.

NTMs may also affect trade by impacting firms' export flows. As is now well-established in the trade literature, firms are heterogeneous, especially in terms of size and productivity. More productive exporters are more resilient to cost-increasing NTMs than less productive ones (UNCTAD, 2018). Moreover, the overall impact of NTMs on country exports can be quite ambiguous as some firms may lose, while some others may potentially benefit from the presence of NTMs in the export markets. The mechanisms at play are as follows. First, consider an NTM increasing the marginal production. Low-productive firms are likely to be harmed by this increase, and some will be excluded from the export market. Depending on the relative price impact of this industry-wide effect, incumbent firms may experience an increase in demand. Second, suppose now that the NTM leads to an increase in fixed costs. The effect will be similar to the one previously observed, except that the effect on market structure is likely to be stronger, as a larger number of low-productivity firms will stop exporting. In such a case, and given that a few firms usually account for the bulk of industry output, the effect of the NTM on the industry's aggregate production costs, as well as the overall impact on exports, should be smaller.

Empirical evidence confirms this heterogeneous effect of NTMs across firms. Based on French firm-level customs data which provide exports per firm-product-destination and year over the period 1996-2005, Fontagné et al. (2015) highlight that large firms are less affected by NTMs than small firms, both at the extensive and intensive margins of trade. Interestingly, NTMs tend to drive the average firm out of the market, thereby reducing the competition between firms in the NTM-imposing market. Similar results are observed by Fernandes et al. (2019) and Curzi et al. (2020) for agrifood firms in Peru. Furthermore, multi-destination firms switch to new TBT-free destinations more easily than mono-destination firms (Fontagné and Orefice, 2018). A final important result concerns domestic NTMs and the ability of firms to respond to foreign demand shocks. In the presence of such shocks, firms have to optimally adjust their input mix. This adjustment will be more difficult for firms that import inputs and face NTMs on these imports. As a result, these firms may experience a larger decline in their exports compared to firms that are not facing NTMs

(Cali et al., 2022). Using micro-firm data for Ukraine, Movchan et al. (2020) find that SPS regulations on imported inputs in food processing lead to higher prices and higher quality of exported food products, but at the cost of a reducing both extensive and intensive margins.

NTMs are also likely to affect the labour market. The mechanisms at play are well-identified in the literature. When a country enforces NTMs, such measures act as a protection against foreign competition. As a result, wages and employment are likely to be higher in protected sectors and lower in unprotected sectors. Consumer prices may also be impacted, with consequent effects on real wages. Similarly, when trade partners impose NTMs, this may affect wages and employment in export-oriented sectors.

Thus, the removal (or harmonization/mutual recognition) of NTMs is likely to have repercussions on labour markets. Such repercussions will depend on labour market frictions and labour mobility across sectors (UNCTAD, 2018). If labour is not mobile, then only wages and employment in sectors facing NTMs will be affected. At the other extreme, if labour is perfectly mobile across sectors, then wages and employment of all workers are impacted. Finally, if labour is imperfectly mobile, wages and employment of all workers are again affected, but at a different extent. The size of the competitive shock, the degree of labour mobility and the wage differences across sectors will determine this heterogeneous impact.

There is however a dearth of empirical research on this area. Summing up, the impact of NTMs on social and just indicators has mainly been addressed indirectly through the influence of NTMs on trade. Direct analysis has focused on the impact of measures adopted by developed economies, in particular the EU, on developing economies. Consequently, little is known about the social impact within the EU borders. The use of macro-data predominates, which does not allow the analysis of redistributive effects within geographical units. Micro-data on firms has allowed the nuances of the impact of NTMs on industrial resilience to be observed. However, access to micro-data is costly and difficult and the studies carried out are concentrated in a few EU countries.

## **5. Ex post impact of EU climate and nutrient policies**

Climate and nutrient policies targeted to the agricultural sector are diverse. This section focuses on the most important policies for agriculture and on those that have been already implemented, to assess their ex-post impact assessment in the literature. These are: the Effort Sharing Regulation (ESR) (no. 2018/482); the Nitrates Directive (91/676/EEC) (ND); the Water Framework Directive (2000/60/EC) (WFD); the National Emission reduction Commitments Directive (NECD, 2016/2284/EU); the Marine Strategy Framework Directive (MSFD, 2008/56/EC); the Integrated Pollution Prevention and Control Directive (IPPC, 2008/1/EC) [which later was transferred to the Industrial Emissions Directive \(2010/75/EU\) \(IED\)](#).

The mitigation of non-CO<sub>2</sub> GHG emissions from EU agriculture (namely, methane-CH<sub>4</sub>-and nitrous oxide-N<sub>2</sub>O) is covered by the EU ESR, which provides for national annual emissions targets for different sectors (including agriculture). MS are set free to reach their mitigation target by using different tools, including the CAP incentives of the AEEM or the Eco-Schemes. As regards CO<sub>2</sub> emissions from Land Use, Land Use Change and Forestry, the related Regulation was revised in 2023. For the period 2021-2026 the revision confirms the current “no debit” rule, i.e., each MS shall ensure that accounted emissions are compensated by at least equivalent removals. Also, some national or regional initiatives exist that provide incentives for carbon (C) storage in agricultural soils; these range from voluntary carbon markets to result-based AEEM schemes. In this respect, in December 2024, a specific Regulation (n. 2024/3012) has entered into force to establish a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products. The ND is the core regulation to govern the use of chemical nitrogen fertilizer and manure in EU agriculture. It aims at the protection of surface and groundwater from nitrates.

The WFD generates a framework to protect groundwater and surface waters, aiming at good ecological, chemical, and quantitative status. Therefore, the WFD is an overarching regulation to protect water bodies; here we focus on its role as nutrient management policy. MS establish a program of measures for river basin districts, which include basic measures, namely other EU directives such as the ND, and supplementary measures.

Like the WFD and freshwater, the MSFD generates a framework to protect marine waters and EU MS are obliged to take measures to achieve a good environmental status in the marine environment. The MSFD does not prescribe exact measures, but MS must develop programs to reach the goals of the MSFD.

The NECD defines national emission reduction commitments for EU MS for five pollutants. Agriculture contributes by a relevant share to sulphur dioxide, ammonia, non-CH<sub>4</sub> volatile organic compounds, nitrogen oxides, and particulate matter. As agriculture is a major contributor to ammonia emissions (EEA, 2023), the directive encourages better fertilizing management and livestock waste control. In line with the WFD and MSFD, the NECD does not prescribe measures but defines environmental targets which MS need to reach.

The IPPC and IED directives aim at the prevention and control of emissions from industrial activities, being relevant for agriculture in the case of intensive rearing of poultry and pigs. MS mainly define permits for industrial processes that need to reflect the Best Available Technique, addressing in the case of agriculture different forms of reactive nitrogen and phosphorus.

### 5.1 SOS Outcomes

The literature search for the ESR did not return any result, maybe as these policies do not set legally binding targets solely for the sole agricultural sector, nor MS have designed national legislation that imposes such targets. Thus, we have analysed the literature found using more general keywords, by referring to climate policies or carbon markets (see Online Annex 1).

Climate policies that address the issues of GHG emissions from agriculture cover the impact on biosphere integrity and climate change under the Safe dimensions. Researchers have noted several options to reduce non-CO<sub>2</sub> emissions in food and agriculture systems which can be classified into the following four categories: increase in agricultural productivity and efficiency, implementation of specific technologies, change in human diet and reduction in food waste (Bryngelsson et al., 2016). However, studies in this field often apply ex-ante simulation models of the likely imposition of stringent mitigation targets, rather than appraising ex-post impacts.

From the supply side, for example, several works have considered a tax to incentivize farms to contain emissions within an established threshold, or a subsidy to incentivise those farms that reduce this negative externality (see among others: Fellmann et al., 2018; Coderoni et al., 2024b). Others have instead considered the environmental and economic impacts of the imposition of a GHG reduction target on Italian agricultural emissions (Cortignani and Coderoni, 2022). These works use mainly ex-ante modelling tools based on FADN data.<sup>1</sup>

Other studies combine supply and demand side options together. Using a simulation model Bryngelsson et al. (2016) show that non-CO<sub>2</sub> emissions from food consumption in Sweden may be reduced to the necessary extent to achieve the EU climate target<sup>2</sup> through technological improvements, but technological options would need to be combined with changes in diet toward low-emitting food. The impact of price-based

<sup>1</sup> In particular, Fellmann et al. (2018) use the CAPRI that is a partial equilibrium model, which links a supply module, focusing on the EU, with a global multi-commodity market module and uses data from EUROSTAT, FADN and FAOSTAT. Cortignani and Coderoni (2022) and Coderoni et al. (2024b) use the AGRITALIM model, an agro-economic supply model that uses much of the information reported in the FADN dataset on economic, financial, productive, market, political and structural aspects.

<sup>2</sup> In response to the global 2°C target, the EU roadmap allocates 500 kg CO<sub>2</sub>-eq per capita per year for the 80% reduction level (European Commission, 2011).

instruments (i.e. consumption taxes) on diet changes and on emissions have been studied by many authors. For a detailed analysis of this field of literature, please refer to Moghayer et al. (2024).

As regard voluntary carbon markets and C credits, the only SOS dimensions covered by all the relevant papers are biodiversity and climate change. Three studies use different types of farm financial analysis to assess break-even point for the financial viability of different C markets. Two studies apply Net Present Value (NPV) analysis (Hall, 2018; De Leijster et al., 2020).<sup>3</sup> Hall (2018) uses NPV to establish what C price would be necessary for the financial viability of a beef enterprise in a 20 years period in Estonia. With predetermined cattle revenue and C sequestration rates, viability evidently depends on the discount rate and C price. Leijster et al. (2020) examined the evolution of the NPV for almond farms in Spain using a stochastic cash-flow model of several agroecological practises (compost, green manure-GM, and no tillage-NT) in comparison to conventional tillage (CT), as well as the impact of internalising externalities through costs associated with erosion and payments for soil carbon sequestration and explore the effects of price premiums and public greening payments on farm NPV. Results point to a trade-off between income and costs from unaccounted externalities. Incentives from both public and private policies may change this result, but it would imply a significant public expenditure.

Abdul-Salam et al. (2019) analyse the economic performances of alternative crop production systems when C trading markets are in place. The authors simulate the farm financial analysis of two model arable farms in the period 2011–2016 if they had each followed one of the two farm management systems (i.e., conventional vs. integrated) as applied to the experimental fields. The study confirms that conventional management is more profitable than a low-carbon management system even when the cost of C is considered in the framework of a C market. Only coupling an appropriate price for C and a premium price on products from low-carbon systems would allow to compete with conventional systems.

Other studies apply instead simulation models. Blandford et al. (2015) use a mathematical programming-price-endogenous-partial equilibrium model of Norwegian agriculture to analyse the relationship between trade liberalization and GHG emissions. The authors find that only an effective trade liberalization or a C tax could help reaching the proposed Norwegian emissions reduction (-30% in 2020 compared to 1990). However, these could negatively impact on agricultural activity; thus, only allowing for credits for C sequestration activities on land taken out of agricultural production could help keeping current aggregate production level.

Poppe et al. (2021) use a microeconomic model called Farmdyn (Britz et al., 2016) to compare options for reducing GHG emissions from peat soils in Dutch agriculture. Results suggest that a pressure drainage system's technological solution may be appealing if the costs are offset, for example, by C credit payments. Results also propose an analysis of the trade-offs concerning CO<sub>2</sub> and NH<sub>3</sub> emission reductions and biodiversity.

O' Sullivan et al (2015) use a modified version of the DeNitrification-DeComposition model - a simulation tool of carbon and nitrogen biogeochemistry in agro-ecosystems - to investigate the trade-offs between the soil functions of productivity and carbon storage in response to the use of land drainage systems for grasslands in Ireland. These trade-offs are examined in relation to the nominal cost of C credits. Results confirm that the price of CO<sub>2</sub> determines how these conflicting soil functions are prioritised and incentivized. The agronomic benefits outweigh the adjusted environmental costs at the present CO<sub>2</sub> pricing. The study also highlights large variability in environmental costs at geographical level.

The main modelling gaps of these studies are that they mostly refer to specific farm types and sizes (Hall, 2018; Abdul-Salam et al. 2019; De Leijster et al, 2020) or soil types (Poppe et al, 2021; O' Sullivan et al.,

---

<sup>3</sup> The NPV is calculated as the cumulated yearly present value of an entire project, that takes all costs and benefits generated during the project life time into account and uses a discount factor to correct for the time discrepancy (FAO, 1991).

2015). Also, ecosystem service valuation, when present, can be considered controversial since it involves making assumptions about the value of ecosystem services, both monetary and non-monetary, which is subject to fluctuations in external circumstances, and is challenging, if not impossible, to value non-material ecosystem services (De Leijster et al., 2020). Modelling gaps refer also to the trade-offs in relation to the delivery of other soil functions like water purification, habitat and nutrient cycling in response to land drainage interventions (O' Sullivan et al., 2015).

The ND is directly linked to the safe space dimension of nutrient flows. Existing literature focuses on ex-post monitoring of nitrates concentration in ground and surface water in case study settings and partly links it to the measures of the ND (Gomes et al., 2023; Hooda et al., 1997; Lagzdins et al., 2015; van Grinsven et al., 2012). Such monitoring activities are also part of the frequent reports by the MS to the EU Commission on their implementation of the ND. In addition, indicators for nitrogen losses such as nitrogen balances are estimated at different scale and related to ND measures (Buckley et al., 2016a; Cameira et al., 2019; van Grinsven et al., 2012).

Modelling at field, farm, catchment, and regional scale is mainly used for ex-ante evaluation of measures of the ND on nitrogen emissions (Ackermann et al., 2016; Belhouchette et al., 2011; Berentsen and Tiessink, 2003; Costa et al., 2021; Koos et al., 2021; Oenema et al., 2009; Wilk et al., 2019; Wolf et al., 2003) or for ex-post simulations where empirical observations are challenging (Motarjemi et al., 2021; van Calker et al., 2004). Research on the ND also partially covers phosphorus emissions (Buckley et al., 2016b; McDonald et al., 2019) as the ND implementation in MS often addresses both nutrients. Generally, existing research mainly provides case study results for a catchment or a region, reflecting the diverse implementation of the ND in MS. Cross-country comparisons and EU wide analysis are rare (Oenema et al., 2009; van Grinsven et al., 2012), but valuable for understanding the impact of specific measures and a general evaluation of the ND.

Little research is present on possible synergies and trade-offs between the ND and other safe space dimensions beyond nutrient flows. However, the ND is clearly related to climate change, biosphere integrity, and aerosol loading. The MS' implementation also foresees an environmental impact assessment, following the EU directive on the assessment of the effects of certain public and private projects on the environment (2011/92/EU), which covers environmental impacts beyond nutrient flows (see for example German revision at BMEL, 2016). Empirical research hints for instance at the link between buffer zones provided for surface water quality and biodiversity (Izydorczyk et al., 2018) and linkage between reduced N inputs and lower measured nitrous oxide emissions (Cocco et al., 2018). Generally, model analyses provide more frequently the impact of the ND measures on various safe space indicators (Belhouchette et al., 2011; Oenema et al., 2009; Prado and Scholefield, 2008; van Calker et al., 2004) and also address the possible trade-off and synergies between different environmental goals (Paterson and Holden, 2019; Splinter and Peerlings, 2023). However, ex-post estimations of the impacts of the ND on other safe dimensions are rare but crucial for a broader understanding of policy impacts. They need to cover amongst other the impact on climate change due to changes of N<sub>2</sub>O emissions and the impact on ammonia emissions, being linked to terrestrial biodiversity via exceeding critical nitrogen loads and the formation of aerosols.

The WFD is linked to the safe operating space dimensions of biodiversity, nutrient flows, chemical pollution, and water use. The WFD directly targets aquatic biodiversity, and its land-oriented measures to protect waters can also impact terrestrial biodiversity. Ex-post evaluation and monitoring of the WFD cover the ecological status of water bodies (Boets et al., 2021; Gozlan et al., 2019; Newton et al., 2022) and also its impacts on small standing waters not covered directly by the directive (Bolpagni et al., 2019). Existing research does not evaluate the WFD concerning terrestrial biodiversity but focuses on single measures also implemented by the directive (e.g. Cole et al., 2012), such as riparian field margins.

Most literature on the WFD focuses on nitrogen and phosphate in ground and surface waters. This field is dominated by monitoring research (e.g. Rodrigues et al., 2023; Stefanidis et al., 2020; Vystavna et al., 2017) and ex-ante modelling of measures to reach the goals of the WFD (e.g. Bouraoui and Grizzetti, 2014; Cerro et al., 2014; De Girolamo and Lo Porto, 2012), being also driven by the needs of governmental institutions

when designing the river basin management plans. However, ex-post assessments of the implementation of the WFD or even selected measures are found little in the relation to their EU-wide implementation (Boets et al., 2021; Cooper and Hiscock, 2023; Newton et al., 2022; Noges et al., 2022; Urresti-Estala et al., 2016; Wuijts et al., 2021) but would have been useful to evaluate and adapt management plans.

The WFD also targets chemical pollutants. Existing research strongly focuses on monitoring (e.g. Arditoglou and Voutsas, 2010; Diarnanti et al., 2020; Neamtu et al., 2009), and there are few ex-post evaluations of the WFD concerning pesticides from agriculture (Bouleau et al., 2020; Cooper and Hiscock, 2023; Dolan et al., 2012; Weisner et al., 2022; Wuijts et al., 2021). In ex-ante assessments, chemical pollutants from agriculture are less frequently included than nutrient losses (Bartolini et al., 2007; Vernier et al., 2017). The safe dimension of water use, relating in the original concept to the consumptive use of blue water (Steffen et al., 2015), is also reflected in the WFD that aims at a good quantitative status of groundwater and includes, amongst others, water flow into the ecological evaluation of surface waters. In line with chemical pollutants, this part of the WFD is also little reflected in scientific literature, and no comprehensive ex-post assessments of the WFD have been found. Existing research focuses on monitoring (e.g. Zoumides et al., 2013) and ex-ante assessments (e.g. Blanco-Gutierrez et al., 2013).

Land use, aerosol loading, and climate change are not directly linked to the WFD, but its measures can, in principle, also impact these dimensions. No literature has been found on the impact of WFD on land conversion, but on the impact of land use changes on reaching the WFD targets (e.g. Hughes et al., 2016). There might be a linkage between the WFD and land use changes when the directive impacts the production level. No literature has been found on the impacts of the WFD on aerosol loading. However, measures of the WFD targeting nitrate losses might also impact ammonia emissions, which are an important contributor to aerosol loading. Also, the impact of the WFD on reducing GHG emissions is not addressed in the literature, but synergies between climate change mitigation and reaching the goals of the WFD are discussed (Kaspersen et al., 2016a, 2016b).

As regards the MSFD in relation to agriculture, bio-geochemical flows are the most relevant safe dimension but also other dimensions such as biosphere integrity or novel entities are of interest. Measures against eutrophication are evaluated in terms of descriptors of the MSFD in ex-ante modelling (Ackermann et al., 2016; Friedland et al., 2021; Grizzetti et al., 2021) but assessments of measures specific to the MSFD in the action plans of MS are missing. Finally, little research is found on impacts of the MSFD in relation to agriculture. This is because most relevant measures are part of other EU policies, such as the ND and CAP (Salomon and Dross, 2013), and their implementation in MS.

The NECD is directly linked to the safe dimensions of bio-geochemical flows, biosphere integrity, ozone depletion and aerosol loading. Ex-post analysis links the NECD to calculated emission inventories (van Grinsven et al., 2016, 2015) which are also covered by compulsory reporting of the MS. The majority of research are ex-ante assessments for the analysis of measures and scenarios to meet the ceilings of the NECD at different scales (Ferreira et al., 2017; Hu and Schmidhalter, 2021; Lumbreras et al., 2008; Mircea et al., 2015; van Grinsven et al., 2015). Ex-post and ex-ante assessments also go beyond the calculation of air pollutants and estimate actual impacts, such as nitrogen deposition in the Baltic sea (Gauss et al., 2021), critical load exceedance (Hettelingh and Posch, 2019) and health impacts (Giannakis et al., 2019), as well as use monitoring data (De Marco et al., 2019; Serrano et al., 2019; van Grinsven et al., 2016).

The IPPC and IED directives are directly linked to the safe dimension of bio-geochemical flows as well as aerosol loading and biosphere integrity. The implementation of the directives in MS is a crucial measure to meet emission ceilings under the NECD. Little research exists on the impacts of the directives on relevant safe dimensions. Ex-ante modelling at different scale is conducted to assess the emission reduction (Pellini and Morris, 2001; Webb et al., 2006), partly also relating emissions to actual impacts (Angus et al., 2006). Cross-country comparisons give helpful insights but only are only found sporadic (Loyon et al., 2016, Kunes et al., 2022). There is no literature found on the emission or impact reduction of the directive on a country or EU scale or on synergies and tradeoffs with safe dimensions besides the targeted emissions.

However, the impacts of the directives on relevant emissions are reflected in the reporting of MS under e.g., the NECD.

From the perspective of the SOS framework, limited research has been conducted on the environmental effects of policies beyond their target impacts. This is partly due to the availability of data, as official monitoring activities, and consequently, data provided to researchers, are predominantly focused on the direct impacts of policies. Moreover, existing research tends to prioritize indicators (e.g., nutrient concentrations) rather than actual environmental outcomes (e.g., biodiversity loss). The availability of data for certain indicators is often better than for the actual environmental impacts, which are typically more complex, costly to measure, and influenced by numerous variables. In terms of methodology, the literature is dominated by case studies and ex-ante analyses. However, to align with the SJOS framework, which operates at global or regional scales, policies should be analysed at these broader levels. The findings from case studies are often not easily generalizable, yet their prevalence is driven by factors such as data consistency, funding institution priorities, and the expertise of researchers. Additionally, ex-post policy analyses remain underrepresented in the literature, despite their critical role in informing future policy design. Estimating the causal effects of policies on environmental dimensions presents large methodological challenges, as such analyses must rely on observational data rather than controlled experiments. These challenges, as presented by Hennings et al. (2024) in the context of applied economics, likely contribute to the limited emphasis on ex-post evaluations in existing research on environmental and climate policies and the safe space dimensions.

## 5.2 JOS outcomes

As regards climate policies and C markets, the only just dimensions covered are those on income and sectoral employment.<sup>4</sup> For C markets, all studies analyse impacts on farms viability, but only three studies address the issue explicitly. Poppe et al. (2021) show estimates of farm income losses for three different changes in water levels in peat soils associated with changes in production methods, showing that giving a value to C credits could obviously help reducing these income losses. De Leijster et al. (2020) analyse the trade-offs between income losses and environmental externalities generate, while O'Sullivan et al. (2015) show that the environmental costs do not translate into a change in farmers' income, in presence of a C price. Modelling gaps include the analysis of trade-offs with the other dimensions of the JOS.

Little is known also on the impacts of the ND on the JOS. Mainly farm income is addressed in modelling studies, estimating on-farm compliance costs or income change with bio-economic farm models (Belhoucette et al., 2011; Berentsen and Tiessink, 2003; Kuhn et al., 2019; Pahmeyer et al., 2021; van Calker et al., 2004) or sectoral economic indicators with large-scale models (Oenema et al., 2009). Ex-post empirical work of past ND implementation on wider economy and further just dimension is needed. The impact of fertilizer restrictions as part of the ND are evaluated in field trials with respect to yield, quality, and economic implications (Pirko et al., 2020; Szafranska et al., 2023), also indicating possible impacts on the food dimension. However, a comprehensive analysis of yield and market effects of the ND, going beyond the field level and single ND measures, is missing.

Also, about the WFD, little research has been done on the just dimensions. Health is directly linked to the WFD, which focuses, amongst others, on nitrate concentration and pesticides in drinking water sources. No literature is found directly on such health impacts of the directive, only a case study on bathing water quality (Kay et al., 2007). Many ex-ante studies include cost-efficiency in their analysis of measures to reach the goals of the WFD (e.g. O'Shea and Wade, 2009; Peña-Haro et al., 2010, 2009), which allow limited conclusions on the just dimensions of economy and farm resilience. Furthermore, few analyses exist on the effects on farm income (Fezzi et al., 2010, 2008) and on synergies and trade-offs between bioenergy production and the goals of the WFD (De Girolamo and Lo Porto, 2012; Kaspersen et al., 2016b; von Buttlar

<sup>4</sup> Hall (2018) only mentions gender issues, by stressing that the C credit rewarding system presented could easily be applied within a policy framework aimed at gender equity.

and Willms, 2016). With regard to sustainable water use, a larger body of literature deals with the economic and social impacts of water pricing and rights, mainly in case study settings and ex-ante analyses (e.g. Quiroga et al., 2014, Bazzani et al., 2004). However, ex-post analysis or more comprehensive assessments of the WFD in relation to economy and farm resilience are missing. Social equity and nutrition security have not yet been researched in the context of the WFD; only one study has been found with a general focus on social sustainability (Manos et al., 2011). However, in line with land use change, measures of the WFD, which lower production, might also impact food availability, whereas sustainable water use implemented by the directive can sustain nutrition security long-term.

About the MSFD, no research is found on the just dimension.

The NECD addresses air pollutants and is therefore directly linked to the just dimension of health. A body of literature related to air quality changes and health impacts exists, partly also opposing health benefits and costs (Giannakis et al., 2019; Piersanti et al., 2021; Schucht et al., 2018; van Grinsven et al., 2016). The inclusion of the costs of measures also addresses the economic and farm resilience dimensions, while research on the NECD regarding other just dimensions is missing. As with the MSFD and WFD, other EU and national policies prescribe the actual measures to meet the NECD and are subject to research, also allowing conclusion for the NECD.

Existing research on the IPPC directive also includes the assessment of abatement costs and cost-efficiency of measures (Angus et al., 2006; Webb et al., 2006), given hints at the impacts on the economy and farm resilience dimensions. Though, more comprehensive research on income effects of the IPPC directive as well as other just dimensions is missing.

In line with the SOS dimensions that are not directly targeted by the policy, the JOS dimensions remains largely overlooked in the evaluation of environmental and climate policies. This presents a challenge when assessing policies based on existing knowledge within the framework of the SJOS concept. Most research tends to focus on standard economic variables, such as income, while just dimensions, including health and social equity, are rarely examined. These dimensions, along with their associated indicators (e.g., food access), are often more difficult to quantify, leading to a scarcity of high-quality data. Beyond data limitations, the difficulty of estimating causal effects using observational data further complicates the evaluation process, contributing to the predominance of ex-ante research approaches.

## 6. Discussion

The scoping review carried out in the previous sections provides a comprehensive picture of the relationships between some key policies affecting agriculture and food and the various dimensions of the SJOS, identifying some established results as well as some research gaps that need to be filled. Moreover, exploring the methodologies adopted to analyse these relationships, some potential implications for modelling the ex-ante impact of policies can be drawn. Table 1 provides a summary of the main results distinguishing the different groups of policies and the different SJOS dimensions. These results are further discussed in the next sub-sections.

### 6.1 CAP tools

Concerning the CAP tools, the first important observation is the relative scarcity of studies concerning the JOS dimensions. While the environmental dimensions implied by the SOS are deeply explored, there is a clear research gap concerning the social dimensions, for which the available evidence is concentrated on issues related to income and labour. A second clear research gap has to do with the availability of proper data. Most ex-post CAP evaluation studies are based on FADN, where some crucial information is missing. In particular, for all issues concerning input use, especially chemical inputs (fertilisers, pesticides, antibiotics, etc.), researchers are very often forced to use expenditure data rather than actual quantities, thus creating strong approximations in estimating the impact of policies on issues like nutrient flows or chemical pollution. In this respect, the protocols proposed for the new EU Farm Sustainability Data Network (FSDN)

collection, which is expected to start in 2025, represent a (potential) substantial improvement in the quality of the available data.

In terms of impact evaluation, most of the available studies are concentrated on the impact of AECMs, since these policies are explicitly targeted to the SOS dimensions. In this respect, most of the available evidence shows that the AECMs were at least partly effective in improving biodiversity indicators, land conversion rates and GHG emissions, while for nitrogen and phosphorus loading results are somehow mixed, with several studies reporting no or little effects. On the JOS dimensions, results are also mixed: the impact of CAP tools (first and second pillar) on agricultural employment have been shown to be positive in some studies and negative in others, while the impact on income distribution in agriculture is also uncertain, with several studies showing a reverse effect, with an increase in income inequality. However, as mentioned above, the most striking result is that several JOS dimensions (health, nutrition security, farm resilience) are virtually neglected in this literature.

In terms of methodologies, there is a clear evolution in methods: while the first available studies were using simple regression techniques, a second stream of studies has used a wide range of matching techniques, comparing participants in the relevant policy programme with matched non-participants via the Average Treatment Effect (ATE), often integrated with DID, to explore the time dimension. However, some of the most recent studies use machine learning matching algorithms, which seem very promising also in their potential extension to ex-ante evaluation, given their ability to explore heterogeneous farm responses to policies, both in terms of economic and environmental impacts.

## *6.2 Non-tariff measures*

The literature on NTMs is interesting especially for its focus, which typically goes beyond the EU and tries to evaluate the impact of trade policies on the SJOS dimensions in third countries, especially developing countries. Another element that deserves special attention is its prominent interests in the JOS dimensions, which are at the core of many studies.

Starting from the SOS outcomes, it is quite clear that EU environmental standards, such as those on biodiesel, can positively impact land conversion rates, while the impact of climate policies is quite complex and imply relevant trade-offs. For example, carbon pricing, combined with trade liberalisation, may create a shift of GHG emissions from the EU to less emission-efficient countries, with little impact on global emissions. Several studies also highlight the potential positive impact on air pollution of environmental standards linked with trade agreements. Nonetheless, several areas remain unexplored. For example, virtually no studies have explored the relationships between trade policies, and NTMs in particular, with nutrient flows, while the relationships with water use goes beyond the food sector and involves also trade policies for non-food commodities, although further studies seem to be needed also in this area.

In terms of the JOS outcomes, many studies explore the relationships between trade liberalisation and gender issues (i.e., wage gap) as well as on nutrition security. In general, while trade liberalisation may improve some nutrition outcomes, through the availability of more healthy food options, some studies underline also the potential incentives to negative dietary shifts, with increase in obesity ratios. Among the potential positive outcomes of NTMs, increase in standards by importers may stimulate investments and quality upgrading, although this may divert trade from lower purchasing power countries. In terms of impact on labour, NTMs may impact wages and prices, with differences between domestically protected sectors and export-oriented sectors, with a differentiated impact on purchasing power of different segments of the population.

In general, the literature on NTMs may contribute to refine ex-ante evaluation models, which are typically focused on the impact of tariff/subsidy measures, although the linkage with several SJOS dimensions is not easy to model. Moreover, trade-offs between different policies and different SJOS dimensions are still weakly explored.

### 6.3 Climate and nutrient policies

Most studies concerning the impact of EU climate policies, targeting emission reductions, explore their alternative impact with or without some carbon pricing policies, mostly with ex-ante modelling tools. In general, these studies conclude that only with an emission trading system in place, climate policies may reach the emission reduction targets without seriously harming farmers' income, as this could allow exploiting farms' heterogeneous abatement costs. For this reason, studies concerning the potential impact of the presence of carbon markets are especially important.

In the SOS area, the need for a carbon reward system is emphasised in simulation studies exploring the switch from conventional farming to low-carbon farming systems, the adoption of more climate-friendly precision technologies, as well as the incentives for new soil management systems. However, the evaluation of these issues tends to rely on case studies, which are difficult to generalise, and often lack a proper evaluation of non-market ecosystem services, which are typical outcomes of the introduction of new farming systems.

The role of the various climate and nutrient EU directives (ND, MSFD, NECD, WFD, IPPC, IED) has been explored typically via case studies. Thus, results are sector and region specific, while cross-country comparisons and EU-scale analyses are rare. In addition, the available studies tend to concentrate only on the specific SOS dimension targeted by the specific directive (i.e., the ND on nutrient flows and ammonia emissions, the WFD on water use...), without exploring any other SOS dimension that may be impacted by each directive. In general, the joint impact of different policies and the synergies and trade-offs among different SOS dimensions are seldom explored.

As regards the JOS area, studies exploring the impact of voluntary carbon markets typically analyse their impact on income and labour. In general, these studies emphasise the potential income losses of adopting low-carbon farming systems/technologies, and the potential restoration of a well-functioning carbon market.

The impact on farm income is also at the core of the analyses of the climate and nutrient directives, especially the ND, although, once again, these analyses are mostly case studies, often referring to specific provisions of each directive. Thus, any generalisation is difficult and, in addition, studies analysing synergies and trade-offs among different JOS dimensions are totally missing.

In terms of implications for ex-ante policy modelling, the nature of the climate and nutrient policies allows some straightforward implementation, especially when they have the nature of restrictions on input use (i.e., manure, chemical fertilisers, water...). A very interesting potential extension is the explicit modelling of carbon markets, that may become a key aspect of climate policies as the EU Regulation for certification of carbon farming practices has been recently published.

## 7. Conclusions

In this paper we have carried out a scoping review of the literature on the relationships between some key public policies affecting agricultural and food and the SJOS dimensions. Our results show that the available evidence is somehow scattered across the SJOS thematic areas, with a clear prevalence of the environmental themes (SOS) compared to the social (JOS) ones. Thus, there is clear research gap in exploring the impact of public policies on JOS issues such as social equity, health and nutrition security. A second problem has to do with the quality of the data, since many studies are based on FADN and in this database some crucial information is missing. Moreover, very few studies explore synergies and trade-offs between different SJOS dimensions.

Despite this clear knowledge gaps, we can generally conclude that the EU public policies analysed in this paper (CAP tools, Non-tariff measures, Climate and nutrient policies), have positively influenced the

transition toward a SOS, although in many cases their impact has been rather low. On the transition toward a JOS, the evidence is limited and less clear.

However, our scoping review has some limitations, linked especially to the heterogeneity of the policies and of the measurement of their impacts. Such heterogeneity makes it very difficult to synthesise the results of the surveyed studies in a clear and consistent framework. A more focused approach on some specific policy areas is probably more appropriate to draw this type of conclusions.

Finally, from a methodological perspective, the available studies provide some interesting hints for extending the available toolkit for ex-ante policy modelling, which deserve further research.

### **Acknowledgement**

This research received financial support from the European Union under the Horizon Europe program - Food, Bioeconomy, Natural Resources, Agriculture and Environment, Grant Agreement No. 101060075.

### **Conflict of interest**

The authors declare no conflict of interest

### **Data availability**

No new data was generated or analysed in support of this research. Rather, existing literature was reviewed.

## References

- Abdul-Salam, Y., Hawes, C., Roberts, D., & Young, M. (2019). 'The economics of alternative crop production systems in the context of farmer participation in carbon trading markets'. *Agroecology and Sustainable Food Systems*, 41: 67–91
- Abman, R., & Lundberg, C. (2020). 'Does free trade increase deforestation? The effects of regional trade agreements', *Journal of the Association of Environmental and Resource Economists*, 7: 35-72
- Abman, R., Lundberg, C., & Ruta, M. (2021). 'The effectiveness of environmental provisions in regional trade agreements', *Policy Research Working Papers*, 9601
- Ackermann, A., Mahnkopf, J., Heidecke, C., Venohr, M. (2016) 'Reducing agricultural nitrogen inputs in the German Baltic Sea catchment - trends and policy options', *Water Sci Technol*, 74: 1060–1068
- Ait Sidhoum, A., Canessa, C., & Sauer, J. (2023a) 'Effects of agri-environment schemes on farm-level eco-efficiency measures: Empirical evidence from EU countries', *Journal of Agricultural Economics*, 74: 551–569
- Ait Sidhoum, A., Mennig, P., & Sauer, J. (2023b) 'Do agri-environment measures help improve environmental and economic efficiency? Evidence from Bavarian dairy farmers', *European Review of Agricultural Economics*, 50: 918-953
- Allanson, P. (2006) 'The redistributive effects of agricultural policy on Scottish farm incomes', *Journal of Agricultural Economics*, 57: 117-128
- Allevi, E., Gnudi, A., Konnov, I., & Oggioni, G. (2018) 'Evaluating the effects of environmental regulations on a closed-loop supply chain network: A variational inequality approach', *Annals of Operations Research*, 261: 1-43
- Angus, A.J., Hodge, I.D., Sutton, M.A. (2006) 'Ammonia abatement strategies in livestock production: A case study of a poultry installation', *Agric. Syst*, 89: 204–222
- Arata, L., & Scokkai, P. (2016) 'The impact of agri-environmental schemes on farm performance in five E.U. member States: A DID-matching approach', *Land Economics*, 92: 167-186
- Arditsoglou, A., Voutsas, D., (2010). 'Partitioning of endocrine disrupting compounds in inland waters and wastewaters discharged into the coastal area of Thessaloniki, Northern Greece', *Environmental Science and Pollution Research*, 17: 529–538
- Armstrong, P. R., Acs, S., Dallimer, M., Gaston, K. J., Hanley, N., & Wilson, P. (2012) 'The cost of policy simplification in conservation incentive programs', *Ecology Letters*, 15: 406-414
- Baghdadi, L., Martinez-Zarzoso, I., & Zitouna, H. (2013) 'Are RTA agreements with environmental provisions reducing emissions?', *Journal of International Economics*, 90: 378-390
- Baliamoune-Lutz, M. (2007). 'Globalisation and gender inequality: Is Africa different?', *Journal of African Economies* 16(2): 301-348.
- Baylis, K., Nogueira, L., & Pace, K. (2022) 'Something fishy in seafood trade? The relation between tariff and non-tariff barriers', *American Journal of Agricultural Economics*, 104: 1656-1678
- Baráth, L., Bakucs, Z., Benedek, Z., Fertő, I., Nagy, Z., Vigh, E., Debrenti, E., et al. (2024) 'Does participation in agri-environmental schemes increase eco-efficiency?', *Science of The Total Environment*, 906: 167518

- Barros, L. & Martínez-Zarzoso, I. (2022). 'Systematic literature review on trade liberalization and sustainable development'. *Sustainable Production and Consumption* 33: 921-931.
- Bartolini, F., Bazzani, G.M., Gallerani, V., Raggi, M., Viaggi, D., (2007). 'The impact of water and agriculture policy scenarios on irrigated farming systems in Italy: An analysis based on farm level multi-attribute linear programming models', *Agricultural Systems*, 93: 90–114
- Batáry, P., Báldi, A., Kleijn, D., & Tschamntke, T. (2011) 'Landscape-moderated biodiversity effects of agri-environmental management: A meta-analysis', *Proceedings of the Royal Society B: Biological Sciences*, 278
- Batáry, P., Dicks, L. V., Kleijn, D., & Sutherland, W. J. (2015) 'The role of agri-environment schemes in conservation and environmental management', *Conservation Biology*, 29: 1006:1016
- Bazzani, G.M., Di Pasquale, S., Gallerani, V., Viaggi, D., (2004). 'Irrigated agriculture in Italy and water regulation under the European Union water framework directive', *Water Resources Research*, 40: W07S04.
- Belhouchette, H., Louhichi, K., Therond, O., Mouratiadou, I., Wery, J., van Ittersum, M., Flichman, G. (2011) 'Assessing the impact of the Nitrate Directive on farming systems using a bio-economic modelling chain', *Agr. Syst.*, 104: 135–145
- Bellebaum, J., & Koffijberg (2018). 'Present agri-environment measures in Europe are not sufficient for the conservation of a highly sensitive bird species, the Corncrake *Crex crex*', *Agriculture, Ecosystems and Environment*, 257: 30-37
- Beltrán-Esteve, M., Gómez-Limón, J. A., & Picazo-Tadeo, A. J. (2012) 'Assessing the impact of agri-environmental schemes on the eco-efficiency of rain-fed agriculture', *Spanish Journal of Agricultural Research*, 10: 911-925
- el Benni, N., Finger, R., & Mann, S. (2012) 'Effects of agricultural policy reforms and farm characteristics on income risk in Swiss agriculture', *Agricultural Finance Review*, 72: 301-324
- Berentsen, P.B.M., Tiessink, M. (2003). 'Potential Effects of Accumulating Environmental Policies on Dutch Dairy Farms', *Journal of Dairy Science*, 86: 1019–1028
- Bertoni, D., Aletti, G., Cavicchioli, D., Micheletti, A., & Pretolani, R. (2021) 'Estimating the CAP greening effect by machine learning techniques: A big data ex post analysis', *Environmental Science and Policy*, 119: 44-53
- Bertoni, D., Curzi, D., Aletti, G., & Olper, A. (2020) 'Estimating the effects of agri-environmental measures using difference-in-difference coarsened exact matching', *Food Policy*, 90: 101790
- Bieroza, M., Bol, R., & Glendell, M. (2021) ,What is the deal with the Green Deal: Will the new strategy help to improve European freshwater quality beyond the Water Framework Directive?' *The Science of the Total Environment* 791: 148080
- Blanco-Gutierrez, I., Varela-Ortega, C., Purkey, D.R., (2013). 'Integrated assessment of policy interventions for promoting sustainable irrigation in semi-arid environments: A hydro-economic modeling approach', *Journal of Environmental Management*, 128: 144–160
- Blandford, D., Gaasland, I., & Vårdal, E. (2015) 'Trade Liberalization versus Climate Change Policy for Reducing Greenhouse Gas Emissions in Agriculture: Some Insights from Norway' *Applied Economic Perspectives and Policy*, 37/3: 418–436

- BMEL (2016). Umweltbericht im Rahmen der Strategischen Umweltprüfung: Nationales Aktionsprogramm zum Schutz der Gewässer vor Verunreinigung durch Nitrat – Teilprogramm zur Verordnung zur Neuordnung der guten fachlichen Praxis beim Düngen.
- Boets, P., Dillen, A., Mertens, J., Vervaeke, B., Van Thuyne, G., Breine, J., Goethals, P., Poelman, E., (2021). 'Do investments in water quality and habitat restoration programs pay off? An analysis of the chemical and biological water quality of a lowland stream in the Zwalm River basin (Belgium)', *Environmental Science & Policy*, 124: 115–124
- Boix-Fayos, C., & de Vente, J. (2023). 'Challenges and Potential Pathways Towards Sustainable Agriculture Within the European Green Deal', *Agricultural Systems*, 207: 103634. DOI: 10.1016/j.agry.2023.103634
- Bolpagni, R., Poikane, S., Laini, A., Bagella, S., Bartoli, M., Cantonati, M., (2019). 'Ecological and Conservation Value of Small Standing-Water Ecosystems: A Systematic Review of Current Knowledge and Future Challenges', *Water*, 11: 402
- Bonfiglio, A., Arzeni, A., & Bodini, A. (2017) 'Assessing eco-efficiency of arable farms in rural areas', *Agricultural Systems*, 151: 114-125
- Borchert, I., Conconi, P., Di Ubaldo, M., & Herghelegiu, C. (2020) 'The Pursuit of Non-Trade Policy Objectives in EU Trade Policy', *World Trade Review*, 20: 623-647
- Bouleau, G., Barbier, R., Halm-Lemeille, M.-P., Tassin, B., Bucbc, A., Halle, F.P., (2020). 'Despite Great Expectations in the Seine River Basin, the WFD Did Not Reduce Diffuse Pollution', *Water Alternatives*, 13: 534–555
- Bouraoui, F., Grizzetti, B., (2014). 'Modelling mitigation options to reduce diffuse nitrogen water pollution from agriculture', *Science of the Total Environment*, 468–469: 1267–1277
- Britz, W., B. Lengers, T. Kuhn and D. Schafer (2016) 'A Highly Detailed Template Model for Dynamic Optimization of Farms', *Institute for Food and Resource Economics: Bonn*
- Bryngelsson, D., Wirsenius, S., Hedenus, F., & Sonesson, U. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. *Food Policy*, 59, 152-164.
- Buckley, C., Wall, D.P., Moran, B., O'Neill, S., Murphy, P.N.C., (2016a) 'Farm gate level nitrogen balance and use efficiency changes post implementation of the EU Nitrates Directive', *Nutr Cycl Agroecosyst*, 104: 1–13
- Buckley, C., Wall, D.P., Moran, B., O'Neill, S., Murphy, P.N.C., (2016b) 'Phosphorus management on Irish dairy farms post controls introduced under the EU Nitrates Directive', *Agr. Syst.* 142: 1–8
- Cali, M., Ghose, D., Montfaucon, A.F., Ruta, M. (2022) 'Trade Policy and Exporters' Resilience: Evidence from Indonesia', *World Bank Policy Research*, Working Paper 10068
- Calvi, G., Campedelli, T., Tellini Florenzano, G., & Rossi, P. (2018) 'Evaluating the benefits of agri-environment schemes on farmland bird communities through a common species monitoring programme. A case study in northern Italy', *Agricultural Systems*, 160: 60-69
- Cameira, M.R., Rolim, J., Valente, F., Faro, A., Dragosits, U., Cordovil, C.M.D.S., (2019) 'Spatial distribution and uncertainties of nitrogen budgets for agriculture in the Tagus river basin in Portugal - Implications for effectiveness of mitigation measures', *Land Use Pol.*, 84: 278–293
- Cecchini, M., Warin, L. (2016) 'Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analysis of randomized studies'. *Obesity Reviews* 17/3: 201-10

- Cerro, I., Antigueedad, I., Srinivasan, R., Sauvage, S., Volk, M., Sanchez-Perez, J.M., (2014). 'Simulating Land Management Options to Reduce Nitrate Pollution in an Agricultural Watershed Dominated by an Alluvial Aquifer', *Journal of Environmental Quality*, 43: 67–74
- Chabé-Ferret, S., & Subervie, J. (2013) 'How much green for the buck? Estimating additional and windfall effects of French agro-environmental schemes by DID-matching', *Journal of Environmental Economics and Management*, 65: 12-27
- Ciliberti, S., Severini, S., Ranalli, M. G., Biagini, L., & Frascarelli, A. (2022) 'Do direct payments efficiently support incomes of small and large farms?', *European Review of Agricultural Economics*, 49: 796–831
- Cipollina, M., Laborde Debucquet, D., & Salvatici, L. (2014) 'The tide that does not raise all boats: An assessment of EU preferential trade policies', *Review of World Economics*, 153: 199-231
- Cisilino, F., Marangon, F., & Troiano, S. (2015). Conservation and efficient use of natural resources through Payments for Ecosystem Services: The role of CAP in supporting a collective approach. 147th Seminar, October 7-8, 2015, Sofia, Bulgaria 212247, European Association of Agricultural Economists.
- Cisilino, F., Bodini, A., & Zanolì, A. (2019). 'Rural development programs' impact on environment: An ex-post evaluation of organic farming', *Land Use Policy*, 85: 454-462
- Cocco, E., Bertora, C., Squartini, A., Delle Vedove, G., Berti, A., Grignani, C., Lazzaro, B., Morari, F. (2018) 'How shallow water table conditions affect N<sub>2</sub>O emissions and associated microbial abundances under different nitrogen fertilisations', *Agriculture, Ecosystems & Environment*, 261: 1–11
- Coderoni, S., & Esposti, R. (2018) 'CAP payments and agricultural GHG emissions in Italy. A farm-level assessment', *Science of the Total Environment*, 627: 427-437
- Coderoni S., Esposti R., Varacca A. (2024a). 'How differently do farms respond to agri-environmental policies? A probabilistic machine-learning approach'. *Land Economics*, 100 (2): 370–397
- Coderoni S., Dell'Unto D., Cortignani R. (2024b). Curbing methane emissions from Italian cattle farms. An agro-economic modelling simulation of alternative policy tools, *Journal of Environmental Management*, 351 (2024) 119880, <https://doi.org/10.1016/j.jenvman.2023.119880>
- Cole, L.J., Brocklehurst, S., McCracken, D.I., Harrison, W., Robertson, D., (2012). 'Riparian field margins: their potential to enhance biodiversity in intensively managed Grasslands', *Insect Conservation and Diversity*, 5: 86–94
- Cooper, R.J., Hiscock, K.M., (2023). 'Two decades of the EU Water Framework Directive: Evidence of success and failure from a lowland arable catchment (River Wensum, UK)', *Science of the Total Environment*, 869: 161837
- Cortignani, R. and Coderoni, S. (2022). The impacts of environmental and climate targets on agriculture: Policy options in Italy. *Journal of Policy Modelling*, 44(6), 1095-1112.
- Costa, L.R.D., Hugman, R.T., Stigter, T.Y., Monteiro, J.P. (2021) 'Predicting the impact of management and climate scenarios on groundwater nitrate concentration trends in southern Portugal', *Hydrogeol J*, 29: 2501–2516
- Cuevas García-Dorado, S., Cornselsen, L., Smith, R., Walls, H. (2019) 'Economic globalization, nutrition and health: a review of quantitative evidence', *Globalization and Health*, 15: 15

- Curzi, D., Luarasi, M., Raimondi, V., Olper, A., (2018) 'The (lack of) international harmonisation of EU standards: import and export effects in developed versus developing countries', *Applied Economics Letters* 25: 1552-1556
- Curzi, D., Schuster, M., Maertens, M. and Olper, A. (2020). Standards, trade margins and product quality: Firm-level evidence from Peru. *Food Policy* 91: 101834
- De Girolamo, A.M., Lo Porto, A., (2012). 'Land use scenario development as a tool for watershed management within the Rio Mannu Basin', *Land Use Policy*, 29: 691–701
- De Leijster, V., Verburg, R. W., Santos, M. J., Wassen, M. J., Martínez-Mena, M., de Vente, J., & Verweij, P. A. (2020) 'Almond farm profitability under agroecological management in south-eastern Spain: Accounting for externalities and opportunity costs', *Agricultural Systems*, 183: 102878
- De Marco, A., Proietti, C., Anav, A., Ciancarella, L., D'Elia, I., Fares, S., Fornasier, M.F., Fusaro, L., Gualtieri, M., Manes, F., Marchetto, A., Mircea, M., Paoletti, E., Piersanti, A., Rogora, M., Salvati, L., Salvatori, E., Screpanti, A., Vialto, G., Vitale, M., Leonardi, C., (2019) 'Impacts of air pollution on human and ecosystem health, and implications for the National Emission Ceilings Directive: Insights from Italy', *Environ. Int.*, 125: 320–333
- Desjeux, Y., Dupraz, P., Kuhlman, T., Paracchini, M. L., Michels, R., Maigné, E., & Reinhard, S. (2015) 'Evaluating the impact of rural development measures on nature value indicators at different spatial levels: Application to France and the Netherlands', *Ecological Indicators*, 59: 41-61
- Diarnanti, K.S., Alygizakis, N.A., Nika, M.-C., Oswaldova, M., Oswald, P., Thomaidis, N.S., Slobodnik, J., (2020). 'Assessment of the chemical pollution status of the Dniester River Basin by wide-scope target and suspect screening using mass spectrometric techniques', *Analytical and Bioanalytical Chemistry*, 412: 4893–4907
- Disdier, A.-C., Fontagné, L., Cadot, O. (2015) 'North-South standards: Harmonisation and International Trade', *The World Bank Economic Review*, 29/2: 327–352
- Dolan, T., Howsam, P., Parsons, D.J., (2012). 'Diffuse pesticide pollution of drinking water sources: impact of legislation and UK responses', *Water Policy*, 14: 680–693
- EEA, 2023. National air pollutant emissions data viewer 2005-2021, available at <https://www.eea.europa.eu/en/topics/in-depth/air-pollution/national-air-pollutant-emissions-data-viewer-2005-2022> (accessed on 17/01/2025)
- Eder, A., Salhofer, K., & Scheichel, E. (2021) 'Land tenure, soil conservation, and farm performance: An eco-efficiency analysis of Austrian crop farms', *Ecological Economics*, 180: 106861.
- Essaji, A. (2008) 'Technical regulations and specialization in international trade', *Journal of International Economics* 76/2: 166-176
- European Commission, 2011. A Roadmap for Moving to a Competitive Low Carbon Economy in 2050. Documentation available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0112>
- FAO, 1991. Financial Analysis in Agricultural Project Preparation. Food and Agriculture Organization of the United Nations. Rome, Italy.
- Fellmann, T., Witzke, P., Weiss, F., Van Doorslaer, B., Drabik, D., Huck, I., ... and Leip, A. (2018). Major challenges of integrating agriculture into climate change mitigation policy frameworks. Mitigation and Adaptation Strategies for Global Change, 23, 451-468.

- Fernandes, A.M., Ferro, E. & Wilson, J.S.. (2019). 'Product standards and firms' export decisions'. *World Bank Economic Review* 33(2): 353-374.
- Ferreira, J., Leitao, J., Monteiro, A., Lopes, M., Miranda, A.I., (2017) 'National emission ceilings in Portugal-trends, compliance and projections', *Air Qual. Atmos. Health*, 10: 1089–1096
- Fezzi, C., Hutchins, M., Rigby, D., Bateman, I.J., Posen, P., Hadley, D., (2010). 'Integrated assessment of water framework directive nitrate reduction measures', *Agricultural Economics*, 41: 123–134
- Fezzi, C., Rigby, D., Bateman, I.J., Hadley, D., Posen, P., (2008). 'Estimating the range of economic impacts on farms of nutrient leaching reduction policies', *Agricultural Economics*, 39: 197–205
- Fontagné, L., Orefice, G. (2018) 'Let's Try Next Door: Technical Barriers to Trade and Multi-destination Firms', *European Economic Review*, 101: 643-663
- Fontagné, L., G. Orefice, R. Piermartini, Rocha, N. (2015) 'Product Standards and Margins of Trade: firm level evidence', *Journal of International Economics* 97: 29-44
- Francois, J., Hoekman, B., Manchin, M., & Santi, F. (2023) 'Pursuing Environmental and Social Objectives through Trade Agreements', Policy Research Paper 10323. World Bank
- Friedland, R., Macias, D., Cossarini, G., Daewel, U., Estournel, C., Garcia-Goriz, E., Grizzetti, B., Gregoire, M., Gustafson, B., Kalaroni, S., Kerimoglu, O., Lazzari, P., Lenhart, H., Lessin, G., Maljutenko, I., Miladinova, S., Mueller-Karulis, B., Neumann, T., Parn, O., Paetsch, J., Piroddi, C., Raudsepp, U., Schrum, C., Stegert, C., Stips, A., Tsiaras, K., Ulses, C., Vandenbulcke, L., (2021) 'Effects of Nutrient Management Scenarios on Marine Eutrophication Indicators: A Pan-European, Multi-Model Assessment in Support of the Marine Strategy Framework Directive', *Front. Mar. Sci.*, 8
- Fuentes-Montemayor, E., Goulson, D., & Park, K. J. (2011) 'The effectiveness of agri-environment schemes for the conservation of farmland moths: Assessing the importance of a landscape-scale management approach', *Journal of Applied Ecology*, 48: 532–542
- Fugazza, D., Aletti, G., Bertoni, D., & Cavicchioli, D. (2022) 'Farmland use data and remote sensing for ex-post assessment of CAP environmental performances: An application to soil quality dynamics in Lombardy', *Remote Sensing Applications: Society and Environment*, 26: 100723
- Garrone, M., Emmers, D., Olper, A., & Swinnen, J. (2019) 'Jobs and agricultural policy: Impact of the common agricultural policy on EU agricultural employment', *Food Policy*, 87: 101744
- Gauss, M., Bartnicki, J., Jalkanen, J.-P., Nyiri, A., Klein, H., Fagerli, H., Klimont, Z. (2021) 'Airborne nitrogen deposition to the Baltic Sea: Past trends, source allocation and future projections', *Atmos. Environ.*, 253: 118377
- Ghods, M., Grüber, J., Reiter, O., & Stehrer, R. (2017) 'The evolution of non-tariff measures and their diverse effects on trade' wiiw Research Report No. 419
- Giannakis, E., Kushta, J., Bruggeman, A., Lelieveld, J., (2019) 'Costs and benefits of agricultural ammonia emission abatement options for compliance with European air quality regulations', *Environ. Sci Eur.* 31: 93
- Godoy-Durán, Á., Galdeano- Gómez, E., Pérez-Mesa, J. C., & Piedra-Muñoz, L. (2017) 'Assessing eco-efficiency and the determinants of horticultural family-farming in southeast Spain', *Journal of Environmental Management*, 204: 594-604
- Gomes, E., Antunes, I.M.H.R., Leitao, B., (2023), 'Groundwater management: Effectiveness of mitigation measures in nitrate vulnerable zones - a Portuguese case study', *Groundwater Sustain. Dev.*, 21: 100899



- Izydorczyk, K., Michalska-Hejduk, D., Jarosiewicz, P., Bydalek, F., Frątczak, W., (2018) 'Extensive grasslands as an effective measure for nitrate and phosphate reduction from highly polluted subsurface flow – Case studies from Central Poland', *Agricultural Water Management* 203: 240–250
- Janssens, C., Havlík, P., Krisztin, T., Baker, J., Frank, S., Hasegawa, T., ... & Maertens, M. (2021) 'International trade is a key component of climate change adaptation', *Nature Climate Change*, 11: 915-916
- Kaligarič, M., Skornik, S., Ivajnsic, D., & Čuš, J. (2019) 'The failure of agri-environment measures to promote and conserve grassland biodiversity in Slovenia', *Land Use Policy*, 80: 127-134
- Kareem, F.O. (2017) 'European Union's SPS and TBT Measures, Gender Specific Obstacles and Agricultural Employment', *EconStor Preprints* 171726, ZBW - Leibniz Information Centre for Economics
- Kaspersen, B.S., Christensen, T.B., Fredenslund, A.M., Moller, H.B., Butts, M.B., Jensen, N.H., Kjaer, T., (2016a). 'Linking climate change mitigation and coastal eutrophication management through biogas technology: Evidence from a new Danish bioenergy concept', *Science of the Total Environment*, 541: 1124–1131
- Kaspersen, B.S., Jacobsen, T.V., Butts, M.B., Boegh, E., Muller, H.G., Stutter, M., Fredenslund, A.M., Kjaer, T., (2016b). 'Integrating climate change mitigation into river basin management planning for the Water Framework Directive - A Danish case', *Environmental Science & Policy*, 55: 141–150
- Kay, D., Aitken, M., Crowther, J., Dickson, I., Edwards, A.C., Francis, C., Hopkins, M., Jeffrey, W., Kay, C., McDonald, A.T., McDonald, D., Stapleton, C.M., Watkins, J., Wilkinson, J., Wyer, M.D., (2007). 'Reducing fluxes of faecal indicator compliance parameters to bathing waters from diffuse agricultural sources: The Brighthouse Bay study, Scotland', *Environmental Pollution*, 147: 138–149
- Keeney, M. (2000) 'The Distributional Impact of Direct Payments on Irish Farm Incomes', *Journal of Agricultural Economics*, 51: 252-265
- Kleijn, D., & Sutherland, W. J. (2003) 'How effective are European agri-environment schemes in conserving and promoting biodiversity?', *Journal of Applied Ecology*, 40: 947-969
- Kleijn, D., Baquero, R. A., Clough, Y., Díaz, M., De Esteban, J., Fernández, F., ... & Yela, J. L. (2006). Mixed biodiversity benefits of agri-environment schemes in five European countries. *Ecology letters*, 9(3), 243-254.
- Koos, S., Pirko, B., Szatmari, G., Csatho, P., Magyar, M., Szabo, J., Fodor, N., Pasztor, L., Laborczi, A., Pokovai, K., Szabo, A., (2021) 'Influence of the Shortening of the Winter Fertilization Prohibition Period in Hungary Assessed by Spatial Crop Simulation Analysis', *Sustainability* 13: 417
- Kuhfuss, L., & Subervie, J. (2018) 'Do European Agri-environment Measures Help Reduce Herbicide Use? Evidence From Viticulture in France', *Ecological Economics*, 149: 202-211
- Kuhn, T., Schäfer, D., Holm-Müller, K., Britz, W., (2019) 'On-farm compliance costs with the EU-Nitrates Directive: A modelling approach for specialized livestock production in northwest Germany', *Agr. Syst.*, 173: 233–243
- Kunes, R., Havelka, Z., Olsan, P., Smutny, L., Filip, M., Zoubek, T., Bumbalek, R., Petrovic, B., Stehlik, R., Bartos, P., (2022) 'A Review: Comparison of Approaches to the Approval Process and Methodology for Estimation of Ammonia Emissions from Livestock Farms under IPPC', *Atmosphere*, 13: 2006
- Lagzdins, A., Jansons, V., Sudars, R., Grinberga, L., Veinbergs, A., Abramenko, K., (2015) 'Nutrient losses from subsurface drainage systems in Latvia', *Acta Agric. Scand. Sect. B-Soil Plant Sci.*, 65: 66–79

- Lillemets, J., Fertő, I., & Viira, A. H. (2022) 'The socioeconomic impacts of the CAP: Systematic literature review', *Land Use Policy*, 114: 105968
- Loyon, L., Burton, C.H., Misselbrook, T., Webb, J., Philippe, F.X., Aguilar, M., Doreau, M., Hassouna, M., Veldkamp, T., Dourmad, J.Y., Bonmati, A., Grimm, E., Sommer, S.G., (2016) 'Best available technology for European livestock farms: Availability, effectiveness and uptake', *Journal of Environmental Management*, 166: 1–11
- Lumbreras, J., Borge, R., de Andres, J.M., Rodriguez, E., (2008) 'A model to calculate consistent atmospheric emission projections and its application to Spain', *Atmos. Environ.*, 42: 5251–5266
- Manos, B., Bournaris, T., Chatzinikolaou, P., (2011). 'Impact assessment of CAP policies on social sustainability in rural areas: an application in Northern Greece', *Operations Research*, 11: 77–92
- Mao, R., Liu, Y., & Wang, X. (2023) 'Economic and environmental impacts of agricultural non-tariff measures: evidence based on ad valorem equivalent estimates', *International Food and Agribusiness Management Review*, 26: 379 – 396
- Mary, S. (2013) 'Assessing the Impacts of Pillar 1 and 2 Subsidies on TFP in French Crop Farms', *Journal of Agricultural Economics*, 64: 133-144
- Martínez-Zarzoso, I., & Oueslati, W. (2018) 'Do deep and comprehensive regional trade agreements help in reducing air pollution?', *International Environmental Agreements: Politics, Law and Economics*, 18: 743-777
- McDonald, N.T., Wall, D.P., Mellander, P.E., Buckley, C., Shore, M., Shortle, G., Leach, S., Burgess, E., O'Connell, T., Jordan, P. (2019) 'Field scale phosphorus balances and legacy soil pressures in mixed-land use catchments', *Agric. Ecosyst. Environ.* 274: 14–23
- Michalek, J. (2022) 'Environmental and farm impacts of the EU RDP agri-environmental measures: Evidence from Slovak regions', *Land Use Policy*, 113: 105924
- Mircea, I., Falup, O., Ivan, R., Samoila, I., Ionel, I., (2015) 'Romanian Projections for Certain Atmospheric Pollutants by 2030, as a Result of Implementation the Environmental Legislation', *Rev. Chim.* 66: 247–250.
- Moghayer S., Manouchehrabadi B., Tiboldo G., Ferrer-Pérez H., Kozicka M., van Dijk M., Farina G., Castellari E., Moro D., Philippidis G. (2024). A scoping review of food consumer aspects in transitioning to a safe and just agrifood system, *Q Open*: qoae030.
- Motarjemi, S.K., Rosenbom, A.E., Iversen, B.V., Plauborg, F. (2021) 'Important factors when simulating the water and nitrogen balance in a tile-drained agricultural field under long-term monitoring', *Science of The Total Environment*, 787: 147610
- Movchan, V., Shepotylo, O., & Vakhitov, V. (2020). 'Non-tariff measures, quality and exporting: evidence from microdata in food processing in Ukraine'. *European Review of Agricultural Economics* 47(2): 719-751
- Müller, M., Guyomard, H., Détang-Dessendre, C., Bardazzi, E., Stehfest, E., Krüger, C., van Dijk M., de Jong, B., M'Barek, R., van Meijl, H., Sckokai, P., Balázs, K., Podmaniczky, L., Sturm, V., Frank, S., Storm, H., Aladesuro, D., vant Veen, H., Vrolijk, H. (2024). Deliverable D1.1 (D01) *An operational concept for dimensions and indicators of the SJOS*. BrightSpace Horizon Europe project GA Nr. 101060075.
- Munn, Z., Peters, M.D.J., Stern, C., Tufanaru, C., McArthur, A., Aromataris, E. (2018). 'Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach', *BMC Med Res Methodol* 18: 143.

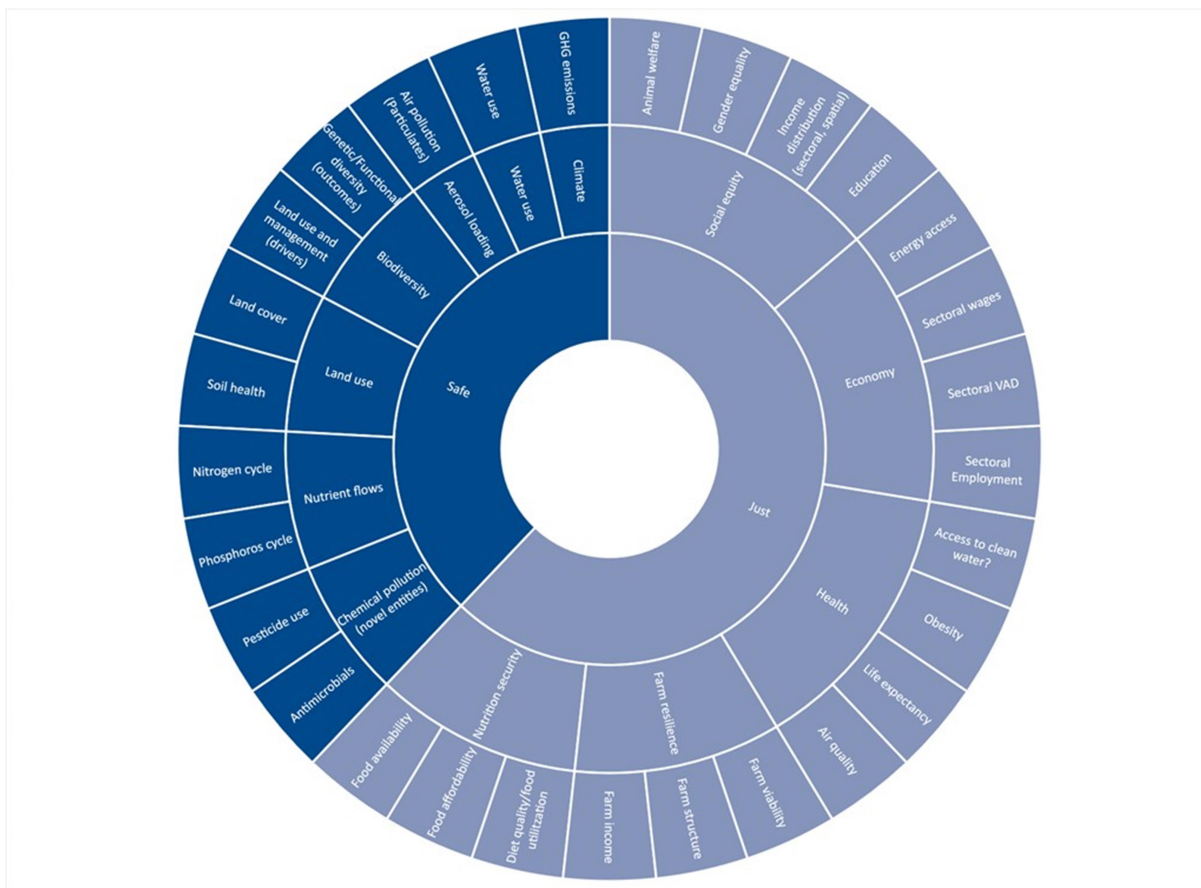
- Neamtu, M., Ciomasu, I.M., Costica, N., Costica, M., Bobu, M., Nicoara, M.N., Catrinescu, C., van Slooten, K.B., De Alencastro, L.F., (2009). 'Chemical, biological, and ecotoxicological assessment of pesticides and persistent organic pollutants in the Bahlui River, Romania', *Environmental Science and Pollution Research*, 16: 76–85
- Nesme, T., Roques, S., Metson, G., & Bennett, E. (2016) 'The surprisingly small but increasing role of international agricultural trade on the European Union's dependence on mineral phosphorus fertiliser', *Environmental Research Letters*, 11: 025003
- Newton, A., Canedo-Arguelles, M., March, D., Goela, P., Cristina, S., Zacarias, M., Icely, J., (2022). 'Assessing the effectiveness of management measures in the Ria Formosa coastal lagoon, Portugal', *Frontiers in Ecology and Evolution*, 10: 508218
- Noges, T., Vilbaste, S., McCarthy, M.J., Tamm, M., Noges, P., (2022). 'Long-term data reflect nitrogen pollution in Estonian rivers', *Hydrology Research*, 53: 1468–1479
- Oenema, O., Witzke, H.P., Klimont, Z., Lesschen, J.P., Velthof, G.L. (2009) 'Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27', *Agr. Ecosyst. Environ.* 133: 280–288
- Olper, A., Curzi, D. and Pacca, L. (2014a) 'Do food standards affect the quality of EU imports?', *Economics Letters*, 122: 233–237
- Olper, A., Raimondi, V., Cavicchioli, D., & Vigani, M. (2014b) 'Do CAP payments reduce farm labour migration? A panel data analysis across EU regions', *European Review of Agricultural Economics*, 41: 843–873
- O'Shea, L., Wade, A., (2009). 'Controlling nitrate pollution: An integrated approach', *Land Use Policy*, 26: 799–808
- O' Sullivan, L., Creamer, R. E., Fealy, R., Lanigan, G., Simo, I., Fenton, O., Carfrae, J., & Schulte, R. P. O. (2015) 'Functional Land Management for managing soil functions: A case-study of the trade-off between primary productivity and carbon storage in response to the intervention of drainage systems in Ireland' *Land Use Policy*, 47: 42–54
- Pahmeyer, C., Kuhn, T., Britz, W., (2021) 'Fruchtfolge: A crop rotation decision support system for optimizing cropping choices with big data and spatially explicit modeling', *Computers and Electronics in Agriculture*, 181: 105948
- Paterson, K.C., Holden, N.M., (2019) 'Assessment of policy conflict using systems thinking: A case study of carbon footprint reduction on Irish dairy farms', *Environmental Science & Policy*, 101: 38–45
- Pellini, T., Morris, J., (2001) 'A framework for assessing the impact of the IPPC directive on the performance of the pig industry', *Journal of Environmental Management*, 63: 325–333
- Peña-Haro, S., Llopis-Albert, C., Pulido-Velazquez, M., Pulido-Velazquez, D., (2010). 'Fertilizer standards for controlling groundwater nitrate pollution from agriculture: El Salobral-Los Llanos case study, Spain', *Journal of Hydrology*, 392: 174–187
- Peña-Haro, S., Pulido-Velazquez, M., Sahuquillo, A., (2009). 'A hydro-economic modelling framework for optimal management of groundwater nitrate pollution from agriculture', *Journal of Hydrology*, 373: 193–203
- Peters, M.D.J., Godfrey, C. M., Khalil, H., McInerney, P. Parker, D. Soares, C.B. (2015). 'Guidance for conducting systematic scoping reviews', *International Journal of Evidence-Based Healthcare*, 13(3): 141–146

- Petrick, M., & Zier, P. (2011) 'Regional employment impacts of Common Agricultural Policy measures in Eastern Germany: a difference-in-differences approach', *Agricultural Economics*, 42: 183–93
- Picazo-Tadeo, A. J., Gómez-Limón, J. A., & Reig-Martínez, E. (2011) 'Assessing farming eco-efficiency: A Data Envelopment Analysis approach', *Journal of Environmental Management*, 92: 114–125
- Piersanti, A., D'Elia, I., Gualtieri, M., Briganti, G., Cappelletti, A., Zanini, G., Ciancarella, L., (2021) 'The Italian National Air Pollution Control Programme: Air Quality, Health Impact and Cost Assessment', *Atmosphere*, 12: 196
- Piet L., Desjeux Y. (2021). New perspectives on the distribution of farm incomes and the redistributive impact of CAP payments. *European Review of Agricultural Economics* 48(2): 385-414
- Pirko, B., Koos, S., Szabo, J., Radimsky, L., Csatho, P., Arendas, T., Fodor, N., Szabo, A., (2020) 'Results of Hungarian field test trials set up for establishing new maximum permitted N dose values', *Stud. Agric. Econ.*, 122: 77–85
- Poppe, K., van Duinen, L., & de Koeijer, T., (2021) 'Reduction of Greenhouse Gases from Peat Soils in Dutch Agriculture', *EuroChoices*, 20: 38–45
- Pothen, F., & Hübner, M. (2018) 'The interaction of climate and trade policy', *European Economic Review*, 127: 1-26
- Prado, A. del, Scholefield, D., (2008). 'Use of SIMSDAIRY modelling framework system to compare the scope on the sustainability of a dairy farm of animal and plant genetic-based improvements with management-based changes', *The Journal of Agricultural Science*, 146: 195–211
- Primdahl, J., Peco, B., Schramek, J., Andersen, E., & Oñate, J. J. (2003) 'Environmental effects of agri-environmental schemes in Western Europe', *Journal of Environmental Management*, 67: 129-138
- Psaltopoulos, D., Balamou, E., & Thomson, K. J. (2006) 'Rural-urban impacts of CAP measures in Greece: An inter-regional SAM approach', *Journal of Agricultural Economics*, 57: 441–458
- Pufahl, A., & Weiss, C. R. (2009) 'Evaluating the effects of farm programmes: Results from propensity score matching', *European Review of Agricultural Economics*, 36: 79–101
- Quiroga, S., Fernandez-Haddad, Z., Suarez, C., (2014). 'Do Water Rights Affect Technical Efficiency and Social Disparities of Crop Production in the Mediterranean? The Spanish Ebro Basin Evidence', *Water*, 6: 3300–3319
- Raworth, K. (2012). *A safe and just space for humanity: Can we live within the doughnut?* Oxfam Policy Pract. Clim. Change Resil. 8.
- Rees, C., Grovermann, C., Finger, R. (2023) 'National organic action plans and organic farmland area growth in Europe', *Food Policy*, 121: 102531
- Rodrigues, S., Xavier, B., Nogueira, S., Antunes, S.C., (2023). 'Intermittent Rivers as a Challenge for Freshwater Ecosystems Quality Evaluation: A Study Case in the Ribeira de Silveirinhos, Portugal', *Water*, 15: 17.
- Salomon, M., Dross, M., (2013) 'Challenges in cross-sectoral marine protection in Europe', *Marine Policy* 42: 142–149
- Scheper, J., Holzschuh, A., Kuussaari, M., Potts, S. G., Rundlöf, M., Smith, H. G., & Kleijn, D. (2013) 'Environmental factors driving the effectiveness of European agri-environmental measures in mitigating pollinator loss - a meta-analysis', *Ecology Letters*, 16: 912-920

- Schmid, E., Hofreither M. K., Sinabell, F. 'Impacts of CAP Instruments on the Distribution of Farm Incomes – Results for Austria', Discussion Papers DP-13-2006, University of Natural Resources and Life Sciences, Vienna, Department of Economics and Social Sciences, Institute for Sustainable Economic Development.
- Schucht, S., Real, E., Couvidat, F., Rouil, L., Brignon, J.-M., Allemand, N., Le Clercq, G., Fayolle, D., (2018) 'Economic analysis of health impacts in the National Air Pollution Control Programme', *Environ. Risque Sante*, 17: 393–400
- Schuh, B., Gorny, H., Kaucic, J., Kirchmayr-Novak, S., et al. (2016) 'The role of the EU's Common Agricultural Policy in creating rural jobs - Research for AGRI Committee', European Parliament
- Serrano, H.C., Oliveira, M.A., Barros, C., Augusto, A.S., Pereira, M.J., Pinho, P., Branquinho, C., (2019) 'Measuring and mapping the effectiveness of the European Air Quality Directive in reducing N and S deposition at the ecosystem level', *Sci. Total Environ.*, 647: 1531–1538
- Severini, S., & Tantari, A. (2015) 'The distributional impact of agricultural policy tools on Italian farm household incomes', *Journal of Policy Modeling*, 37: 124-135
- Stefanidis, K., Christopoulou, A., Poulos, S., Dassenakis, E., Dimitriou, E., (2020). 'Nitrogen and Phosphorus Loads in Greek Rivers: Implications for Management in Compliance with the Water Framework Directive', *Water*, 12: 1531
- Steffen, W., Richardson, K., Rockstrom, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sorlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science* 347: 1259855.
- Stępień, S., Czyżewski, B., Sapa, A., Borychowski, M., Poczta, W., & Poczta-Wajda, A. (2021) 'Eco-efficiency of small-scale farming in Poland and its institutional drivers', *Journal of Cleaner Production*, 279: 123721
- Stetter, C., Mennig, P., & Sauer, J. (2022). 'Using Machine Learning to Identify Heterogeneous Impacts of Agri-Environment Schemes in the EU: A Case Study', *European Review of Agricultural Economics*, 49: 723–759
- Stetter, C., Wimmer, S., & Sauer, J. (2023). 'Are Intensive Farms More Emission Efficient? Evidence from German Dairy Farms', *Journal of Agricultural and Resource Economics*, 48: 136–157
- Shi, Y., Wu, S., Zhou, S., Wang, C., & Chen, H. (2016) 'International food trade reduces environmental effects of nitrogen pollution in China', *Environmental Science and Pollution Research*, 23: 17370–17379
- Splinter, M.A.B.S., Peerlings, J.H.M., (2023) 'Examining the trade-offs between agri-environmental and manure policies in Dutch dairy farming', *NJAS: Impact Agric. Life Sci.*, 95: 2194261
- Swinnen, J. (2016) 'Economics and politics of food standards, trade and development', *Agricultural Economics*, 47: 7-19
- Szafranska, A., Podolska, G., Aleksandrowicz, E., Sulek, A., (2023) 'Implementation of the Nitrates Directive and its influence on the baking value of winter wheat', *Int. Agrophys.*, 37: 79–87
- Tocco B., Davidova, S., & Bailey, A. 'The Impact of CAP Payments on the Exodus of Labour from Agriculture in Selected EU Member States', Factor Markets Working Papers 180, Centre for European Policy Studies
- Trabelsi, I. (2013) 'Agricultural trade face to Non-tariff barriers: A gravity model for the Euro-Med area', *Journal of Studies in Social Sciences*, 3: 20-32
- Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft,

- A., Wilson, M. G., Garritty, C., Lewin, S., Godfrey C.M., Macdonald M.T., Langlois E.V., Soares-Weiser K., Moriarty J., Clifford T., Tunçalp Ö, Straus, S. E. (2018). 'PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation', *Ann. Intern. Med.* 169: 467-473
- Tuck, S. L., Winqvist, C., Mota, F., Ahnström, J., Turnbull, L. A., & Bengtsson, J. (2014) 'Land-use intensity and the effects of organic farming on biodiversity: A hierarchical meta-analysis', *Journal of Applied Ecology*, 51: 746-755
- Udagawa, C., Hodge, I., & Reader, M. (2014) 'Farm Level Costs of Agri-environment Measures: The Impact of Entry Level Stewardship on Cereal Farm Incomes', *Journal of Agricultural Economics*, 65: 212-233
- Uehleke, R., Leonhardt, H., & Hüttel, S. (2023). 'Counterfactual evaluation of two Austrian agri-environmental schemes in 2014-2018', *Agricultural Economics*, 55: 27-40.
- Uehleke, R., Petrick, M., & Hüttel, S. (2022) 'Evaluations of agri-environmental schemes based on observational farm data: The importance of covariate selection', *Land Use Policy*, 114: 105950
- UNCTAD (2018) 'Non-Tariff Measures: Economic Assessment and Policy Options for Development', UNCTAD/DITC/TAB/2017/2, UNCTAD: Geneva.
- UNCTAD (2022) 'Neutral policies, uneven impacts: Non-tariff measures through a gender lens', UNTAD/DITC/TAB/2022/1, United Nations: Geneva.
- Urresti-Estala, B., Jimenez Gavilan, P., Vadillo Perez, I., Carrasco Cantos, F., (2016). 'Assessment of hydrochemical trends in the highly anthropised Guadalhorce River basin (southern Spain) in terms of compliance with the European groundwater directive for 2015', *Environmental Science and Pollution Research*, 23: 15990–16005
- USCAP (2019) 'Asia-Pacific trade and investment report 2019. Navigating Non-tariff measures towards Sustainable Development', United Nations: Geneva.
- van Calker, K.J., Berentsen, P.B.M., Boer, I.M.J., Giesen, G.W.J., Huirne, R.B.M., (2004) 'An LP-model to analyse economic and ecological sustainability on Dutch dairy farms: model presentation and application for experimental farm "de Marke"', *Agr. Syst.*, 82: 139–160
- van Grinsven, H.J.M., Bouwman, L., Cassman, K.G., van Es, H.M., McCrackin, M.L., Beusen, A.H.W., (2015) 'Losses of Ammonia and Nitrate from Agriculture and Their Effect on Nitrogen Recovery in the European Union and the United States between 1900 and 2050', *J. Environ. Qual.*, 44: 356–367
- van Grinsven, H.J.M., ten Berge, H. F. M., Dalgaard, T., FRATERS, B., Durand, P., Hart, A., Hofman, G., Jacobsen, B.H., Lalor, S. T. J., Lesschen, J.P., Osterburg, B., Richards, K.G., Techen, A.-K., Vertès, F., Webb, J., Willems, W.J., (2012) 'Management, regulation and environmental impacts of nitrogen fertilization in northwestern Europe under the Nitrates Directive; a benchmark study', *Biogeosciences*, 9: 5143–5160
- van Grinsven, H.J.M., Tiktak, A., Rougoor, C.W., (2016) 'Evaluation of the Dutch implementation of the nitrates directive, the water framework directive and the national emission ceilings directive', *NJAS:Wagen. Life. Sc.*, 78: 69–84
- Varacca, A., Arata, L., Castellari, E., & Sckokai, P. (2023) 'Does CAP greening affect farms' economic and environmental performances? A regression discontinuity design analysis', *European Review of Agricultural Economics*, 50: 272-303
- Vernier, F., Leccia-Phelpin, O., Lescot, J.-M., Minette, S., Miralles, A., Barberis, D., Scordia, C., Kuentz-Simonet, V., Tonneau, J.-P., (2017). 'Integrated modeling of agricultural scenarios (IMAS) to support





**Figure 1 legend (title and source)**

*Figure 1: Safe and Just Operating Space (SJOS) thematic dimensions (inner circle) and indicators (outer circle).*

Source: Muller et al, 2024

ORIGINAL UNEDITED MANUSCRIPT

Table 1: Coverage of the SJOS dimensions by the literature in different policy areas (both direct and indirect effects)\*

|                 |                                     | Common Agricultural Policy |                | Non-Tariff Measures | Climate and nutrient policies |                |                    |                           | Environmental policies               |                                     |   |
|-----------------|-------------------------------------|----------------------------|----------------|---------------------|-------------------------------|----------------|--------------------|---------------------------|--------------------------------------|-------------------------------------|---|
|                 |                                     | CAP, Pillar I              | CAP, Pillar II |                     | Climate policies              | Carbon markets | Nitrates directive | Water framework directive | National Emission Ceilings Directive | Marine Strategy Framework Directive | Integrated Pollution Prevention and Control Directive |
| Safe dimensions | Biodiversity                        | Y                          | Y              | Y                   | Y                             | Y              | Y                  | Y                         | Y                                    | Y                                   | Y   |
|                 | Land use                            | N                          | Y              | Y                   | N                             | N              | N                  | Y                         | N                                    | N                                   | N   |
|                 | Climate                             | Y                          | Y              | Y                   | Y                             | Y              | Y                  | Y                         | N                                    | N                                   | N   |
|                 | Water use                           | N                          | N              | Y                   | N                             | N              | N                  | Y                         | N                                    | N                                   | N   |
|                 | Nutrient flows                      | Y                          | Y              | N                   | N                             | N              | Y                  | Y                         | Y                                    | Y                                   | Y   |
|                 | Chemical pollution (novel entities) | Y                          | Y              | Y                   | N                             | N              | N                  | Y                         | N                                    | N                                   | N   |
|                 | Aerosol loading                     | N                          | N              | N                   | N                             | N              | N                  | N                         | Y                                    | N                                   | Y   |
| Just dimensions | Nutrition security                  | N                          | N              | N                   | N                             | N              | N                  | N                         | N                                    | N                                   | N   |
|                 | Health                              | N                          | N              | Y                   | N                             | N              | N                  | Y                         | Y                                    | N                                   | N   |
|                 | Economy                             | Y                          | Y              | Y                   | N                             | Y              | Y                  | Y                         | Y                                    | N                                   | Y   |
|                 | Farm resilience                     | Y                          | Y              | N                   | N                             | N              | Y                  | Y                         | Y                                    | N                                   | Y   |
|                 | Gender equality                     | N                          | N              | Y                   | N                             | N              | N                  | N                         | N                                    | N                                   | N   |
|                 | Social equity                       | N                          | N              | Y                   | N                             | N              | N                  | Y                         | N                                    | N                                   | N   |

\*Y=yes, N=no