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Decoupling or delusion: Can Europe's agricultural production grow while its greenhouse gas emissions shrink?

Evelyne Bücheler

1. Introduction

In the age of climate change, the agriculture of the European Union (EU) faces a trade-off, between the need for growing agricultural production and reducing GHG emissions. Agriculture contributes 17 % of global GHG emissions (FAO, 2020), meanwhile being highly vulnerable to climate change itself (Jacobs et al., 2019). Yet, global agricultural production is expected to expand by approximately one percent annually over the next decade (OECD & FAO, 2023). To address this challenge, climate policies aim for decoupling, an approach that targets that the economic output continues to increase while GHG emissions are reduced (Fetting, 2020; UNFCCC, 2015).

To facilitate the decoupling of emissions and economic output within the EU agricultural sector, exploring the pattern of its occurrence, as well as its success and failure factors is necessary. Decoupling has been studied at global (Bennetzen et al., 2016) and at national EU (Andrei et al., 2022) levels. Nevertheless, significant heterogeneity within countries and its potential drivers, such as climate, soil, and farming systems, remains unstudied (Rasool & Abler, 2023). So far, decoupling has been found to be facilitated by the implementation of agricultural GHG mitigation strategies (Smith et al., 2007) and climate-smart agriculture (Palombi & Sessa, 2013). Previous literature suggests that livestock production (Herrero et al., 2016) and organic agriculture (Seufert & Ramankutty, 2017) present drivers associated with decoupling. Consequently, this study addresses the following three research questions: (i) Did the agricultural greenhouse gas emissions and the economic value of agricultural outputs of the EU decouple between 2000 and 2021? (ii) Is the size of the livestock population, or (iii) the share of organic agriculture of a region, associated with the decoupling of agricultural greenhouse gas emissions and economic value of agricultural output?

To address these research questions the Tapio decoupling framework was applied (Tapio, 2005). It categorized decoupling performance into eight types of which Strong Decoupling is the best possible outcome. Furthermore, it identified high-performing regions and provided the foundation for further analysis. The initial results also indicated that the extent of decoupling was strongly heterogeneous within the EU countries. Thus, estimating a random effects model provided evidence that regions widely affect the outcomes. Additionally, statistical tests explored the associations between decoupling and livestock population size and the share of organic agriculture. Both factors significantly influenced decoupling, though their exact roles remain unclear. These findings provide a basis for future research and directions for further investigation.

2. Methods

To answer the research questions, the expost analyses were conducted in three main steps. Firstly, the Tapio decoupling framework (Tapio, 2005) was applied to investigate whether agricultural GHG emissions and economic outputs of the EU NUTS 2 (Nomenclature des unités territoriales statistiques) regions decoupled between 2000 and 2021. Additionally, the analysis was conducted using varying baseline years and time periods to ensure robustness. Secondly, a random effects model (Meier, 2022) was established to capture heterogeneity within and between EU regions over time. Thirdly, ANOVA, Tukey HSD tests, and quartile stratification were used to identify associations between decoupling and the factors livestock population size and share of organic agriculture. Together, these methods provided insights into decoupling dynamics and influencing factors.

3. Data and Descriptive Statistics

The datasets used were compiled at the NUTS 2 regional level for EU countries and consisted of 241 regions with a complete data record from 2000 to 2021. The emission data was sourced from the Emissions Database for Global Atmospheric Research (EDGAR v8.0) (Crippa et al., 2022). The data reports sectoral greenhouse gas (GHG) emissions (CO_2, CH_4, N_2O, and F-gases) in kilotons of CO_2 equivalents, weighted by Global Warming Potential values (GWP-100) (Crippa et al., 2022). The economic data was derived from the Annual Regional Database of the European Commission (ARDECO, 2023), measuring regional economic activity via gross value added (GVA) at constant prices. Average annual GHG emissions were 1'682.06 kt CO_2 eq., with extremes from 0.19 to 23'775.33 kt CO_2 eq., while GVA ranged from 0.67 to 10'320.69 million euros, averaging 793.47 million euros. Visualizing the data trends showed declining GHG emissions and growing GVA at the EU level.

Moreover, breaking these observations down on a country level, showed heterogeneity between the countries. This led to the assumption that looking at the regions individually, will provide even deeper insights. Additional data, to test possible associations with the decoupling outcomes included livestock population (Eurostat, 2024) and share of organic agriculture (Eurostat, 2023) per region. The combined datasets provided insights into decoupling trends and variability at the regional level.

4. Results and Implications

This study investigates whether GHG emissions and GVA in EU NUTS 2 regions decoupled between 2000 and 2021 and examines whether this decoupling is associated with livestock population size or the share of organic agriculture. By using the Tapio decoupling framework, this study identified that 46.14 % of regions achieved Strong Decoupling in reference to the baseline year 2000, while the other half fell into one of the seven other categories. A key finding is that within-country variability contributes significantly to heterogeneous decoupling results, which underscores the need for regional analysis. Furthermore, livestock population size and share of organic agriculture were investigated for possible relations to the decoupling outcome. They were found to be significantly related to the regional extent of decoupling. Moreover, additional research is required to establish how these findings can be leveraged to enhance decoupling efforts.

While this study identifies progress in decoupling of agricultural GHG emissions and economic output, it has several limitations. Notably, achieving decoupling does not inherently guarantee that environmental damage from GHG emissions will be entirely mitigated. The concept of decoupling is only of value if economic development and environmental pressures are sufÏciently decoupled to prevent environmental harm in the long run (Parrique et al., 2019). To make definitive conclusions, decoupling should be evaluated in the context of environmental thresholds and political targets (Parrique et al., 2019). To do so, distance-to-target analyses could be applied (Spiegel et al., 2024).

Furthermore, the availability of data at the NUTS 2 level limited the scope of this study in assessing other potential drivers of decoupling. Enhanced analyses using finer spatial scales could provide deeper insights, but obtaining such detailed data remains a major challenge.

The findings of this study can be used for the development of targeted agricultural policymaking. For instance, the generated maps identify the efÏcacy of the regions and show high-performing regions. Moreover, promoting organic agriculture may enhance GHG emissions' decoupling from agricultural GVA, although simply increasing the land share of organic agriculture is unlikely to yield the desired outcomes without understanding the conditions under which decoupling occurs. Notably, the observed associations do not establish causation.

Future research should focus on high-performing regions to uncover the specific factors deriving their decoupling success, as this presents the most promising opportunities for advancing decoupling efforts.

Additional metrics, such as livestock density or the monetary value of animal production, could provide deeper insights. Moreover, this study lays the foundation for assessing whether regions that show Strong Decoupling are on track to achieving political objectives, such as the EU Green Deal or the Paris Agreement.

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Understanding Farmer's Willingness to Participate in a Landscape-Level Biodiversity Scheme.

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Abstract
Agricultural systems play a crucial role in halting biodiversity decline as they are intertwined with their surrounding ecosystems (Batáry et al., 2015; IPBES, 2019). Therefore, agri-environmental schemes for biodiversity have been established in many countries (Batáry et al., 2015; Schaub et al., 2023). Nonetheless, they are often insufficient to halt biodiversity decline on farmland (Kleijn and Sutherland, 2003; Lienhoop and Schröter-Schlaack, 2018; McKenzie et al., 2013; Pe'er et al., 2014). Thus, there is an ongoing discussion on how to improve biodiversity promotion in agriculture.

A promising approach to improve biodiversity promotion in agriculture is to shift the focus from the farm level to the landscape level with collective agri-environmental schemes (CAES) (Kleijn et al., 2006; OECD, 2023). The idea of CAES is to have regional farmers' collectives that coordinate their biodiversity promotion across farm borders. This can happen both collaboratively or cooperatively, where discretion lies either with the farmers' collective or with the regional government, respectively. CAES are thought to have a positive impact: they increase farmers' social capital (Barghusen et al., 2021; Mills et al., 2021) and may have a greater effect on biodiversity, as ecological processes can be taken into account (Macfarlane, 1998; OECD, 2023; Westerink et al., 2017). However, for CAES to be successful, a high level of participation is important. Hence, the policy design must be adapted to farmers' preferences. Therefore, this Master's thesis aims at better understanding farmers' preferences for a landscape-level biodiversity scheme and their willingness to participate in it.

To investigate this, the farmers' policy design preferences for a CAES were measured with a choice experiment. The choice experiment included ten choice sets, where participants indicated their preference among three policy design options. These policy design options are distinguished by varying levels of four attributes: group size of the farmers' collective, payment level, monitoring, and discretion. A further description of the attribute levels can be found in Table 1. The choice experiment was presented to the farmers in an online survey along with socio-economic and behavioural questions. The survey was designed and sent to all farmers in the Swiss canton of Grisons by Viviane Fahrni in 2024. A total of 206 farmers completed the survey.

Table 1: Attributes and attribute levels of the Choice Experiment.

Attribute	Attribute Description	Attribute Levels
Payment level	The amount the farmers' collective receives per ha and year when implementing the CAES	- 500 CHF - 1'000 CHF - 1'500 CHF
Group Size	The number of farmers, one would have to work with	1,3,6,10 or 20
Monitoring	How authorities verify that the CAES is correctly implemented	- In person - Digitally
Discretion	The organ responsible for the development and the implementation coordination of the CAES	- Cooperation (Discretion with Canton) - Collaboration (Discretion with farmers' collectives)

As preference heterogeneity among the farmers was expected, it was decided to use a latent class analysis (LCA) to analyse the choice experiment data. LCAs divide participants into homogeneous subgroups. Hence, by applying an LCA, the farmers' preference heterogeneity is examined and explained through the existence of latent subgroups that share policy design preferences. In this way, underlying patterns of preference heterogeneity can be found. In a second step, the subgroups were tested for significant differences in their socio-economic and behavioural factors.

Through conducting the LCA, four subgroups are found, each different in their CAES policy design preferences and their willingness to participate in a CAES. All subgroups prefer small group sizes of the farmers' collective. An explanation for this observation could be that, according to Prager (2022), trust and relationship can only be created in small groups. Furthermore, most groups show a higher willingness to participate when the payment level is higher. This supports the finding of Barghusen et al. (2021) that biodiversity payments are of high importance for the agricultural income and that the financial contribution is, hence, an important motivational factor.

The subgroups differ considerably in their preferences for monitoring. The majority prefers monitoring to be done in person, but one subgroup prefers digital monitoring, and one subgroup is indifferent. This heterogeneity could be explained by differences in their socio-economic and behavioural factors. It can be seen that the subgroup that prefers digital monitoring has a significantly higher proportion of seasonal mountain farms, a significantly lower social orientation, and a significantly lower perception of self-efficacy than the subgroups that prefer monitoring in person. In other words, the subgroup contains fewer farmers who believe it possible to halt biodiversity decline and who are inspired by others. For them, thus, being able to talk to an expert when monitored in person is less of an added value. In addition, as the subgroup has a high proportion of seasonal mountain farms, which are usually spread over a large area, monitoring in person might be associated with time and effort.

Preference heterogeneity is also observed among the subgroups regarding the question of discretion. Most participants prefer the discretion to be with the regional government, but one subgroup prefers it to be with the farmers' collectives, and one subgroup is indifferent. There are significant differences in the subgroups' behavioural factors that might explain this preference heterogeneity. The subgroup that prefers the discretion to be with the farmers' collectives also shows a higher cooperation attitude and social orientation. This gives the impression that this subgroup's members would like to actively participate in a farmers' collective as they like working together with other farmers. The reasons for the other subgroups to prefer the discretion to be with the canton could be a preference for professionalism or a preference to keep transaction costs low, which, according to Splinter and Dries (2023), are higher for farmers when the discretion lies with farmers' collectives.

The subgroups also differ considerably in their willingness to participate in a CAES. When linking these results with the subgroups' socio-economic and behavioural factors, possible explanations can be found. The subgroups with a lower willingness to participate in a CAES have significantly bigger farms. An explanation for this could be that bigger farms come with more opportunity costs, and farmers might, therefore, be less willing to take financial risks through the implementation of a new scheme. Furthermore, the subgroups with a low willingness to participate show a significantly lower willingness to take collaboration risks. A low willingness to take risks comes hand in hand with a higher tendency to have a status quo bias (Kahnemann et al., 1991; Ortoleva, 2010). This could explain why the other subgroups' willingness to participate is higher. Another factor potentially contributing to the subgroups' lower willingness to participate could be their lower perception of self-efficacy and their lower biodiversity attitude. According to Barghusen et al. (2021) and Thompson et al. (2024) a high perception of self-efficacy and a high level of problem awareness increase farmers' willingness to participate in agri-environmental schemes.

These results lead to the conclusion that collective agri-environmental schemes should be considered, given the elevated willingness to participate among many farmers. To further increase their willingness to participate, the policy design must be adapted to farmers' preferences. Hence, the policy should be designed for farmers' collectives of small group sizes, which still show an ecological effect, and an appropriate payment level should be promised. Moreover, an open policy design is recommended, allowing farmers to select their preferred monitoring option and to choose if they want the discretion to be with the canton or with a farmers' collective. Furthermore, farmers' awareness of biodiversity decline and their self-efficacy should be enhanced, as these factors show to favour a high willingness to participate in a CAES. The Canton of Grisons should furthermore take CAES into consideration as they combine many of the stated goals and measures of the canton's new biodiversity strategy. The canton aims to improve the quality and connectivity of biodiversity promotion in agriculture and give more responsibility to the farmers (Kanton Graubünden, 2023). Additionally, it aims to promote the exchange of experiences among farmers and improve their ecological expertise. These objectives could be reached with CAES by facilitating regular exchange between farmers and giving them more responsibility through the creation of local farmers' collectives. Furthermore, the canton's objective to increase ecological awareness and expertise among farmers is highlighted through the findings of this thesis.

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Leverage Points for Biodiversity Promotion in the Swiss Agricultural System identified with Participatory Causal Loop Diagrams.

Pinja Pöytäniemi

Extended summary

The current agri-food system is locked in an unsustainable cycle of declining biodiversity. While agriculture is fundamental to food security, its intensification has led to significant biodiversity loss. This intensification, characterised by increased mechanisation, heavy pesticide usage, and expansion of field sizes, has disrupted habitats and altered ecological balances (Helfenstein et al., 2020; Stoate et al., 2001). The Swiss federal government's biodiversity and impact monitoring programs reveal Switzerland's declining quality and area of valuable habitats. Half of the habitats and one of Europe's highest number of species are classified as threatened in Switzerland (Gattlen et al., 2017).

Acknowledging the need for agricultural system transformation, I used the „deep leverage point approach" approach of Meadows (1999) to explore pathways for biodiversity-friendly agriculture in Switzerland. The „deep leverage point" approach has been suggested as a tool to identify areas in complex systems with the potential to create fundamental changes (Abson et al., 2016; Davelaar, 2021; Dorninger et al., 2020). While some issues are generalisable in multiple agri-food systems, context-tailored solutions are often necessary (Conti et al., 2021; Williams et al., 2024). Considering this, causal loop diagrams created with stakeholder insights generate an understanding of the issues grounded in the realities of societal actors. The participants included farmers, biodiversity advisors, and representatives of government, agricultural, and non-governmental organisations. Utilising causal loop diagrams, I integrated diverse stakeholder knowledge and system analysis to identify lock-ins and leverage points for improving habitat and ecological quality on agricultural land.

(Dentoni et al., 2022). To this end, the study addresses the following research questions:

1 What are the barriers and leverage points for improving habitat and ecological quality on agricultural land in Switzerland?
2 Which transformation pathways do stakeholders envision for a biodiversity-friendly agri-cultural system in Switzerland?
3 What are the challenges and opportunities of using Causal Loop Diagrams in a participa-tory manner in agri-environmental research?

I navigated challenges such as conflicting stakeholder perspectives, power structures, and timeconstraints with purposeful participant selection and engagement. The causal loop diagram was developed in iterative steps consisting of one-hour interviews with ten key experts, validation of the causal loop diagram with an online survey, a participatory system mapping workshop (three hours with nine participants), and feedback collection (two online meetings). The research had a total of 14 participants. The methods included the use of visualisation tools facilitating system thinking and transparency. The participants' mental maps (a bit like mind maps) were visualized during the interviews, and the causal loop diagram was used in the workshop to identify the leverage points for biodiversity promotion. My findings highlight the pathways envisioned by Swiss experts in biodiversity promotion visualised as a Theory of Change diagram.

The results include system „factors" (variables of the system) with their meanings and relationships, bottlenecks, barriers (visualised in the causal loop diagram), leverage points, and interventions (visualised in the theory of change diagram). The causal loop diagram has 21 factors with 45 connections. The primary lock-in preventing efficient biodiversity promotion on agricultural land is related to trade-offs between biodiversity promotion and food production. With the current capacity of farmers and market incentives, biodiversity promotion is not economically viable. Moreover, the opinions at the societal level are polarised. The actors of agri-food value chains tend to defend the status quo, arguing for food security and focusing on maximising production (Williams et al., 2024). Meanwhile, strict environmental regulations force farmers into dire straits. Moreover, society blaming farmers for environmental problems while individuals are not willing to pay a higher price for sustainable products drives farmers to take a defensive stand. The stakeholders identified the polarisation of opinions as the most significant barrier to biodiversity promotion. Furthermore, farmers participating in biodiversity promotion schemes face significant challenges, such as limited management flexibility, high administrative burdens and insufficient financial compensation. These barriers undermine farmers' capacity and motivation to promote biodiversity effectively. Hence, administrative efforts and restrictive regulations need to be minimised for financial compensation to be effective.

Meadows' leverage points can be categorised into four system characteristics that interventions can target: „parameters" (for example, taxes, incentives, standards or material flows), „feedbacks" (the strength of the feedback loops and the length of delays), „design" (the system's social structures, such as rules, information flows, and power distribution), and „intent" (the system's goal, norms and paradigm). These groups represent a hierarchy of leverage from shallowest to deepest, where interventions may be made (Abson et al., 2016). The research participants envisioned interventions strategically targeting shallow and deep leverage points. Firstly, farmers' capacity and motivation to engage in effective biodiversity promotion should be enhanced by providing alternative compensation systems for biodiversity promotion. Flexible economic support for experimentation, goal-oriented payments rewarding farmers for higher habitat and ecological quality and landscape-level collaboration for site-specific goal setting and management were identified as potential deep interventions. Secondly, the institutional capacity to provide the necessary knowledge, training and farm-tailored advice should be strengthened (shallow interventions). Furthermore, there is a need to increase the feeling of farmers that their efforts are appreciated. In the current situation, society communicates mistrust and unappreciation to farmers through strict environmental regulations. Therefore, while the farmers may fulfil the minimum regulations, their motivation to engage in effective biodiversity promotion is low. Providing higher compensation for biodiversity promotion, farm-tailored advice, and acknowledgement of farmers' local ecological knowledge were assumed to increase farmers' feelings of appreciation.

Based on these findings, advocating for stricter environmental regulations for the farmers might backfire. While the direct impact of the regulations may be positive on habitat and ecological quality, increasing them would also strengthen the barriers, reducing biodiversity promotion efficiency. Moreover, the polarisation of opinions would likely increase due to the negative consequences to farmers and reduced feeling of appreciation. Therefore, any further initiatives for biodiversity promotion might be blocked by farmers and their representatives, as was seen with the last biodiversity initiative in September 2024 (Reuters, 2024). Consequently, my recommendation is to build experience, trust, and collaboration through smaller-scale success stories until sufficient support is gained for the initiative/project. Furthermore, the continued inclusion of farmers and consensus building seems vital due to the trade-offs between agricultural production and biodiversity promotion.

Together, these interventions create a potential pathway towards sustainable system transfor-mation where shallow and deep leverage points are triggered. Changing the compensation structures through economic support for experimentation, quality-based payments, and landscape approach allows farmers to apply knowledge and thus motivate them to acquire it. The desirable change is further amplified by strengthening the institutional capacities for knowledge provisioning. However, utilising consensus-building processes and including farmers in decision-making are necessary to mitigate the significant barrier related to polarised societal opinions.

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