https://doi.org/10.17221/51/2023-AGRICECON

# The impacts of agricultural subsidies of Common Agricultural Policy on agricultural emissions: The case of the European Union

*Jeremiás Máté Balogh**

*Department of Agricultural Economics, Institute of Sustainable Development, Corvinus University of Budapest, Budapest, Hungary*

**Corresponding author: jeremias.balogh@uni-corvinus.hu*

**Citation:** Balogh J.M. (2023): The impacts of agricultural subsidies of Common Agricultural Policy on agricultural emissions: The case of the European Union. Agric. Econ. – Czech., 69: 140–150.

**Abstract:** Agriculture is one of the main contributors to carbon emissions and is also significantly affected by changing climate. This article investigates the impacts of agricultural support on greenhouse gas emissions (GHG) from agriculture in the European Union. Panel regression models were used to examine the influence of subsidies in the Common Agricultural Policy (CAP) on reducing GHGs from agriculture. First, estimates show that direct agricultural subsidies encouraged agricultural-related carbon emissions. Second, the study concludes that the expansion of organic agriculture and the rural development expenditures contributed to emissions reduction in the member states. Finally, the CAP Health Check reform decreased while the Ciolos reform stimulated GHG emissions.

**Keywords:** agricultural payments; agricultural policy reforms; climate change; environmental pollution; sustainable agriculture

Agriculture is significantly affected by changing climatic conditions, and the sector also contributes to the development of global warming, with higher emissions of methane ($CH_4$) and nitrogen dioxide ($N_2O$). Following carbon dioxide, methane has the highest negative impact on the climate of the Earth, persisting in the air for about 11–12 years but having a higher global warming potential. In addition, nitrogen dioxide emitted can persist in the atmosphere for up to a century (Hansen et al. 2007). Anthropogenic climate change is caused by multiple pollutants, with $CO_2$, $CH_4$, and $N_2O$ being the three largest individual contributors to global warming (Myhre et al. 2013). Agriculture and food production both are associated with all three of these gases. However, direct agricultural emissions are unusual in being dominated by $CH_4$ and $N_2O$ (Lynch et al. 2021). Compared to other industries, it is said to be relatively low. However, agriculture also contains hidden emissions attributed to other sectors; emissions from fossil fuels and electricity used and the manufacture of fertilisers are accounted for in the energy sector (Underwood et al. 2013). Furthermore, intensification and modernisation brought increased productivity and employment driven by demand. At the same time, many

Supported by the National Research, Development and Innovation Office, Hungary (Project No. 128232 and 134668).

https://doi.org/10.17221/51/2023-AGRICECON

people lost their jobs in the agricultural sector (Knickel et al. 2013). Agriculture must respond to an increasing scarcity of natural resources and challenges such as climate change, urbanisation, demographic change, and food security.

Agriculture received around 600 billion USD annually worldwide in government support on average from 2014 to 2016 (Searchinger et al. 2020; Laborde et al. 2021), however, the environmental impact of these subsidies on greenhouse gas (GHG) emissions is rarely quantified. The climate mitigation impacts of the subsidies are ambiguous. Decoupled subsidies from agricultural production may increase global farm output and expand emissions-intensive agricultural activities without any emission offset on demand. In addition, emissions leakage (for example, an increase of emissions outside the EU) often occurs, weakening the global mitigation effect (Searchinger et al. 2020; Jansson et al. 2021; Laborde et al. 2021).

Agriculture production represented 38.2% of the total land area of the European Union (EU) Member States and contributed 1.3% to the Gross Domestic Product (GDP) of the EU, providing farming opportunities for 9.2 million workers and creating a gross value added of 181.5 billion EUR in 2019. Organic agriculture covered 13 million ha in the EU in 2018 (EUROSTAT 2020). In addition, the EU is one of the world's largest agricultural exporters. Agriculture accounts for approximately 12% of total EU GHG emissions (EEA 2022), excluding land use, land-use change, and forestry emissions (Underwood et al. 2013). In the European Union, agriculture is responsible for 53.8% of methane, 43.6% of nitrogen dioxide, and 2.5% of carbon dioxide (EEA 2022). In the EU, the largest, 45% of agricultural emissions are derived from the enteric fermentation of animals, 37.8% from agricultural soils, 14.7% from manure management, and 2.5% from other sources (Mielcarek-Bochenska and Rzeznik 2021). The Common Agricultural Policy (CAP) launched in 1962 is a common policy for all EU countries, providing financial support to farmers in member states. The CAP for 2014–2020 represents 38% of the total EU budget. This budget consists of two main categories: direct payments (e.g. annual payments to farmers to help stabilise farm revenues) and payments for rural development (aimed at achieving balanced territorial development and sustaining a farming sector), also called Pillar I and II (European Council 2023). However, since 2000, the CAP has put more emphasis on climate mitigation; the research investigating the impacts of the CAP on emissions reduction using econometric techniques is limited. The paper investigates how agricultural subsidies under the CAP, along with Health Check and Ciolos reform, could contribute to reducing agricultural emissions in the EU between 2004 and 2019. This research addresses the question of how the different CAP subsidies can influence greenhouse gas emissions from agriculture and serve emission targets. The findings suggest recommendations for the EU decision-makers to be able to limit agricultural-related emissions.

**Review of relevant literature**

***Impact of EU agriculture on climate change.*** In the EU, small farms dominate agriculture. In particular, two-thirds of the 10 million EU farms have less than 5 ha of land, while the majority of these farms do not exceed 2 ha. Approximately 20 million people work on EU farms, including full- and part-time farm managers and employees, seasonal labour, and farm family members (European Commission EUROSTAT 2020). In the EU, most agricultural GHG emissions are derived from enteric fermentation (45%), soils (37.8%), manure management (14.7%) and other sources (2.5%), discussed by Mielcarek-Bochenska and Rzeznik (2021). The role of the EU in mitigating climate change in the agricultural sector is crucial because the EU sets environmental standards and co-finances most of the agricultural expenditure of the Member States. The development of environmental-related components in the CAP has undergone several stages (European Court of Auditors 2021).

***Role of agricultural subsidies in climate change.*** There is increasing literature investigating the impacts of agricultural subsidies on GHG emissions. According to Laborde et al. (2021), in the past, government support has incentivised the development of high-emission farming systems. However, today has only a slight impact, inducing additional global GHG emissions from agricultural production. Combined, coupled subsidies and border measures slightly increase global farm output (+1.1%) while reducing global GHG emissions from agriculture (–1.7%). In contrast, coupled subsidies provide incentives to expand emission-intensive agricultural activities without any offset impact on demand. Therefore, reducing GHG emissions from agriculture requires shifting support to directly targeted emission reduction, such as GHG taxes on output or consumer demand, R&D funding in emission-saving technologies, and subsidising climate adoption costs.

Searchinger et al. (2020) evaluated how government transfers (direct government spending, targeted

https://doi.org/10.17221/51/2023-AGRICECON

tax benefits, and market barriers) help increase agricultural production and mitigate emissions from agriculture and support programmes could be changed. They concluded that there is potential to redirect farm support to mitigate climate change. There are multiple solutions to this. For example, Europe has created a model of phasing down market prices while boosting direct aid. Moreover, it is essential to redirect funding to focus on mitigation, including measures that increase efficiency in using natural resources. In addition, support for land retirement efforts is needed where land is being abandoned, farmland is unproductive, and putting more emphasis on restoring native forests. Condition farm payments are a potential solution to protect native areas. Finally, combining financial support for mitigation requirements can achieve improvements to avoid carbon leakage, moral hazard, and resource waste. Jansson et al. (2021) analysed the impact of removing voluntary coupled support for ruminants under the EU CAP. Their results show that removing voluntary coupled support for ruminants can lead to a 0.5% decrease in agricultural GHG emissions annually in the EU. In turn, emissions leakage significantly hampers the global mitigation effect. On the other hand, emission leakage is magnified by emissions-intensive production methods used in Brazil and India, where production could expand, illustrating problems with unilateral policies affecting mainly EU production volumes.

***Role of CAP reforms in greenhouse gas emission.*** Since 1962, the CAP has undergone several reforms. In anticipation of the 2004 EU enlargement, the Agenda 2000 reform led to creating a second pillar of the CAP dedicated to Rural Development policy. Agenda 2000 introduced Rural Development to improve agricultural competitiveness, providing alternative sources of income in rural areas, and strengthening social cohesion in those areas (European Council 2022). The Fischler reform adopted in 2003 was an essential step in the history of the CAP. This reform decoupled the direct payments from agricultural production and introduced the Single Payment Scheme (SPS) and cross-compliance measures (Cunha and Swinbank 2011). Health Check was the mid-term review of the Fischler reform, addressing three specific issues; simplify the Single Payment Scheme (SPS), improve the market orientation of the CAP, and provide adequate policy tools for new challenges such as climate change and biofuels (Timerman 2009). By 2013, the CAP had reached a phase of reconsideration. The 2013 Ciolos reform has laid the foundations for a future strategy with enough potential to harness environmental components. Introduced by the 2013 CAP reform, greening or green direct payments become the only direct payment financially rewarding farmers to improve the environmental performance of the CAP and climate goals (European Commission 2020). Greening measures entered their final form in 2015 as compulsory compliance, providing a 30% contribution from direct payments if farmers meet al. its subcomponents. Crop diversification, permanent grasslands, and ecological areas were enforced, but participation was not mandatory for farmers participating in the agri-environment scheme (European Commission 2018a). For rural development, six priorities were established, one of which encouraged the reduction of greenhouse gases, although Member States could set additional targets in this category (EEA 2019). Since 2013, climate mitigation has been one of the main objectives of the CAP. It seeks to ensure a sustainable future for European farmers, provide more targeted support to smaller farms, and allows greater flexibility for EU countries to adopt measures under local conditions (European Court of Auditors 2021). The report of the European Commission (2018b) concludes that a reduction of 26.2 million tonnes of GHG emissions (in $CO_2$ equivalent) can be attributed to the operation of the CAP annually. Although these helped agriculture reduce emissions in line with the Kyoto Protocol, they do not reveal an entire picture of its efficiency. Many studies suggest that carbon emissions leakage of 35–91% can be identified as a result of CAP subsidies (Fellmann et al. 2012; Van Doorslaer et al. 2015; Pérez Domínguez et al. 2016). The CAP, during its reforms, put more emphasis on agri-environmental payments and extended the measures encouraging climate mitigation; the research analysing the impact of the EU CAP on emissions is limited (Lesschen et al. 2009; Vlontzos and Pardalos 2017; Zafeiriou et al. 2018).

However, to date, the CAP and its reforms (Cunha and Swinbank 2011) have been evaluated by some studies (Timerman 2009; Fellmann et al. 2012; Van Doorslaer et al. 2015; Pérez Domínguez et al. 2016; Jansson et al. 2021) and reports (European Commission 2018b; EEA 2019; European Court of Auditors 2021) in the literature, the role of agricultural payments, as well as Fischler and Ciolos reforms played in the reduction of agricultural GHG emissions was not analysed by econometric methods. In conclusion, this can be identified as a potential research gap in this field. Four hypotheses are investigated in line with the literature researching the role of CAP subsidies in agricultural GHG emissions.

https://doi.org/10.17221/51/2023-AGRICECON

$H_1$: The increase in organic farmland contributed to reduced greenhouse gas emissions from agriculture in the EU.

The total organic agricultural area increased fivefold globally and quadrupled in the EU between 2000 and 2020. In 2020, organic agriculture represented 1.5% of the total agricultural land in the world, while organic agriculture reached 9.2% of the total agricultural land in the EU (Holka et al. 2022).

Many studies (Gomiero et al. 2011; Reganold and Wachter 2016; Meemken et al. 2018) have shown that organic farms are responsible for fewer carbon emissions from combusted fossil fuels by using less natural gas, diesel, and gasoline and synthetic fertilisers or pesticides in the management of soil fertility and pests. Organic farming can reduce GHG emissions and improve organic carbon sequestration by eliminating synthetic nitrogen fertilisers resulting in higher organic carbon content in soil (Holka et al. 2022). According to these findings, the increase in organic farm area is assumed to reduce agricultural greenhouse gas emissions in the EU.

Agricultural support has incentivised the development of high-emission farming systems while having a moderate impact on inducing additional global GHG emissions from production (Laborde et al. 2021). Gocht et al. (2017) revealed small environmental impacts (greenhouse gas emissions, nitrogen surplus, ammonia emissions, soil erosion, and environmentally friendly farming practices) of CAP greening or green direct payments. However, some regions may see greater effects than others (Pe'er et al. 2017; European Court of Auditors 2021). A high proportion of farmers were already complying with the essential requirements. Thus, payments for production-oriented Ecological Focus Areas options offered gains with no costs. Pe'er et al. (2017) added that implementing the greening measure could not notice environmental trends due to broad exemptions (low requirements for crop diversification, lack of management criteria, and providing ineffective options for Ecological Areas). Furthermore, the CAP climate measures were also inefficient (targeting livestock production and nitrogen fertiliser use). In addition, the CAP funds attributed to climate action had little impact on agricultural emissions (European Court of Auditors 2021). Literature suggests that most of the mitigation measures supported by the CAP have a low potential to combat climate change.

$H_2$: Direct CAP subsidies indicated increased greenhouse gas emissions from agriculture in the EU.

After the mid-term review of the Agenda 2000 reform of CAP, several supporting measures were introduced from an agri-environmental perspective, including an increase in the amount of CAP Pillar II payments (subsidies for Rural Development), as well as the introduction of cross-compliance (standards connected financial support to EU rules on the environment, plant, and animal health) and mandatory modulation (Cunha and Swinbank 2011) (An instrument introduced by the 2003 reform allowed resources aimed at direct aid for farmers to be transferred to CAP rural development measures during the period preceding 2013.). The European agri-environment scheme has been beneficial for farmland biodiversity, leading to a moderate increase in the number of species (Batáry et al. 2015). However, some studies indicate (Pe'er et al. 2017) that the efficiency of rural development programmes is mixed. These measures reinforced the commitment of the EU to environmental protection and climate mitigation.

$H_3$: CAP payments for rural development indirectly contributed to reducing EU carbon emissions.

By 2013, the CAP had reached a stage of reconsideration. Since 2013, climate action has been one of the main objectives of the CAP. It provided targeted support to small farms and allowed EU countries to adopt measures for local conditions (European Court of Auditors 2021).

$H_4$: CAP reforms between 2004 and 2019 (Health Check and Ciolos reform) attempted to reduce agricultural greenhouse gas emissions.

## MATERIAL AND METHODS

Most of the empirical literature (Fellmann 2012; Pérez Domínguez et al. 2016; Pe'er et al. 2017) used impact assessment (e.g. CAPRI model) for analysis while applying partial equilibrium models investigated by panel regressions was limited in the methodologies. This paper used panel data econometrics to analyse the impact of EU direct and rural agricultural subsidies on agricultural greenhouse gas emissions between 2004 and 2019. During this investigation, the impacts of determinants of greenhouse gas emissions (expressed in $CO_2$ equivalent) related to CAP payments are studied in the 27 EU Member States. An environmental pollution function is applied in line with empirical research (Balsalobre-Lorente et al. 2019; Balogh and Leitao 2022), and the following Equation (1) is estimated:

https://doi.org/10.17221/51/2023-AGRICECON

$$\ln\left(EU\_agr\_CO_2\right)_{it} = \beta_0 + \beta_1 \ln\left(EU\_agr\_CO_2\right)_{it-1} + \beta_2 organic\_area_{it} + \beta_3 \ln\left(CAP\_rural\_payments_{it}\right) + \\ + \beta_4\left(CAP\_direct\_payments_{it}\right) + \beta_5 Health\_Check_i + \beta_6 Ciolos_i + \varepsilon_{it} \quad (1)$$

where: $i$ – EU-27 Member States; $t$ – time expressed in years; $\beta_0$ – constant; $\beta_i$ – estimated coefficients for explanatory variables of EU Member State $i$; $\varepsilon_{it}$ – error term; *EU_agr_CO₂* – greenhouse gas emissions from agriculture in $CO_2$ equivalent in the EU-27; *organic_area* – organic farm area as a share of total farmland in percent in the EU-27; *CAP_rural_payments* – total support for rural development in the EU-27; *CAP_direct_payments* – total support for direct payments in the EU-27; *Health_Check* – CAP Health Check reform (2009); *Ciolos* – CAP Ciolos reform (2013).

The dependent variable is captured by EU agricultural GHGs (emissions in $CO_2$ equivalent calculated based on the Intergovernmental Panel on Climate Change – IPCC Fifth Assessment Report AR5, expressed in kilotonnes). Explanatory variables are organic farming, the CAP direct payments, and support for rural development expressed in EUR. Data are collected from the Food and Agriculture Organisation Statistical Database (FAOSTAT 2021), the Farm Accountancy Data Network (FADN) of the European Union Statistical Database (EUROSTAT 2021), and the FiBL (2022) database of the Research Institute of Organic Agriculture (Table 1). Panel fixed-effects, and dynamic panel regression estimations are applied.

To select the appropriate estimation method, panel tests were calculated. Autocorrelation tests suggest that the data has first-order autocorrelation. The cross-sectional dependency test (Pesaran 2004; 2015 confirmed that the variables are cross-sectionally dependent Table 2).

Since variables are autocorrelated and cross-sectionally dependent, panel corrected standard error model (PCSE), and dynamic panel estimations (Arellano-Bover/Blundell and Arellano-Bond) were performed to support the robustness of the results.

Table 1. Description of variables

| Variables | Description | Data source |
|---|---|---|
| ln(*EU_agr_CO₂*) | greenhouse gas emissions from agriculture in $CO_2$ equivalent IPCC AR5 kilotonnes in the EU | FAOSTAT (2021) |
| *EU_organic_area* | organic farm area as a share of total farmland in percent in the EU | FiBL (2022) |
| ln(*CAP_rural_payments*) | total support for rural development in EUR in the EU-27 | EUROSTAT (2021) |
| ln(*CAP_direct_payments*) | total support for direct payments in EUR in the EU-27 | EUROSTAT (2021) |
| *Health_Check* | equals to 1 if year > 2008, 0 otherwise | own elaboration |
| *Ciolos_reform* | equals to 1 if year > 2012, 0 otherwise | own elaboration |

CAP – Common Agricultural Policy; IPCC AR5 – Intergovernmental Panel on Climate Change, Fifth Assessment Report
Source: Author's own elaboration

Table 2. Tests for autocorrelation and cross-sectional dependency (CD)

| Tests | Variables | Statistics |
|---|---|---|
| Wooldridge test for autocorrelation | – | 15.128* |
| CD tests | ln(*EU_agr_CO₂*) | 13.656* |
| | *EU_organic_area* | 53.159* |
| | ln(*CAP_rural_payments*) | 26.349* |
| | ln(*CAP_direct_payments*) | 26.349* |

* *P*-value = 0.000; Wooldridge test – under the null hypothesis of no first-order autocorrelation; CD tests – under the null hypothesis of cross-section independence; CAP – Common Agricultural Policy; for description of variables see Table 1
Source: Author's own elaboration

https://doi.org/10.17221/51/2023-AGRICECON

## RESULTS AND DISCUSSION

During 1990–2018, agricultural emissions in the EU-27 decreased by 23.9%, while global agricultural emissions increased by 16.4% (Climate Watch 2022). This is explained by increasing energy efficiency, the introduction of agri-environmental measures under the CAP, and the new climate regulation adopted by the EU. Many additional factors have increased agricultural-related GHG emissions globally over the past decades. Among others, the expansion of livestock farming, rice cultivation (wet field release of $CH_4$ through fermentation processes in the soil), the use of increased animal manure and fertiliser on arable land (increased $N_2O$), landfill and wastewater practices (Olivier et al. 2017). Since the late 2000s, a slight increase in emissions has been caused by increased agricultural activity and deforestation in tropical regions (Ritchie and Roser 2021). Figure 1 shows that the share of agricultural GHG emissions from the EU varied between 7–10%, similar to the proportion of the USA (7–8%) and Brazil (7–9%).

The organic farm area increased by 271% to 2019 (14 million ha) compared to 2000 (3.8 million ha) in the EU-27 (Figure 2). Regarding the share of organic farms, Austria had the highest proportion of organic areas (19.3%) in the total land area of the EU, followed by Sweden (12.25%) and Estonia (11.15%) from 2000 to 2019. Excluding France, the smaller western (The Netherlands and Luxembourg), eastern (Hungary, Poland, Romania, and Bulgaria), and southern European countries (Croatia, Greece, Malta, and Cyprus) had only a limited proportion of organic areas.

Regarding the distribution of CAP, the share of direct payments varied between 67–73%, while the rural development payments reached 24–29% of the total subsidies in the EU-27 on average between 2004 and 2019 (Figure 3). It indicates that direct payments have a dominant impact on European agriculture.

Regression estimates suggest (Table 3) that the agri-environmental measures included in the CAP under Rural Development helped increase the share of organic agriculture that encouraged the abatement of GHGs between 2004 and 2019. The expansion of organic agriculture and the rural development payments contributed significantly to reducing greenhouse gas emissions at the EU level ($H_1$ and $H_3$ are accepted). In contrast, direct CAP payments increased agricultural greenhouse gas emissions ($H_2$) in all estimated models (1–5). According to the CAP reforms included, the Health Check helped reduce (models 1–5), while the Ciolos reform stimulated GHG emissions (models 1, 3–5) in the EU-27 (Table 3). Accordingly, $H_4$ is partly accepted.

Based on Arellano-Bond tests of dynamic panels (Table 3, models 4–5), we can reject the $H_0$ of no first-order serial correlation in the first differences (AR1). In turn, the $H_0$ of no higher-order serial correlation in the first

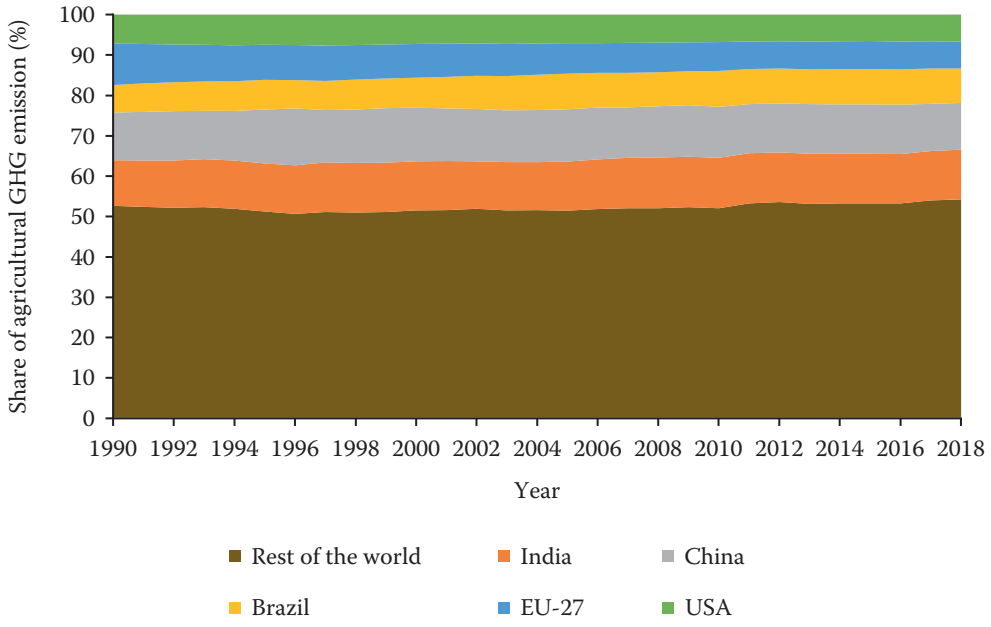


Figure 1. The share of agricultural greenhouse gas (GHG) emissions by the highest emitters (1990–2018)

Source: Author's own elaboration based on Climate Watch (2022)

https://doi.org/10.17221/51/2023-AGRICECON

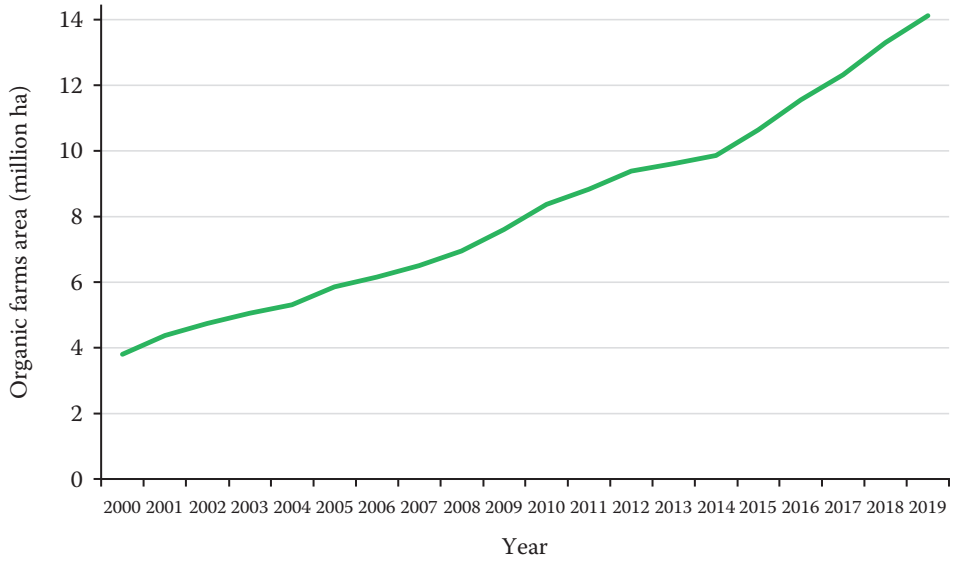


Figure 2. Evolution of the organic farm area in the EU-27, in ha (2000–2019)

Source: Author's own elaboration based on FiBL (2022)

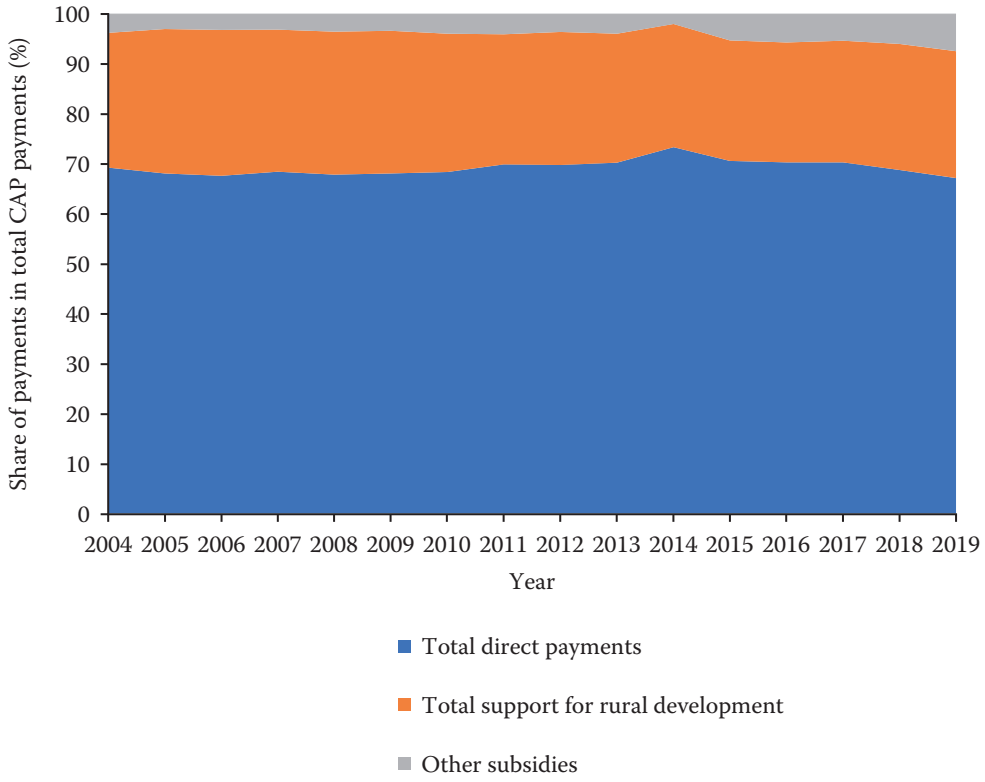


Figure 3. Share of direct payments and payments for rural development in total subsidies in the EU-27, on average (2004–2019)

CAP – Common Agricultural Policy
Source: EUROSTAT (2021)

differences (AR2) cannot be rejected. This indicates that the idiosyncratic error term in levels is serially uncorrelated. Also, we cannot reject the $H_0$ of the Sargan test of overidentifying restrictions are valid (the set of instruments is valid), indicating that dynamic models are correctly specified.

https://doi.org/10.17221/51/2023-AGRICECON

Table 3. Results of the panel estimation for agricultural emissions (2004–2019)

| Variables | ln(*EU_agr_CO*$_2$) | | | | |
|---|---|---|---|---|---|
| | model 1 | model 2 | model 3 | model 4 | model 5 |
| | AR | PCSE | FE | DPDSYS | ABOND |
| ln(*EU_agr_CO*$_2$)$_{t-1}$ | – | – | 0.684*** | 0.920 *** | 0.568*** |
| | | | (0.037) | (0.062) | (0.003) |
| *EU_organic_area* | –0.003 | 0.064*** | –0.001 | –0.004*** | –0.005*** |
| | (0.002) | (0.006) | (0.001) | (0.001) | (0.001) |
| ln(*CAP_direct_payments*) | 0.051*** | 1.153*** | 0.043*** | 0.021** | 0.051*** |
| | (0.018) | (0.068) | (0.008) | (0.009) | (0.005) |
| ln(*CAP_rural_payments*) | –0.010 | –0.853*** | –0.008** | 0.003 | –0.003 |
| | (0.006) | (0.072) | (0.004) | (0.002) | (0.002) |
| *Health_Check* | –0.024** | –0.097*** | –0.011*** | –0.003* | –0.015*** |
| | (0.009) | (0.034) | (0.004) | (0.002) | (0.002) |
| *Ciolos_reform* | 0.003 | –0.159*** | 0.007* | 0.012*** | 0.012*** |
| | (0.009) | (0.030) | (0.003) | (0.002) | (0.002) |
| Constant | 8.408*** | 4.609*** | 2.448*** | –0.496 | 3.344*** |
| | (0.182) | (0.217) | (0.313) | (0.518) | (0.342) |
| Observations | 413 | 413 | 390 | 390 | 363 |
| $R^2$ | 0.198 | 0.278 | 0.605 | – | – |
| Number of countries | 27 | 27 | 27 | 27 | 27 |
| Number of instruments | – | – | – | 125 | 111 |
| Arellano-Bond (AR1) test | – | – | – | 0.003 | 0.004 |
| Arellano-Bond (AR2) test | – | – | – | 0.256 | 0.344 |
| Sargan test | – | – | – | 1.000 | 1.000 |

* $P < 0.1$; ** $P < 0.05$; *** $P < 0.01$; robust standard errors in parentheses; AR – fixed- and random-effects linear models with an AR1 disturbance; PCSE – panel corrected standard errors; FE – fixed-effect; DPDSYS – Arellano-Bover/Blundell-Bond – linear dynamic panel-data estimation; ABOND – Arellano-Bond linear dynamic panel estimation; CAP – Common Agricultural Policy; for description of variables see Table 1

Source: Author's own elaboration

## CONCLUSION

This study investigated the impacts of agricultural subsidies under the CAP on GHG emissions from agriculture in the EU. Dynamic panel data models are used to evaluate the effectiveness of CAP subsidies and their reforms in reducing agricultural emissions between 2004 and 2019. Regression estimates suggest that the expansion of organic agriculture and the payments on rural development significantly reduced EU agricultural GHG emissions. In contrast, CAP direct payments significantly stimulated emissions in line with the expansion of emission-intensive farming activity. Considering the CAP reforms, the Health Check contributed to an increasing share of agri-environmental subsidies, creating support for emission reduction and boosting organic farming, while the Ciolos reform launched in 2013 stimulated GHG emissions in most models. This suggests a mixed effect of CAP reforms on the mitigation of GHG emissions in accordance with Gocht et al. (2017) and Zafeiriou et al. (2018). Financial support is also required to encourage mitigation to prevent carbon leakage in third countries (Searchinger et al. 2020). To conclude, the analysis of the CAP subsidies has highlighted its weaknesses in climate mitigation policy, such as CAP direct payments and the Ciolos reform induced higher GHG emissions in most of the estimated models. Despite the greater ambition of the EU to reduce agricultural emissions, the rules of cross-compliance and the measures for rural development changed little from 2014 to 2020 compared to 2007–2013. These

https://doi.org/10.17221/51/2023-AGRICECON

schemes did not motivate farmers to adopt effective climate mitigation measures. Although the greening scheme was supposed to improve the environmental performance of the CAP, its impact on climate mitigation has been limited (European Court of Auditors 2021). In the future, targeted subsidies and increased support for sustainable organic agriculture could be one of the solutions for policymakers. Moreover, from an environmental perspective, it could be advantageous to consider expanding green financial support. It would create an additional stimulus for agriculture, providing resources for sustainable, low-carbon production and incentives for emission cuts in the sector. The results draw attention to the need for action to curb EU agricultural emissions by reforming the system of CAP direct payments (single area payment and farm payments) and the transformation of agricultural subsidies as a whole. Sustainability can be incorporated into EU policy by expanding green investments, greening budgets, stimulating energy efficiency and renewable energy, and increasing spending on information technology, research, innovation, education, and training. The last reform of the CAP was adopted in 2021. The new legislation that starts in 2023 aims to provide 'a fairer, greener, and more' performance-based policy (European Commission 2022). Several policies, such as the Farm to Fork strategy, ecosystems, and biodiversity strategies, are designed to achieve sustainability in the EU, but their climate impacts are still unidentified. Further research is needed to evaluate the impacts of the new European Green Deal and related agricultural strategies on climate mitigation. There are a few limitations to the search. First, the panel covered the restricted period from 2004 to 2019, as the CAP subsidies were available from 2004 in the FADN database (Eurostat 2021). Second, CAP Direct Payments and payments on Rural Development were applied. Finally, a linear environmental pollution function has been estimated; however, a nonlinear framework (Zafeiriou et al. 2018) can be used in the future.

## REFERENCES

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.

Climate Watch (2022): Data Explorer. Data Source CAIT. Washington, World Resources Institute. Available at www.climatewatchdata.org (accessed Sept 30, 2022).

Cunha A., Swinbank A. (2011): An Inside View of the CAP Reform Process: Explaining the MacSharry, Agenda 2000, and Fischler Reforms. Oxford, OxfordAcademic: 256.

EEA (2022): EEA greenhouse gas – data viewer. [Dataset]. European Environment Agency. Available at https://www.eea.europa.eu/publications/data-and-maps/data/data-viewers/greenhouse-gases-viewer (accessed Sept 28, 2022).

European Commission (2018a): CAP explained: direct payments for farmers 2015–2020. Available at https://data.europa.eu/doi/10.2762/572019 (accessed Nov 13, 2022)

European Commission (2018b): Evaluation study of the impact of the CAP on climate change and greenhouse gas emissions: Final report. https://data.europa.eu/doi/10.2762/54044 (accessed Nov 14, 2022)

European Commission (2020): Agriculture and rural development. Sustainable land use (greening). Sustainable use of farmland and how this benefits farmers financially. Available at https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/greening_en (accessed Jan 30, 2022).

European Commission (2022): Food farming fisheries. Key policies. Common Agricultural Policy. The new common agricultural policy: 2023–2027. Available at https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-2023-27_en (accessed Sept 28, 2022).

European Commission EUROSTAT (2020): Agriculture, Forestry and Fishery Statistics: 2020 edition. Luxembourg, Publications Office of the European Union. Available at https://data.europa.eu/doi/10.2785/143455 (accessed Nov 13, 2022).

European Council (2022): Common Agricultural Policy. Timeline – History of the CAP. Available at https://www.consilium.europa.eu/en/policies/cap-introduction/timeline-history/ (accessed Nov 15, 2022).

European Council (2023): Reform of the Common Agricultural Policy post 2013. Available at https://www.consilium.europa.eu/en/policies/cap-reform/ (accessed Feb 8, 2023).

European Court of Auditors (2021): Special Report Common Agricultural Policy and climate. Special report 16/2021. Available at https://www.eca.europa.eu/Lists/ECADocuments/SR21_16/SR_CAP-and-Climate_EN.pdf (accessed Dec 10, 2021).

EUROSTAT (2021): FADN Public Database (SO) Subsidies. [Dataset]. Available at https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html (accessed Dec 29, 2021).

FAOSTAT (2021): Climate Change. Emissions. Emissions Totals. [Dataset]. Available at https://www.fao.org/faostat/en/#data/GT (accessed Dec 10, 2021).

https://doi.org/10.17221/51/2023-AGRICECON

Fellmann T. (2012): The assessment of climate change-related vulnerability in the agricultural sector: reviewing conceptual frameworks. In: Proceedings of a Joint FAO/OECD Workshop: Building Resilience for Adaptation to Climate Change in the Agriculture Sector, Apr 23–24, 2012. Rome, FAO: 37–63.

FiBL (2022): Area data on organic agriculture in Europe 2000–2019: Organic area [Dataset]. Research Institute of Organic Agriculture (FiBL). Available at https://statistics.fibl.org/europe/area.html (accessed Sept 30, 2022).

Gocht A., Ciaian P., Bielza M., Terres J.-M., Röder N., Himics M., Salputra G. (2017): EU-wide economic and environmental impacts of CAP greening with high spatial and farm-type Detail. Journal of Agricultural Economics, 68: 651–681.

Gomiero T., Pimentel D., Paoletti M.G. (2011): Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. Critical Reviews in Plant Sciences, 30: 95–124.

Hansen J., Sato M., Kharecha P., Russell G., Le D.W., Siddall M. (2007) Climate change and trace gases. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 365: 1925–1954.

Holka M., Kowalska J., Jakubowska M. (2022): Reducing carbon footprint of agriculture – can organic farming help to mitigate climate change? Agriculture, 12: 1383.

Jansson T., Nordin I., Wilhelmsson F., Witzke P., Manevska-Tasevska G., Weiss F., Gocht A. (2020): Coupled agricultural subsidies in the EU undermine climate efforts. Applied Economic Perspectives and Policy, 43: 1503–1519.

Laborde D., Mamun A., Martin W., Piñeiro V., Vos R. (2021): Agricultural subsidies and global greenhouse gas emissions. Nature Communications, 12: 2601.

Lesschen J.P., Rienks W., Staritsky I., Eickhout B., Prins A.G. (2009): Greenhouse Gas Emissions for the EU in Four Future Scenarios. Technical Report No. WAB-500102026. Available at http://www.pbl.nl/bibliotheek/rapporten/500102026.pdf (accessed Mar 16, 2023).

Lynch J., Cain M., Frame D., Pierrehumbert R. (2021): Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil $CO_2$-emitting sectors. Frontiers in Sustainable Food Systems, 4: 518039.

Meemken E.M., Qaim M. (2018): Organic agriculture, food security, and the environment. Annual Review of Resource Economics, 10: 39–63.

Mielcarek-Bochenska P., Rzeznik W. (2021): Greenhouse gas emissions from agriculture in EU countries-state and perspectives. Atmosphere, 12: 1396.

Olivier J., Schure K., Peters J. (2017): Trends in Global $CO_2$ and Total Greenhouse Gas Emissions: 2017 Report. The Hague, PBL Netherlands Environmental Assessment Agency 2017: 69. Available at https://www.pbl.nl/sites/default/files/downloads/pbl-2017-trends-in-global-co2-and-total-greenhouse-gas-emissons-2017-report_2674_0.pdf (accessed Sept 30, 2022).

Pe'er G., Lakner S., Müller R., Passoni G., Bontzorlos V., Clough D., Moreira F., Azam C., Berger J., Bezak P., Bonn A., Hansjürgens B., Hartmann L., Kleemann J., Lomba A., Sahrbacher A., Schindler S., Schleyer C., Schmidt J., Schüler S., Sirami C., von Meyer-Höfer M., Zinngrebe Y. (2017): Is the CAP Fit for Purpose? An Evidence-Based Fitness Check Assessment. Halle-Jena-Leipzig, German Centre for Integrative Biodiversity Research: 261. Available at https://www.greens-efa.eu/files/doc/docs/f9a6e0b649a9a238d21f6620886dd014.pdf (accessed Mar 16, 2023).

Pérez Domínguez I., Fellmann T., Weiss F., Witzke P., Barreiro-Hurlé J, Himics M., Jansson T., Salputra G., Leip A. (2016): An Economic Assessment of GHG Mitigation Policy Options for EU Agriculture: EcAMPA 2. JRC Science for Policy Report, Luxembourg, Publications Office of the European Union: 130. Available at https://data.europa.eu/doi/10.2791/843461 (accessed Mar 16, 2023).

Reganold J., Wachter J. (2016): Organic agriculture in the twenty-first century. Nature Plants, 2: 15221.

Ritchie H., Roser M. (2021): Deforestation and Forest Loss. Which countries are gaining, and which are losing forest? Our World in Data. Available at https://ourworldindata.org/deforestation (accessed Nov 30, 2022).

Searchinger T.D., Malins C., Dumas P., Baldock D., Glauber J., Jayne T.S., Huang J., Marenya P. (2020): Revising Public Agricultural Support to Mitigate Climate Change. Development Knowledge and Learning. Washington, World Bank: 1–74. Available at http://hdl.handle.net/10986/33677 (accessed Mar 15, 2023).

Timerman P. (2009): The Health Check: Further Steps to Adapt the Common Agricultural Policy to New Realities. European Affairs Program, Working paper 1. Egmont – The Royal Institute for International Relations. Available at http://aei.pitt.edu/47660/1/Final_WP_Health_Check_CAP.pdf (accessed Oct 14, 2022).

Underwood E., Baldock D., Aiking, H., Buckwell A., Dooley E., Frelih-Larsen A., Naumann S., O'Connor C., Polakova J., Tucker G. (2013): Technology Options for Feeding 10 Billion People – Synthesis report: Options for sustainable food and agriculture in the EU. Institute for European Environmental Policy. Available at https://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513539/IPOL-JOIN_ET(2013)513539_EN.pdf (accessed Oct 5, 2022).

Van Doorslaer B., Witzke H., Huck I., Weiss F., Fellmann T., Salputra G., Jansson T., Drabik D., Leip A. (2015): An Economic Assessment of GHG Mitigation Policy Options for

https://doi.org/10.17221/51/2023-AGRICECON

EU Agriculture. EUR 27097. Luxembourg (Luxembourg), Publications Office of the European Union: 122.

Vlontzos G., Pardalos P.M. (2017): Assess and prognosticate greenhouse gas emissions from agricultural production of EU countries, by implementing, DEA Window analysis and artificial neural networks. Renewable and Sustainable Energy Reviews, 76: 155–162.

Zafeiriou E., Mallidis I., Galanopoulos K., Arabatzis G. (2018): Greenhouse gas emissions and economic performance in EU agriculture: An empirical study in a non-linear framework. Sustainability 10: 3837.

Received: February 8, 2023
Accepted: April 11, 2023