AGRICULTURE AND GREENHOUSE GAS EMISSION – RESULTS OF ECONOMETRIC ANALYSIS

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A R T I C L E I N F O

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A B S T R A C T

Agriculture represents the "cause" and the "victim" of climate change. Almost 30 percent of greenhouse gas emissions come from the agricultural sector. They contribute to global warming and therefore significantly affect the sustainability of agricultural production systems. The aim of the paper is to determine which factors have the greatest influence on the greenhouse gas emission from agriculture. For this purpose, a dynamic panel analysis for 26 members of the European Union in the period from 2013 to 2021 in the paper is conducted. The results of the analysis suggest that the capacity for biofuel production, organic agricultural production and greenhouse gas emissions from the previous period have the greatest impact on the same emissions from agriculture. The results of this research can serve policy makers in formulating strategies for the development of food systems that will pollute the environment to a lesser extent and use available resources more rationally.

Introduction

Agriculture is the basic source of food and is very sensitive to climate change. Human activity that includes the burning of fossil fuels in electricity generation, in industry and transportation, as well as agricultural activity that includes the using of artificial fertilizers, the livestock, the changing way of cultivating the land, the growing rice, etc. contribute to the growth of the concentration of greenhouse gases in the atmosphere, that to a significant extent affects climate change and thus leads to an increase in global temperature and other environmental consequences (Houghton et al., 1996).

The share of gas emission from agriculture in total emissions will increase in the future because three reasons: first, gas emissions from other sectors will decrease; second, the volume of food production will increase; and thirdly, the reduction of gas emissions from agriculture is a complex process due to the diversity of its sub-sectors and the complexity of the biophysical processes associated with their activity (Topić,

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2020; Balaban et al., 2023). Agricultural sub-sectors can contribute to mitigating the consequences of climate change, if the increasing of food production will not affect the increasing of gases in the atmosphere. Agriculture has mastered a unique carbon sequestration process. Namely, at the current level of development of technologies, one of the main instruments for sequestering carbon dioxide from the atmosphere are forest complexes and restoration of degraded land.

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The aim of this paper is to examine the influence of selected sources of gas emissions from agriculture, using appropriate econometric methodology. The paper is organized as follows. After the introduction, the second part gives an overview of the literature. In the third part, technology, water resources, agroecology and renewable energy sources, which represent significant determinants of greenhouse gas emissions from this sector, are analyzed. In the fourth part, the methodology and information base of the research are presented. The fifth part refers to the research results and their discussion. The last part presents the most important conclusions.

Literature review

This part presents the results of empirical research that analyzes the influence of numerous factors on greenhouse gas emissions. The special attention is paid to papers that investigate the connection between agricultural production and greenhouse gas emissions, using various econometric techniques.

In a study by Jay Squalli and Gary Adamkiewicz (2018), the effect of organic agriculture on gas emissions in the USA in the period from 1997 to 2010 was investigated. The conducted analysis showed that the impact of organic agriculture was negative and statistically significant. According to the results of this analysis, the increasing area under organic farming by 1% leads to the reducting gas emissions between 0.015% and 0.059%. On the other hand, the results of this analysis robustly and unequivocally indicate the positive impact of the total agriculture - conventional and ecological (organic), on emissions. The increasing area of agricultural land of 1% leads to increasing emissions between 0.103% and 0.131%.

Salari, T. E and colleagues (2021) in the paper "Globalization, renewable energy consumption, and agricultural production impacts on ecological footprint" examined: what effects renewable energy consumption, multilateral and bilateral international trade and agricultural production have on the Ecological footprint index?, using a quantile regression model. The results showed that the consumption of renewable energy at all quantiles, except for the 25th, positively and significantly ($p<0.05$) affects the Ecological footprint index; this effect is more pronounced at higher than at lower quantiles. The agricultural production manifests the strongest influence on the 25th and 50th quantiles.

Siemianowska et al. (2017) surveyed 100 farmers in Poland about the importance of reducing the use of nitrogen fertilizers for a sustainable environment. The results showed that farmers in Poland are well know the agricultural practices of balanced use of artificial fertilizers, as well as that they are aware of the environmental hazards arising from their use. Yasmeen et al. (2021) in the paper "Agriculture, forestry, and environmental sustainability: the role of institutions" analyzed the role of sustainable agricultural production in reducing carbon dioxide emissions. The mentioned empirical study indicated that the use of renewable energy and the adoption of environmentally acceptable practices in agriculture should be encouraged.

Theoretical framework of research

Agriculture and greenhouse gas emissions

This part presents the results of empirical research that analyzes the influence of numerous factors on greenhouse gas emissions. The special attention is paid to papers that investigate the connection between agricultural production and greenhouse gas emissions, using various econometric techniques.

Agriculture represents the "cause" and the "victim" of climate change. Namely, almost 30 percent of greenhouse gas emissions come from the agricultural sector, mainly as a result of the use of chemical fertilizers, pesticides and the use of animal waste (Chataut et al., 2023). Greenhouse gases contribute to climate change and global warming and therefore significantly affect the sustainability of agricultural production systems.

The Food and Agriculture Organization states that greenhouse gas emissions from agriculture, forestry and other land uses (AFOLU) amount to 10.6 gigatonnes (Gt) of CO_2 equivalent. In all regions, the levels and sources of GHG emissions from "Agriculture, forestry and other land use" sector vary. For example, emissions from agriculture represent a significant part of the emissions of the AFOLU sector in all regions of the world, with the exception of sub-Saharan Africa and the Caribbean Basin (FAO, 2016).

When it comes to the sources of gas emissions in agriculture, gas emissions from the intestinal fermentation of ruminants has the largest share (40%); it is the main source of methane emissions. Intestinal fermentation of ruminants is followed by manure that remains on pastures (16%), then artificial fertilizer (12%) and finally, rice cultivation (10%) (FAO, 2016).

At the regional level, the importance of other sources of emissions from agriculture also varies. In East and Southeast Asia, the second main (biggest) source of greenhouse gas emissions is rice cultivation. In Australia, 59 percent of gas emissions arises during cultivating of organic soil. In Sub-Saharan Africa, North Africa and West Asia, as well as in Latin America and the Caribbean basin, the second main source of emissions is manure on pasture, and in the countries of developed regions (North America and Europe) – the consumption of artificial fertilizers.

The determinants of greenhouse gas emission in agriculture

The modern technologies

Not a small amount of greenhouse gases, created by agricultural activity, arrived the atmosphere, contributing to global warming and climate change. Using new technologies, farmers can identify the sources of greenhouse gases and find ways to reduce emissions of these gases. The technique, that uses the stable isotope carbon-13, allows people to assess soil quality and carbon sources from soil. This again provides an opportunity to understand how different combinations of crop rotation, cultivations of the land and land cover can increase production productivity and improve the use of limited natural resources, such as water and different chemical substances (IAEA, 2023).

The absorbing carbon from the atmosphere and retaining or storing carbon in the soil is the best solution for reducing the amount of greenhouse gases in the atmosphere. Modern technologies that reduce the greenhouse gases emission stimulate: the production of biomass, the use of cheap means for regulating the growth of plants and biofertilizers, the use of biochar, nitrogen fixation by leguminous plants, the reduction of the use of pesticides, the application of crop rotation, the mixed livestock production, etc. (Đokić et al., 2022).

The water resources

Lack of water is a real “nightmare” for farmers. For the development of plants in arid regions, it is necessary that every drop of rain to come their roots. The development of plants depends on the soil’s ability to absorb and retain water, and the plant can preserve it if soil contains important microorganisms (HLPE, 2015).

With the help of modern technologies, scientists help agricultural farms to sustain “life” in the soil and to adapt themselves to the impacts of climate change. Thanks to technology, farmers have managed not only to adapt the soil to climate change, but also to reduce the greenhouse gases emissions from soil that cause climate change. (Iliut, 2012). Using the laser technology and the neutron moisture meters, farms can analyze and determine how much water is lost through evaporation from the soil and how much water is lost through transpiration into plants. By these instruments, it can be measured the amount of oxygen that is released in the process of evaporation and determined the place of origin of the water vapor: from the soil or from the plant. After that, agrotechnical methods can be applied, for example, techniques for cultivation land of conservation agriculture that are based on minimal disturbance of the soil structure, or the irrigation schedule can be adjusted to ensure that plants receive water when they need it most (Lohaiza et al., 2011).

Plants absorb carbon dioxide from the atmosphere and use it for photosynthesis. The more carbon dioxide and nitrogen oxides in the soil, the reproduction of microorganisms in it is the more active (Joint FAO/IAEA Programme, 2016). Nitric oxide, that is created in the soil and emit from it, is an integral part of many artificial fertilizers. The using modern technologies, it is possible to determine how much nitrogen a plant can absorb (from the ground) naturally. On the basis of these data, it is possible to provide the plant the exact amount of chemical fertilizer that it needs, and at the same time reduce greenhouse gas emissions into the air to a minimum (Salkever, 2011).

The use of artificial fertilizers

In whole the world on an annual level, 1.2 million tons of nitrogen oxide is emitted from artificial fertilizers, which it, when we talk about the creation of the greenhouse effect, is 260 times more powerful than carbon dioxide. Also, the excessive application of chemical fertilizers costs a lot (Rehman et al., 2020).

Farmers are increasingly using sustainable agricultural practices to increase productivity and reduce nitrogen oxide emissions from chemical fertilizers. For example, farmers plant different types of bobs, such as purple or velvet beans, in whose the root system exist bacteria which converts nitrogen oxide from the air into organic matter that enriches the soil with organic food for plant. After harvesting the bobs, the stubble remains, and later on that part of the field grain crops and cereals are planted, which receive already collected, in the soil, nitrogen with the addition of a minimum amount of chemical fertilizer. This method helps farmers save money. Using this method, some countries are getting closer to their goal – a significant reduction in greenhouse gas emissions to 2030 compared to the level of emissions in 2005 (Fisher, 2018).

The agroecology

According to the HLPE report (2016), agroecology applies ecological concepts and principles to agricultural systems. By focusing attention on the interaction between plants, animals, people and the environment, the organic or agroecological approach to agriculture enables the sustainable development of the agricultural household, which in turn ensures food security.

Ecological principles of agricultural production, defined by Nicholls et. al (2016), are extremely important for adapting to climate change, because they are directed at: 1) improving biomass processing, by breaking down nutrients in an optimal way; 2) strengthening the “immunity” of agricultural systems by expanding functional biodiversity, 3) minimizing the consumption of energy, water, nutrients and genetic resources in order to better preserve and rehabilitate soil, water resources and agrobiodiversity, and 4) promoting, and thus, strengthening key environmental processes and services.

The focus of aggregology is the ecosystem as a whole, while the goal is to generate an environment that is productive and rationally uses natural resources, since it is, at the same time, sustainable on the social level (IAAST, 2008; Altieri & Nicholls, 2005; Ensor, 2009; De Schutter, 2010). In the organic system, indigenous knowledge and modern technologies are used aimed at: 1) the management of biological diversity; 2) the inclusion of biological principles and resources in the agricultural system and 3) the intensification of agricultural production.

Olivier De Schutter (2010) indicates that agroecological practices and methods are a key strategy for improving the resilience and sustainability of agricultural systems. The transition from the conventional (capital-intensive) to the ecological or organic way of production in agriculture is a long-term process, conditioned by a series of challenges of an agronomic, economic and educational nature. Agroecological approaches and methods, that ensure the success of traditional, organic farming in conditions of climate change, include the following: the use of local genetic diversity, the polycultural systems, the gardening and the like (Altieri & Koohafkan, 2008).

Renewable energy

Renewable energy sources use natural processes and resources that are, practically, inexhaustible or are relatively quickly renewed naturally. Renewable energy sources are: hydro power, wind energy, solar energy, etc. Renewable energy sources include biomass (Berdin et al., 2018). Biomass refers to living or recently living matter of plant or animal origin, that can be used as fuel.

The simplest and most common way of producing energy from biomass is burning it. Fire starts easily with dry and resinous wood, and the wood should lie in a certain way. This is the reason why researchers are trying to find more economical technologies that will enable more efficient and environmentally friendly burning processes of plant raw materials of different humidity and content (Koul et al., 2022).

Practices in agriculture, which are largely dependent on energy sources and growth of energy price, are the main limiting factor in improving agricultural production. The extensive research on the possibilities of using new energy sources are undertaken. The use of renewable resources (manure of “energetically” agricultural crops, etc.) in the production of energy and nutrition of plants and animals is an area of research in which modern technologies can play a valuable role (Plimmer, 1984).

The fermentation can generate energy in the form of methane or ethanol from cellulose waste. Although the scientific foundations of the mentioned technology are in the beginning, many limitations have appeared. One of them is the limited ability of microorganisms to digest wood, straw and the like. It should also be said that fermentation processes take place only in narrow ranges of acidity or temperature. That is why energy production processes are tested in numerous laboratories around the world. It is assumed that at lower temperatures, the decomposition of woody fibers and fermentation can be accelerated by applying new cultures of microorganisms. Mutants created by radiation are used to increase the degree of decomposition of agricultural waste that remains after fermentation and distillation of alcohol.

Materials and methods

Based on the analysis of the determinants of GHGs emissions from agriculture, as well as the literature review, an econometric model was formulated. The member countries of the European Union are analyzed in the period from 2013 to 2021. All data were taken from the website of the European Statistical Office (Eurostat, 2023). The dependent variable in the observed model is total greenhouse gas emissions from agriculture. The model, in the most general form, explains the total greenhouse gas emissions from agriculture in the country *i* and in period *t* ($lnGGE_{it}$) as a function of the following variables: Public expenditure on research and development related to agriculture in the country *i* and in period *t* ($lnGBARDa_{it}$), Actual evapotranspiration in the country *i* and in period *t* ($lnETa_{it}$), The share of area under ecological (organic) agriculture in total agriculture in the country *i* and in period *t* ($lnSEA_{it}$), The consumption of chemical fertilizers in the country *i* and in period *t* ($lnCCF_{it}$) and The capacity for biofuel production in the country *i* and in period *t* ($lnCPB_{it}$):

$$lnGGE_{it} = lnGBARD_{ait} + lnET_{ait} + lnSEA_{it} + lnCCF_{it} + lnCPB_{it}. \quad (1)$$

Table 1 lists the variables used in the research, along with their explanation and data source.

Table 1. Description of used variables

Variables	Labels	The explanations	Source
Greenhouse gas emissi ons by agriculture	lnGGE	Emissions of CO_2, N_2O in CO_2 equivalent, CH_4 in CO_2 equivale nt, HFC in CO_2 equivalent PFC in CO2 equivalent, SF6 in CO_2 eq uivalent and NF3 in CO_2 equiva alent from agriculture.	Eurostat
Public expenditures for R&D related to agricult ure	lnGBARDa	Public expenditures for R&D rela ted to agriculture and science re presents gowerment budget alloc ations for R&D related to agricul ture and sciences, measured in million euro. This variable refers to modern technologies.	Eurostat

Variables	Labels	The explanations	Source
Actual evapotranspi ration	lnETa	Actual evapotranspiration is quant ity of water that is removed from a surface due to the processes of evaporation and transpiration and is measured in million cubic metr es.	Eurostat
Share of area under ecological agriculture	lnSEA	Area under ecological agriculture divided by utilized agricultural ar ea multiplied by 100. This varia ble refers to the organic or agro ecological approach.	Eurostat
The consumption of chemical fertilizers	lnCCF	The consumption of chemical fert Ilizers refers to consumption of ni trogen fertilizers and is measured in tonne.	Eurostat
Capacities for the pro duction of pure biogasoline	lnCPB	Capacities for the production of pure bioga soline represents pro duction plants for pure biogasoli ne.	Eurostat

Source: Author's creation

Public expenditures for research and development related to agriculture refer to modern technologies and represent the variable that is the focus of the empirical analysis. The main goal of the model is to determine the influence of each of the potentially significant determinants on GHGs emissions from agriculture through the evaluation of parameters next to the variables in the model. The first model that is evaluated is the model with constant parameters (pooled model). The model with constant parameters can be represented by the following equation:

$$\widehat{lnGGE}_{it} = \hat{\beta}_1 + \hat{\beta}_2 lnGBARD_{ait} + \hat{\beta}_3 lnET_{ait} + \hat{\beta}_4 lnSEA_{it} + \hat{\beta}_5 lnCCF_{it} \quad (2)$$

$$+\hat{\beta}_6 lnCPB_{it} + \mu_{it},$$

where β_1 – free term, β_i, $i = 2, 3, ... 6$ – regression parameters and u_{it} – random error.

The first indication of the inadequacy of the application of the pooled model is given by the Ramsey test. Namely, considering that the null hypothesis about the correctness of the specification is rejected, it is concluded that it is necessary to examine alternative specifications of the empirical model. The existence of individual effects or heterogeneity between observation units is tested by the comparing previous model with a fixed effects model whose free term varies by observation unit, while the parameters next to the independent variables are constant (LSDV1 model). This fixed effects model can be represented as follows:

$$\widehat{lnGGE}_{it} = \hat{\alpha}_1 + \hat{\alpha}_2 D_{2i} + \hat{\alpha}_3 D_{3i} + \cdots + \hat{\alpha}_{20} D_{26i} + \hat{\beta}_2 lnGBARD_{ait} + \hat{\beta}_3 lnET_{ait} + \hat{\beta}_4 lnSEA_{it} + \hat{\beta}_5 lnCCF_{it} + \hat{\beta}_6 lnCPB_{it} + \mu_{it}, \quad (3)$$

Based on this model, it is tested whether the individual effects are statistically significant? For this purpose, the F-test was used that compared the sum of squares of the residuals of the LSDV1 model and the model with constant parameters. Given that the F-test statistic was higher than the critical value, it is concluded that the individual effects in the empirical model of emission from agriculture are statistically significant and that it is necessary to take them into account. The next step is to examine the significance of time effects. The significance of time effects is examined by comparing the fixed effects model whose free term varies by year while the parameters next to the independent variables are constant (LSDV2 model) with the model with constant parameters, using the F test.

Since $F_{(8,69)} \approx 2{,}10$ is higher than the obtained value of the F test (0.017, see table 1 in the Annex), it can be said that the LSDV2 model is worse. We now know that the LSDV 1 is better than the Pooled model and that the Pooled model is better than the LSDV2 model. The empirical model is also evaluated in the form of a stochastic specification. The stochastic specification can be represented by the next equation:

$$\widehat{lnGGE}_{it} = \hat{\beta}_1 + \hat{\beta}_2 lnGBARD_{ait} + \hat{\beta}_3 lnET_{ait} + \hat{\beta}_4 lnSEA_{it} + \hat{\beta}_5 lnCCF_{it} + \hat{\beta}_6 lnCPB_{it} + \mu_i + \mu_{it}. \quad (4)$$

Discrimination between fixed and stochastic specifications ss carried out using the modified Hausman test (Hoechle, 2007). The Hausman test showed that the random effects model is more appropriate, but the R^2 is higher in the LSDV1 model $R^2_{FE} = 0.2789 > R^2_{RE} = 0.0333$), and the residual plots are much better (see Supplement). Furthermore, the estimator of the fixed effects model ($\hat{\beta}_{FE}$) is always consistent, regardless of whether the independent variables are correlated with individual effects (free terms) or not, while this is not the case with the random effects model ($\hat{\beta}_{RE}$). Therefore, it is “safer” to pick the fixed effects model (LSDV1 model). The presence of homoscedasticity in the fixed effects model was tested by a modification of the Wald test (Baum, 2001).

Since certain empirical papers confirm the presence of inertia in the movement of greenhouse gas emissions, i.e. point to the fact that greenhouse gas emissions are largely determined by the level of these emissions in the past (for example, see Jula & Jula, 2013), dynamic specification is applied in the further analysis. The dynamic specification can be represented by the following equation:

$$\widehat{lnGGE}_{it} = \hat{\beta}_0 + \hat{\alpha} lnGGE_{it-1} + \hat{\beta}_1 lnGBARD_{ait} + \hat{\beta}_2 lnGBARD_{ait-1} + \hat{\beta}_3 lnGBARD_{ait-2} + \hat{\beta}_4 lnET_{ait} + \hat{\beta}_5 lnET_{ait-1} + \hat{\beta}_6 lnET_{ait-2} + \hat{\beta}_7 lnSEA_{it} + \hat{\beta}_8 lnSEA_{it-1} + \hat{\beta}_9 lnSEA_{it-2} + \hat{\beta}_{10} lnCCF_{it} + \hat{\beta}_{11} lnCCF_{it-1} + \hat{\beta}_{12} lnCCF_{it-2} + \hat{\beta}_{13} lnCPB_{it} + \hat{\beta}_{14} lnCPB_{it-1} + \hat{\beta}_{15} lnCPB_{it-2} + \mu_{it}. \quad (5)$$

An effective methodological tool for evaluating the dynamic panel model are the methods developed by Arellano and Bond (1991) and Blundell and Bond (1999). The Arellano-Bond method use first differences that eliminate individual effects. Blundell and Bond suggest evaluating systems of equations that include not only first difference equations but also level equations.

Discussions

When analyzing the impact of selected determinants on the emission of gases from agriculture, we started from the evaluation of static models. The results of the estimation of static models are shown in Table 1 in the Appendix. Different specifications are estimated: a model with constant parameters, a fixed effects models (LSDV1 and LSDV2) and a random effects model. However, the conclusion based on static specifications is not reliable, taking into account the test results related to these specifications. The non-fulfillment of the initial assumptions directs to the examination of the adequacy of the dynamic specification. The dynamic specification is estimated using the Arellano-Bond method and the Blandel-Bond method. The evaluation results are presented in Table 2.

Table 2. Results of the dynamic panel models

Models Variables	GMM(1)[(1)]		GMM(2)[(2)]	
	Coef.	P > |z|	Coef.	P > |z|
$lnGGE_{i,t-1}$	.1654905	0.040	.9625664	0.000
$lnGBARDa_{i,t-1}$	-.0407024	0.000	-.0861186	0.000
$lnETa_{i,t}$	.0197961	0.417	.0647495	0.000
$lnSEA_{i,t-1}$	-.1593366	0.015	-.3307523	0.005
$lnCCF_{i,t-1}$	.0703286	0.016	.0365248	0.200
$lnCCF_{i,t-2}$	.0175614	0.005	.0042728	0.807
$lnCPB_{i,t}$	-.109088	0.000	-.0267565	0.108
F test	0.0000		0.0000	
AR (1)	0.1368		(0.1985)	
AR(2)	0.5145		0.6321	

Notes: [(1)] The column GMM(1) refers to the specification estimated by Arellano and Bonds' method of generalized moments. [(2)] The column GMM(2) refers to the specification that was estimated by Blandel and Bonds' system method of generalized moments.

Source: Author's calculation in STATA

The effective methodological tool for evaluating the dynamic panel model are the methods developed by Arellano and Bond (1991) and Blundell and Bond (1999). The Arellano- Bond method use first differences that eliminate individual effects. Blundell and Bond suggest evaluating systems of equations that include not only first difference equations but also level equations.

The results indicate a significant and strong inertia in the movement of greenhouse gas emissions from agriculture. The scores of the coefficients next to the dependent variable $lnGGE_{i,t-1}$ are statistically significant at the 5% level. Based on this, it can be concluded that the persistence of gas emissions originating from agriculture characterizes the observed countries.

The research results show that public expenditures for research and development related to agriculture have a statistically significant and negative effect on gas emission. However, the effects of increasing public expenditure on research and development related to agriculture do not manifest immediately, but after a period of one year. The share of areas under ecological method of production in total agriculture in period t-1 ($lnSEA_{i,t-1}$) is statistically significant at the level of 1%. According to the results of this analysis, increasing the area under ecological method of production of 1% in the period t-1 leads to reducting gas emissions from 0.16% to 0.33% in the current period, depending on the specification. The consumption of chemical fertilizers with a time lag of 1 and 2 years ($lnCCF_{i,t-1}$ and $lnCCF_{i,t-2}$) is statistically significant at the 1% level in the GMM(1) model. The coefficient next to $lnCCF_{i,t-1}$ and $lnCCF_{i,t-2}$ has a positive sign. If the consumption of chemical fertilizers increased in the previous period, it is expected that the emission of agricultural GHGs gases will increase in the current period.

The estimated coefficient of the variable Actual evapotranspiration (lnEtai,t) has a positive sign. The variable $lnEta_{i,t}$ is statistically significant at all levels in the GMM(2) model. The coefficient next to the variable Biofuel production capacity or $lnCPB_{i,t}$ has a negative sign as assumed in the existing literature (Salari et al. 2021). The results of this analysis show that increasing The capacity for biofuel production, on average, reduces greenhouse gas emissions from agriculture.

Conclusions

The aim of this paper is to determine the significant determinants of greenhouse gas emissions from agriculture. The paper analyzed the following variables: Public expenditures for research and development related to agriculture, The share of areas under ecological method of production in total agriculture, The consumption of chemical fertilizers and capacity for biofuel production ect. The results of dynamic panel models showed that the variables Emissions of greenhouse gases, Public expenditures for research and development related to agriculture and Share of areas under ecological production in total agriculture in period t-1 are significant in explaining emissions. Public expenditures for research and development related to agriculture and The share of areas under ecological production in period t-1 reduce the emission of agricultural gases, while emissions from period t-1 increase it.

The results obtained in this research showed that the climate is characterized by significant inertia. More closely, there is a "time gap" between the reducting greenhouse gas emissions, through the introducting modern technologies, the increasing areas under ecological production methods and the using renewable energy sources, and the reduction of the concentration of gases in the atmosphere. Carbon dioxide and other greenhouse gases remain in the atmosphere for years, and for reducting gas emissions, that would affect their concentration in the atmosphere, a certain time should pass.

Likewise, there is a time gap between the decreasing amount of gases in the atmosphere and the temperature. The temperature will continue to rise in the future, after the amount of greenhouse gases in the atmosphere stabilizes (IPCC, 2001). Therefore, the dynamics of the climate system do not allow delay measures (such as: development of new technologies and new sources of energy, increasing the share of organic agriculture in total agriculture) for reducing emissions from agriculture. In order to prevent a larger increase in temperature, for example, by more than 2 degrees Celsius, it is necessary to quickly start the process of reducing emissions. The delay of 5 years must be compensated very quickly. In addition, longer delays are generally not compensable (Mignone et al., 2008).

The main limitations of this research are: a short period of observation, a relatively large number of independent variables and a small number of observations. Future research in this field may be extended to NUTS 2 and NUTS3 level, depending on available data.

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Conflict of interests

The author declare no conflict of interest.

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Appendix

Table 1. Evaluation results of static panel models

Models Variables	Pooled		LSDV1		LSDV2		RE[(1)]	
	Coef.	P > |z|	Coef.	P > |z|	Coef.	P > |z|	Coef.	P > |z|
lnGBARDa	.261571	0.000	-.002251	0.876	.261872	0.000	.003636	0.829
lnETa	.210544	0.024	-.024011	0.484	.231589	0.031	.002391	0. 952
lnSEA	-.628011	0.000	-.026877	0.306	-.631866	0.000	-.02803	0.357
lnCCF	.784142	0.000	.014758	0.354	.785398	0.000	.021633	0.244
lnCPB	.143161	0.014	-.025623	0.408	.142880	0.021	-.00939	0.791
Constant	5.471596	0.000	10.46938	0.000	5.402825	0.000	9.734	0.000
R^2	0.8479		0.9995(0.2789 [(2)])		0.8509		0.0333	
Ramsey test	3.74 (0.0147)							

Models Variables	Pooled		LSDV1		LSDV2		RE[1]	
	Coef.	**P > |z|**	**Coef.**	**P > |z|**	**Coef.**	**P > |z|**	**Coef.**	**P > |z|**
F test			1756.64 (0.0000)					
F test					0.17 (0.9936)			
Wooldridge			1.72 (0.2216)					
M. Wald			193.16 (0.0000)					
M. Hausman					0.02 (1.0000)			

Notes: [1] Column RE refers to the random effects model. [2] The coefficient of determination in the fixed effects model that is estimated by transforming the data within the observation units and that is comparable to the coefficient of determination in the random effects model.

Source: Author's calculations in STATA