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The Contribution of Energy Use and Production to Greenhouse Gas Emissions: Evidence from the Agriculture of European Countries

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Abstract

The submitted study investigates the role of energy use in agriculture and agricultural output in carbon dioxide emissions with the presence of instrumental variables such as rural population and urbanisation. The data set covers 27 European countries during the period 2010–2020. The quantitative approach was applied using cluster analysis with the previous identification of relations between variables by factor analysis. As the second approach, the Two-Stage Least Square (TSLS) model was estimated. Based on the results, three clusters were created. The heatmap demonstrated the similarity between the comprised countries. The most similar countries are Greece and Hungary, while the most different countries are Luxembourg and Malta. Performed TSLS analysis showed that an increase in energy use is associated with an increase in carbon dioxide emissions. On the other hand, greater agricultural output is associated with lower emissions. However, the statistical significance differs across the individual clusters.

Keywords

Agriculture, Energy, CO_2 emissions, cluster analysis, TSLS.

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Introduction

Agriculture is the primary source of food security for human beings all over the world. It helps to fill the necessaries of life while supplies not only the food, but the clothing, medicine, and employment as well. In the past, agriculture was considered to be the clean industry which could be explained by the dependence of farmer`s life on the resource base of agriculture and the environmental quality. However, according to the Food and Agriculture Organization (FAO), it is expected that agricultural production will need to increase by 70 percent by 2050 to fill the needs of the growing population (FAO, 2022). Increasing demand for agricultural products for the sustenance of an increasing population encourages farmers to use various antifouling agents, antibiotics, and fungicides or requires higher consumption of energy that turns into environmental pollution. Despite the significance of agriculture, it is important to highlight that it is currently responsible for about one-third of all greenhouse gas (GHG) emissions that pollute the environment. Most of these GHG emissions are the results of the agricultural industry and therefore it is considered to be an important area to mitigate climate change (Engler and Krarti, 2021). Moreover, one-quarter of all GHG emissions may be caused by the global food system (Mrówczyńska-Kamińska et al., 2021). Although the food security, nutrition, and sustainable development are key interest points of policymakers at a national and international level, it is important to put attention not only on the supporting of agriculture as a center of food security, but on a clean, unpolluted, and healthy environment as well.

As the world population continues to grow, it is needed to increase agricultural production which is associated with greater energy consumption Much more effort and innovation are needed in order to effectively use resources with the aim to reduce environmental pollution. There are different theoretical perspectives explaining the relationship between greenhouse gas emissions and energy consumption. The theory of the Environmental Kuznets Curve (EKC) hypothesis presents the relationship between the economic performance of the agricultural sector and the environment as an inverted U-shape. It means that environmental pollution increases at the beginning of an economic expansion of the agricultural sector but after achieving a peak point, it starts to decline (Wang et al., 2022).

Existing studies demonstrate that the Kuznets Curve hypothesis is valid in developed (Gokmenoglu and Taspinar, 2018; Zhang et al., 2019) and developing countries as well (Xu and Lin, 2017; Rahman and Kashem, 2020) with the presence of investment into research and development.

The positive correlation between energy use across the economic sectors and its efficiency is known as Jevons's paradox. Jevons (1907) argues that technological innovations and development enhance energy efficiency and decrease the price of natural resources such as energy. According to this paradox, better energy efficiency might drive the energy consumption that turns to the rise in CO_2 emissions mainly through the existence of the rebound effect (York and McGee, 2015; Li and Xu, 2020).

To make agriculture more environment-friendly, it is important to introduce regulatory measures and energy-efficient innovations. The appropriateness of policy environmental regulation and its impact on innovation and technological growth is discussed in Porter's hypothesis (Porter and Linde, 1995). However, the effect of regulation on technology innovation can be twofold. Firstly, it is the compliance cost effect that is associated with an increase in the total cost of enterprises due to an increase in environmental protection costs. It produces a crowding-out effect on the technology investments of enterprises (He et al., 2020). Secondly, it is the innovation offset effect explaining that environmental regulations will encourage technological advancement which in turn increase productivity and offset the costs (Fang et al., 2020).

Except for the theoretical approaches, there are a lot of studies providing empirical evidence about the relationship between energy consumption and CO_2 emissions. Park et. al (2018) used Pooled Mean Group (PMG) estimator and found a long-run relationship with the CO_2 emissions that lower environmental quality. The study of Arshad et al. (2020) focused on the Asian and South Asian (SSEA) countries in the period 1990–2014 and relies on a different methodological framework that consisted of the Ordinary Least Squares (OLS), Generalized Method of Moments (GMM), and Dumitrescu-Hurlin causality test. The results showed the existence of bidirectional causality between CO_2 emissions and energy use. Another approach was applied in the study of Zhang et al. (2019) examining the factors increasing CO_2 emissions in China from 1996 to 2015. They employed cluster analysis and Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) panel regression model. According to the results, the most important factors influencing carbon dioxide emissions are investments in research and development, GDP, and energy cleanliness. Most of the mentioned studies examined the linkage between energy consumption and CO_2 emissions mainly in African or Asian countries. Several papers describe the determinants of carbon dioxide emissions in European countries as well. For example, Dogan and Aslan (2017) estimated the nexus between tourism, GDP, energy consumption, and CO_2 emissions. The results revealed a negative relationship between energy consumption and CO_2 emissions, but on the other hand, the effect of tourism and GDP was positive. Dogan and Seker (2016) and Bekun et al. (2019) found that carbon emissions are mitigated mainly by nonrenewable energy. On the other hand, non-renewable energy increases CO_2 emissions.

In the existing literature, we can also find studies that analyse the linkage between agricultural production and CO_2 emissions. The study using Vector Error Correction Model (VECM) applied to Pakistan during the period 1990–2014 concluded that agricultural production positively and significantly affects CO_2 emissions (Mushtaq et al., 2007). Jebli and Yousef (2017), who used Vector Error Correction Model (VECM), confirmed that an increase in agricultural production boost CO_2 emissions in Tunisia during the years 1980–2011. Contrary to this, Jebli and Youssef (2016) found that increase in agricultural production reduces CO_2 emissions. Similarly, Nwaka et al. (2020) confirmed that agricultural production reduces CO_2 emissions only from liquid sources, but it increases the total emissions.

Additionally, Haldar and Sharma (2021) found, that increasing energy consumption resulted in higher greenhouse gas emissions as a consequence of urbanization and population. The similar results that urbanization and rural population are considerable factors for energy consumption, agricultural production, and their role in CO_2 emissions were confirmed in the study of Iheke (2015), and Malik and Ali (2015).

Although agriculture fills the necessities of human life, in order to achieve sustainable development growth and meet the objectives of the Sustainable Development Strategy (Eurostat, 2016), policymakers should put attention to the effect of agriculture on the environment.

The submitted paper aims to group the countries according to agricultural indicators and analyse the importance of agriculture in carbon dioxide emissions in individual clusters. The paper addresses the following research question: „Is greater use of energy in agriculture and agricultural output associated with the increase of CO_2 emissions? "„Is the energy use in agriculture and agricultural output significant in relation to CO_2 emissions?"

The article contributes to the existing literature in several ways. Firstly, most of the papers analyze the role of the total energy use in CO_2 emissions in developing countries. The submitted paper focused on the agriculture in European countries helps to fill this gap. Moreover, existing studies apply the analysis to a whole sample, so it does not take into account the different characteristics of each country. Provided cluster analysis allows to group countries according to the basic economic characteristics and then analyses the relationship individually in each cluster including the most similar countries. Besides, findings from this paper offer new insights to policymakers on various ways of making the energy consumption in agriculture and agricultural output more environmentally friendly with the aim to achieve the goals of sustainable development indicators.

The remaining section of the paper is structured as follows: The second part introduces the data and methods used in this paper. The next section provides and discusses the results of the analysis. Firstly, the empirical study focuses on the similarities and differences between the European countries according to the basic indicators of sustainable development. Secondly, the role of energy consumption in agriculture and agricultural output in CO_2 emissions is analysed. The fourth part of the paper concludes with important remarks and offers recommendations for policymakers as well.

Materials and methods

The analysis presented in the paper utilized a time series dataset sourced from the World Bank, the Global Carbon Project, and European Commission database (Eurostat) to examine the role of energy use in agriculture and agricultural production in carbon dioxide emissions in EU member states. The analysis covered two dimensions: a territorial angle of a view involving 27 countries of the European Union (without Great Britain) and a time perspective represented by the period from 2010 to 2020. An observed dataset consisted of the following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

The variable of carbon dioxide emissions was used as an explained variable, while the energy representing the energy consumption in agriculture and agricultural output as an explanatory variable. Moreover, following the existing literature, population, and urbanisation were used as control variables (Iheke, 2015; Malik and Ali, 2015; Chakamera and Alagidede, 2018; Han et al., 2022).

Several quantitative methods were applied in a comprehensive analysis concerning an econometric point of view: factor analysis, cluster analysis, and regression analysis.

The main assumption for the cluster analysis is no correlation between variables. Therefore, as a first step, the factor analysis was applied to the normalized data. The factor analysis helps to identify the relations between variables and leads to its reduction associated with combining variables into a single factor (Blbas, 2017). The suitability of the correlation matrix for the factor analysis was checked by Bartlett's Test of Sphericity. The null hypothesis H0 states that the correlation matrix of the variables is an identity matrix. It means that the variables are unrelated and not suitable for factor analysis (Bartlett, 1951). The technique used to determine the appropriate number of factors

Variable	Description	Source
Carbon dioxide (CO_2)	CO_2 emissions per capita (thousand tonnes)	Global Carbon Project
Energy	Final energy consumption by agriculture per hectare of utilised agricultural area (million tonnes of equivalent)	Eurostat
Production	Agricultural output at basic price (miliard euros)	Eurostat
Population	Rural population (% of total population)	The World Bank
Urbanisation	Share of population living in rural areas (% of total population)	Eurostat

Source: own processing

Table 1: Variable's description.

(or the number of significant components) was based on the Kaiser criterion (Kaiser, 1960). It explains that eigenvalues higher than 1 are considered significant in the Principal Component Analysis (PCA) (Granato et al., 2018). While some variables recorded a higher correlation with other variables, their assigning to the individual factor could be ambiguous. The varimax rotation solved this issue. Varimax rotation maximizes the variance shared among items and represents how data correlate with each principal component (Allen, 2017). The results of the factor analysis, the factor scores, were used as an input for the cluster analysis.

The second econometric approach applied in the submitted paper was the cluster analysis that allows to group countries based on their similarity (Bardhoshi et al., 2020). The cluster analysis begins with computing the Euclidean distance that computes the similarity of countries based on the selected indicators. The Euclidean distance of two objects p, q defined by the Cartesian coordinates (p_1,p_2) and (q_1,q_2) is given by the following equation (Cohen, 2004):

$$d_{p,q} = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2} \quad (1)$$

Where q represents the first country, p is the second country, and $d_{p,q}$ is the Euclidean distance of the first country p and the second country q.

After determining the optimum number of clusters by the majority rule, the EU countries were included in different clusters using Ward's minimum variance method with squared Euclidean distance (Murtagh and Legendre, 2014; Pelau and Chinie, 2018; Arshad et al., 2020).

In order to validate importance of Energy and Agricultural output in CO_2 emissions, the regression analysis was used in individual clusters. The paper considered the following empirical model:

$$CO2_{i,t} = \alpha_i + \beta_{i,t} Energy_{i,t} + \beta_{i,t}\, Production_{i,t} + \\ + \delta_{i,t}\, Z_{i,t} + \varepsilon_{i,t} \quad (2)$$

Where CO_2 is an explained variable, *Energy* and *Production* represent an explanatory variable. Z is a set of control variables (rural population and urbanisation), ε is the disturbance term, β and δ are estimated coefficients, while the parameter α stands for an intercept. The index i is the analysed cluster (i = 1,2,3,4), and t is the time period covering the years 2010–2020

However, the problem of endogeneity could arise due to several reasons, such as the simultaneous linkage between CO_2 emissions and Energy or CO_2 emissions and Production, the correlation of Energy and Production with the error terms, and the problem of omitted variable bias. It could be solved using instrumental variables in Two-Stage Least Squares (TSLS) regression (Al-Mulali et al., 2015; Chakamera and Alagidede, 2018; Majeed and Khan, 2018). While Energy and Output represent the endogenous regressors and principal variables in Equation 2, in order to deal with the potential endogeneity, the TSLS approach first regresses Energy and Production on all explanatory variables (i.e. Z) in Equation 2. Therefore, the first stage models applied in the paper were as follows:

$$Energy_{i,t} = \gamma_0 + \gamma_1 Urbanisation_{i,t} \\ + \gamma_2\, Population + \varepsilon_{i,t} \quad (3)$$

$$Production_{i,t} = \theta_0 + \theta_1 Urbanisation_{i,t} + \\ + \theta_2\, Population + \varepsilon_{i,t} \quad (4)$$

In the second stage, the following regression model was estimated:

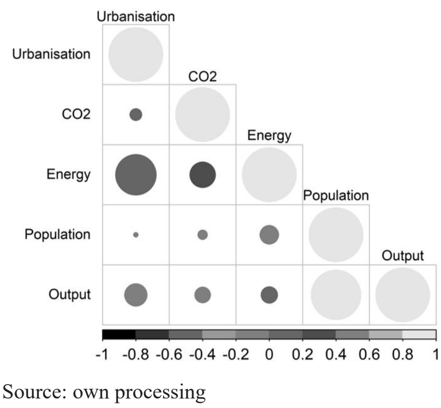
$$CO2_{i,t} = \alpha_i + \beta_{i,t} \widehat{Energy}_{i,t} + \beta_{i,t}\, \widehat{Production}_{i,t} + \\ + \delta_{i,t}\, Z_{i,t} + \varepsilon_{i,t} \quad (5)$$

Where $\widehat{Energy}$ and $\widehat{Production}$ denote the fitted values from the first stage regression model.

The whole analysis was executed in the R statistical environment through the programming language R (R Core Team, 2018) with the additional help of the NbClust package (Charrad et al., 2014), psych (Revelle, 2021), car (Fox et al., 2020), ivreg (Fox et al., 2021).

Results and discussion

While the cluster analysis is associated with no or low correlation (Blbas, 2017), firstly the correlation between variables was checked. The results are displayed in Figure 1.



Source: own processing

Figure 1: Correlation between input variables.

As it can be seen, the greatest correlation was found between the agricultural output and the rural population (84.93%) followed by the correlation between urbanization and energy use (-56.50%). On the other hand, the lowest correlation was recorded between the rural population and CO_2 emissions with a value of -3.11%.

Regarding the correlation between the input variables, the factor analysis was used in the next step of the provided analysis. Results of Bartlett's Test of Sphericity (with the p-value $9.60*10^{-7}$) led to the H0 rejection, which indicated the suitability of the data for the factor analysis. This result was confirmed by Kaiser-Meyer-Olkin (KMO) statistic with the value of 0.66. Kaiser criterion showed that the eigenvalue was greater than one in three cases. It indicated that three components of PCA explained 90.14% of the total variance (Table 2).

According to the results of PCA, variables such as trade recorded a higher correlation with more variables, and their assigning to the individual factor was ambiguous. Therefore, the PCA with the rotation varimax was used. The results are presented in Table 3.

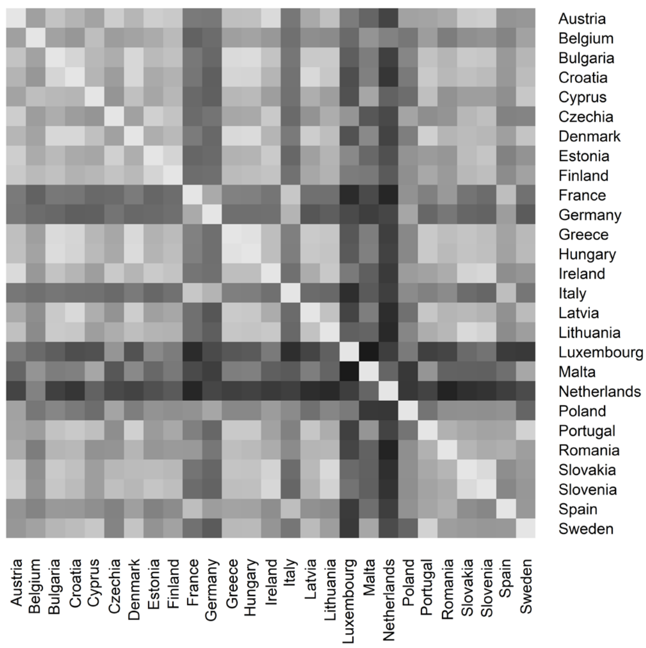
The shades of grey indicate the participation of input variables in individual components. As it can be seen, the first component including agricultural output and rural population explains 37% of the data variability. The second component consists of the energy use and urbanisation contributes to the explanation of data variability by 32%. The third component includes only the CO_2 emissions and explains 21% of the variability. While communalities (h2) of all variables were greater than 0.50, it was not necessary to remove any variable and repeat the factor analysis.

The output of the factor analysis, factor scores that are not correlated, was used as an input variable in the cluster analysis. Firstly, the similarity of countries based on the analysed variables was displayed (Figure 2). A lighter color depicts bigger

Variables	Component 1	Component 2	Component 3	h2	u2
CO_2	-0.03	0.05	0.98	0.97	0.030
Energy	-0.04	0.87	0.26	0.83	0.173
Output	0.96	0.14	-0.06	0.94	0.064
Population	0.97	-0.10	0.00	0.94	0.058
Urbanisation	-0.08	-0.89	0.16	0.83	0.168
Proportion var	*0.37*	*0.32*	*0.21*		

Source: own processing

Table 2: Results of PCA after the rotation varimax.



Source: own processing

Figure 2: Heatmap of European countries.

similarities of countries according to the Euclidean distance. The greatest Euclidean distance was found between Luxembourg and Malta (5.25), Netherlands and Lithuania (4.86) followed by the Netherlands and Latvia with a Euclidean distance of 4.76. Contrary to this, the most similar countries are Greece and Hungary with a Euclidean distance of 0.10, or Bulgaria and Hungary (0.23).

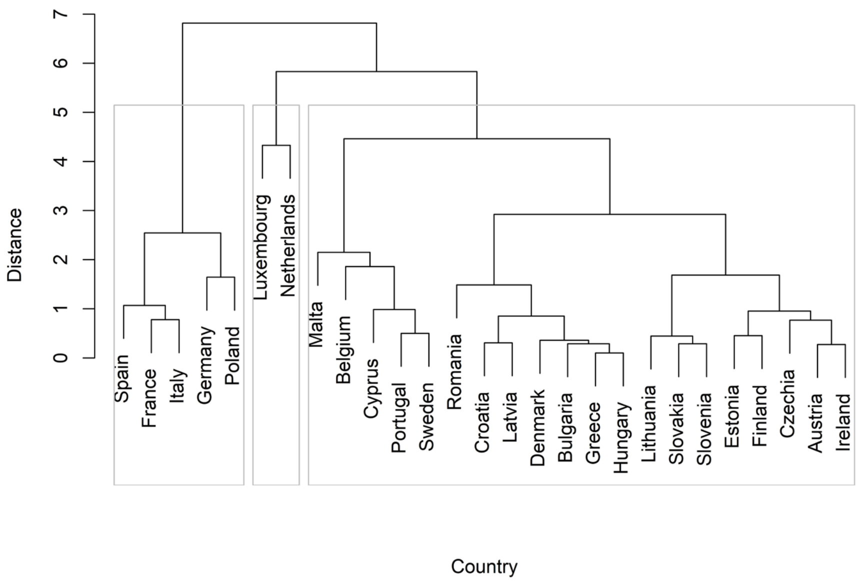
According to the majority rule, eleven indices proposed 3 as the best number of clusters. Indices defining an optimum number of clusters at the value 3 and their values (in parentheses) are: Scott (40.87); Marriot (6135.31); TrCovW (269.13); TraceW (9.99); Silhouette (0.45); PseudoT2 (10.58); Ratkowsky (0.40); Ball (15.54); PtBiserial (0.74); McClain (0.33); and Dunn (0.32). The process of clustering is showed in Figure 3.

The development of analysed variables in individual clusters is displayed in Figure 4. The values are given by the average for all countries included in a certain cluster. While environmental pollution caused by greenhouse gas emissions has become a serious problem, governments of European countries adopted various environmental regulations with the aim to turn the European Union into a resource-efficient, green, and competitive low-carbon economy (Mohammed et al., 2021). As a result, the level of CO_2 emission has decreased (Alola et al., 2020; Mrówczyńska-Kamińska et al., 2021). It can be seen in all clusters during the analysed period. The same trend can be observed in the case of the share of the rural population. As presented by Romanenko et al. (2020), the share of the rural population in EU countries decreases annually. On the other hand, agricultural production has increased in all clusters. According to Toma et al. (2017), Western European countries are more agriculturally productive than those in Eastern Europe. High concentration of energy consumption in agriculture is characteristic for countries with the largest agricultural sector, such as Poland and France (Rokicki et al., 2021). It is confirmed by the comparison of the first, second, and third clusters. Also, the urbanisation in rural areas have increased in the first and second cluster in comparison with 2010 and the energy consumption in agriculture has increased in the first and third cluster as well.

The first cluster created by Spain, France, Germany, Italy, and Poland represented by the red line recorded the highest agricultural output and rural population. The level of CO_2 emissions and energy consumption are comparable with the third cluster.

The second cluster which consists only of two countries – the Netherlands and Luxembourg recorded the greatest value of CO_2 emissions and energy consumption in agriculture. This group of countries can be characterized by the lowest share of rural population and urbanization almost during the whole analysed period.

Within the third cluster, countries with the greatest



Source: own processing

Figure 3: Dendrogram of European countries.

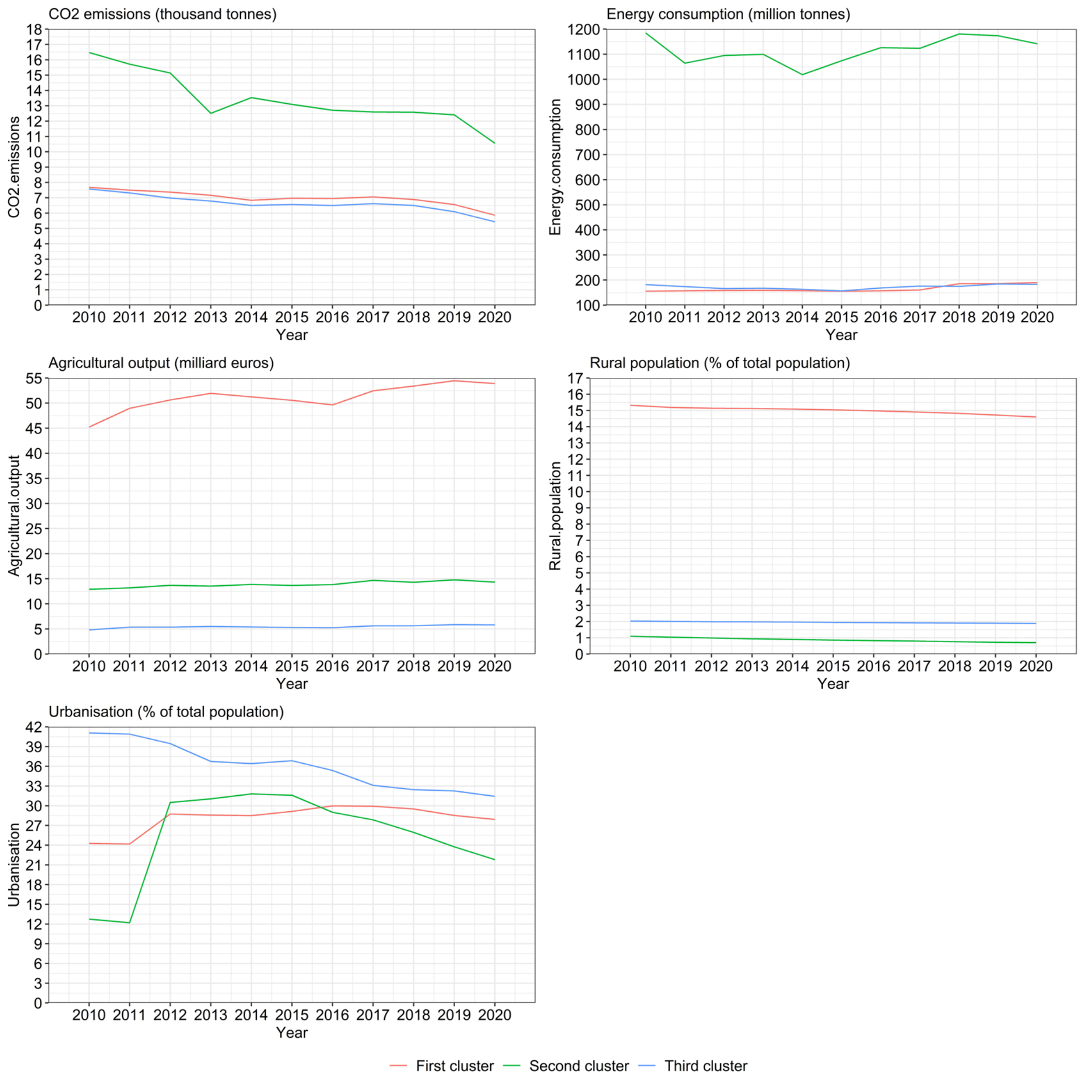


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Figure 4: Development of analysed variables according to the clusters.

share of urbanisation in rural areas can be observed. In the case of other variables, these countries are characterised by the lowest CO_2 emissions and agricultural output.

Based on the characteristics of each cluster, it could be assumed that higher CO_2 emissions are associated with higher energy use (Cluster 1) and lower CO_2 emissions with lower agricultural output (Cluster 3). The role of energy use in agriculture and agricultural output in CO_2 emission was further analysed using a TSLS estimation. Each model was checked for fulfilling key assumptions for regression models. While the heteroskedasticity and autocorrelation were confirmed, to estimate the model, heteroskedasticity, and autocorrelation consistent (HAC) variance-covariance matrix was used for the parameters. Results are presented in Table 3.

According to the results of the TSLS estimation technique, greater energy use in agriculture is associated with an increase in CO_2 emission in all clusters. It confirms the results of existing empirical research (Zaman and Abd-el.Moemen, 2017). The greatest increase of CO_2 associated with an increase in energy was recorded in the third cluster with the coefficient value 0.139 followed by the first cluster (0.026). The use of energy involves the release of emissions that pollute the environment (Weili et al., 2021). Also, Liu et al. (2017) explain that the agricultural industry is considered to be the main contributor to CO_2 emission mainly due to the utilization of energy with the aim to increase agricultural production. Therefore, to achieve sustainable agricultural

Clusters/ Coefficients	Estimates and t-statistics according to the cluster					
	Cluster 1		Cluster 2		Cluster 3	
Intercept	2.723		14.159	***	1.105	*
	(1.578)		(4.163)		(2.396)	
Energy	0.026	***	0.021	***	0.139	.
	(4.183)		(3.156)		(1.717)	
Output	-0.001		-1.703		0.044	
	(-0.067)		(-1.454)		(0.631)	
Diagnostic tests						
Weak instruments	(12.850)	***	(14.586)	***	(54.498)	***
Wu-Hausman	(85.066)	***	(15.287)	***	(20.547)	***
Sargan	(1.756)		(1.210)		(22.895)	***
R^2	*0.715*		*0.732*		*0.800*	

Note: t-statistics in parentheses
***; **; *; . indicate statistical significance at 0.001; 0.01; 0.05; and 0.1 significance levels
Source: own processing

Table 3: Results of the estimation of TSLS model in each cluster.

development in the European Union, more and more countries developed technologies that allow the use of renewable energy in the agricultural sector (Rokicki et al., 2021). On the other hand, there is also a study (Goundar and Appana, 2018) that found that energy use reduces carbon dioxide emissions through efficient energy patterns of production and consumption (Coroama et al., 2012). Although energy efficiency can be improved by these technologies, according to Amin and Rahman (2019), it boosts the energy demand much more and results in environmental degradation. The differences between the results of compared papers can be attributed to different countries that participated in analysis, different time periods, methodology, or variables used in these studies.

Additionally, based on the TSLS results, a greater agricultural output is connected with higher CO_2 emissions. Saudi et al. (2019) discusses that higher dependence on energy in agriculture tends to reduce environmental sustainability. These results are in line with existing empirical research that found a positive relationship between agricultural output and CO_2 emissions such as Mushtaq et al. (2007), Jebli and Yousef (2017). Results obtained from the first and the second cluster differ, while a greater agricultural output is associated with higher CO_2 emissions. According to Nwaka et al. (2020), greater agricultural output lowers the CO_2 emissions but only from the liquid sources. Also, Poeplau and Don (2015) explain that agriculture can induce carbon sequestration due to modified agricultural practices and as a result, the CO_2 emissions decrease.

Regarding the statistical significance of the results, energy use in agriculture plays a statistically significant role in CO_2 emission in all analysed clusters. The level of statistical significance differs across the clusters. However, the statistical significance of agricultural output in CO_2 emissions was not provided in TSLS analysis.

Moreover, the table includes the results of diagnostic tests for each cluster. Durbin-Wu-Hausman's test of endogeneity compares the OLS estimate with the TSLS one. A p-value lower than the critical value $\alpha = 0.05$ led to rejection of the null hypothesis. It implies that one or more regressors are endogenous, so the TSLS estimator is consistent. As it can be seen, the partial first stage statistics for weak instruments were statistically significant as well, mostly at 0.1% significance level. It indicates that the instruments included in the submitted paper are considered strong. Urbanisation and rural population are important factors for agriculture and could reflect in the level of CO_2 emissions (Iheke, 2015; Malik and Ali, 2015; Zhang et al., 2021). The last Sargan test of instrument exogeneity is used only in the case when there are more instruments than endogenous variables and the model is overidentified. While the p-value was greater than the critical value in all cases except for the third cluster, it can be concluded, that the instruments are valid in the two clusters.

Conclusion

In the last decades, food security has become a key interest point of policymakers at a national and international level. With the increasing population, it is expected that agricultural production will need to increase. It requires not only the use of various antifouling agents, antibiotics, and fungicides but higher energy consumption that turns into environmental pollution as well. Therefore, despite the significance of agriculture, it is important to put on a clean, unpolluted, and healthy environment as well.

The submitted paper investigates the role of energy consumption in agriculture and agricultural output in the CO_2 emissions in 27 European countries during the period 2010–2020. While there is previous empirical evidence that the level of urbanization and rural population are important determinants of carbon dioxide emissions, these characteristics of each country were included in the analysis as instruments as well.

First of all, the European countries were clustered using the cluster analysis with the previous application of factor analysis to solve the problem of correlation between the input variables. Based on the results, the most similar countries with the lowest Euclidean distance are Greece and Hungary, or Bulgaria and Hungary. Contrariwise, the greatest difference was recorded between Luxembourg and Malta followed by Euclidean distance between Netherlands and Lithuania.

Secondly, with the aim to analyse the role of energy use and agriculture and agricultural output in carbon dioxide emission, the Two-Stage Least Squares estimation technique was utilized in individual clusters. In response to the research questions, according to the results, an increase in energy consumption is associated with an increase in CO_2 emissions in all created clusters. The opposite result was found in the case of production, however only in the first and the second clusters. Greater agricultural production is associated with lower emissions in all clusters except for the third one, where the coefficient recorded a negative sign. Moreover, the results suggest that instruments used in the submitted paper (rural population and urbanization in rural areas) are valid in all clusters. It means that these variables require considerable attention in the analysis of energy consumption in the agriculture-CO_2 emissions nexus or agricultural production-CO_2 emissions nexus as well.

Obtained results can be served as background for the preparation of common directives of the policy framework for environmental regulation. Based on the empirical evidence that greater energy consumption in agriculture is associated with an increase in carbon dioxide emissions, policy responses are required. Although energy use has become integral part of agriculture, it is needed to focus on its disadvantages. The source of energy that is necessary, comes mostly from the resources that pollute the environment significantly. Further, most of the energy relies on nonrenewable sources. It is important to support and subsidize mainly technologies and agricultural projects with lower or no dire environmental consequences. The support for the project that uses nonrenewable energy could be transferred to clean energy research which might highlight the importance of this issue. However, all policy measures should be implemented very carefully while it might affect the growth rates and prosperity of countries.

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