Analysis of the Impact of the Greenhouse Gas Emissions Component of Environmental Resilience on the New European Development Model

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Abstract

Population well-being is a strategic goal for every political program. We are currently living in the new logic of sustainability which means at the same time economic efficiency, social responsibility and ecological resilience. Two of the key drivers of the new development model of the European Union are ecological and digital resilience. Ecological resilience means promoting the values of the circular economy but also neutrality in terms of emissions. To this end, an ambitious program called the Green Deal has been launched and is being implemented at European level. More and more experts are interested in following the evolution of greenhouse gas emissions and determining the factors with a high influence on their level. The identification of causalities or the relationship between greenhouse gas emissions and the most significant variables has become an interesting research topic. In order to contribute to mitigating the climate changes, both policy makers and entrepreneurs put more and more frequently in their agendas subjects as Gross Domestic Product per capita, Research & Development expenditures per capita, domestic consumption of fossil energy material per capita and red meat production per capita. The authors of this paper set out to analyze and offer some relevant insights linked to correlation and causalities between greenhouse gas emissions volumes and global warming based on Pearson correlation coefficient and the identification of similar countries using the combination of clusters in the Dendrogram using Ward Linkage. Data from the EUROSTAT database with a range from 2013 and until 2019 with a grouping of 27-EU countries were used for the calculation the Pearson correlation coefficient and the combination of clusters in the Dendrogram using Ward Linkage. The findings show there is a negative correlation between both the gross domestic product per capita, research and development per capita and greenhouse gas emissions for high income countries and generally positive correlation between both the domestic consumption of fossil energy materials, the production of red meat per capita towards greenhouse gas emissions.

Keywords

Greenhouse gas emissions, environment, GHG determinants, climate change, clustering

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Introduction

It has become a truism for the entire international community (policy makers, experts in academia and science, business and civil society representatives) that the greenhouse gas emissions (GHG) exert a continuous pressure on the environment, being the main driver of global warming, hence adversely impacting the climate change. GHG emissions may be produced by natural systems (i.e. oceans, wetlands, forest fires, volcanoes or mud volcanoes) or human activities. Although naturally produced GHG emissions represent 33.4%-52.1% of total volumes (YUE and GAO, 2018), due to the fact they are self-balanced (eventually absorbed in ecosystems) and may be influenced in an immeasurable percentage by man, we will analyze the ones coming from main anthropogenic activities with the largest share of emissions issued, namely fossil fuel material combustion (Climate Watch, 2022) and red meat production (González et al.,

2020). The objective of this paper is issuing recommendations in cases where variables have a positive correlation with the GHG emissions volumes, found by means of the calculation of Pearson correlation coefficient and the identification of similar countries using the combination of clusters in the Dendrogram using Ward Linkage.

Our research is based on 2 hypotheses:

H1: there is a negative correlation between both GDP per capita, R&D per capita and GHGs emissions per capita in case of developed countries of EU-27 countries and vice versa.

H2: there is a positive correlation between both fossil energy materials per capita, red meat production per capita and GHG emissions per capita in case of all EU-27 countries.

The paper will be structured as follows: a short review of the scientific literature, the methodology we have used, the authors' findings and conclusions and recommendations.

1. Review of the scientific literature

In the process of developing the economy a country pays less or more attention to the environment degradation or sustainability. Following the Kuznets curve, its usage being extrapolated to environmental issue from the social hypothesis advanced by economist Simon Kuznets, the countries change their less productive and high polluting equipment and activities into more productive and environmentally friendly ones especially through policy change and regulations (Panait, Voica and Rădulescu, 2019). In Romania, a country in a transition stage from efficiency driven to innovation driven economy and situated in the upward part of the environmental Kuznets curve (EKC), despite the authorities claim a sustainable growth, the primary and final energy intensity are more than three times higher than the current average levels in the EU. Moreover, in 2018 the total consumption of resources in the metallurgical industry increased by more than 48% compared to 2014, while the added value recorded a contraction of 2.8%. Regarding the oil processing industry, while the added value increased by 12.6%, the consumption of resources increased by over 50% (Iacobuta, Asandului and Cautisanu, 2020; Sarbu et al., 2020). Fathi, Ashena and Bahari (2021) have conducted a research recently, trying to find out the most efficient countries in a 25 samples group in terms of energy, economic and environmental (E3) strategies, using an integrated Data Envelopment Analysis approach and Nash bargaining game model. The findings are contradictory to the above-mentioned studies in case of Romanian as among the analyzed 25 countries in the latter, the top five countries in terms of E3 efficiency are China, Oman, Bahrain, Romania and Poland, respectively. The in-depth analyze demonstrates Brazil, Malaysia, Poland and Romania are the most efficient countries in the panel in the energy and economic efficiency, but not in the environmental efficiency.

As many researchers underlined the primary and final energy consumption have a severe and negative effect over the environment due to the polluting effect, the authorities should aim at increasing the productivity of sectors using this primary resource. Zaharia et al. (2019) found the most relevant factors with a positive correlation with both types of energy were the greenhouse gas emissions, gross domestic product (GDP), population and labor growth. By contrary, factors such as the increase of energy taxes, healthcare expenditures, research and development (R&D) funding or the proportion of female decision makers influence negatively the consumption of the energy. The study shows a 1% increase of GDP led to an increase of primary energy consumption between 0.32% and 0.38% during the period 1995–2014 depending on the model used. Corroborated with other data provided by specialized agencies (International Energy Agency, 2019; U.S. Environmental Protection Agency, 2022) the influence of GHG emissions on the energy consumption according to the same research (the models showed a 1% growth of GHG emissions led to an increase of the primary energy consumption by 0.75%–0.80% in the period 1995–2014) will palpable determine a spiral with the undisputable result which is the environment degradation.

Another important source of GHG emissions is the agriculture (about 23% of the anthropogenic GHGs), mainly through the process of ruminant enteric fermentation of livestock, which issues a volume between 12% and 18% to the total GHG emissions resulted from human activities. Besides CO2 emissions livestock production has some other negative effects on the environment, especially water footprint, water pollution and water scarcity (González et al., 2020).

2. Research methodology

In order to determine patterns of the greenhouse gas and its influence factors, 4 annual variables were selected besides GHG emissions per capita for 27 countries of Europe Union for period 2013 – 2019 based on EUROSTAT database (EUROSTAT, 2022):

- GDP per capita;
- R&D per capita;
- Fossil energy materials per capita;
- Red meat production per capita.

Using these variables, Pearson correlation has been calculated considering bivariate correlation between GHG emissions and each of the 4 variables on following formula:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (1)$$

where x_i and y_i are the values of those two variables and $\overline{x}$ and $\overline{y}$ are the mean of the values of *x* and *y* variables. The correlations between GHG emissions and the rest of 4 variables on each country for 2013-2019 period are represented in table no 1.

Classification implies the formation of clusters of statistical units according to the degree of similarity between them, taking into account the characteristics to be studied. The hierarchical classification method seeks to obtain more agglomerations in size and as homogeneous as possible. Ward's varied hierarchical classification method evaluates the distances between two agglomerations and is based on maximizing class variability and minimizing variability within classes. Using this method based on Squared Euclidean distance, homogenous groups of countries related to the correlation between different factors to GHG have been created. By applying this technique on selected data, four clusters were defined. (fig. no. 1)

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3. Results and discussion

The table no. 1 illustrates a comparative overview of correlations between the anthropogenic GHG emissions and their main determinants for all EU countries, during the period 2013-2019.

From the table we can observe that the countries with high level of GDP per capita have a strong negative correlation between the GDP per capita and the volume of GHG emissions, being situated on the downward part of the EKC. At the contrary, countries with a developing economy or in transition to innovation driven economies have strong positive correlation, as situated on the upward part of the EKC. The strongest negative correlation is registered in case of Germany (-0.953), Malta (-0.88), Netherlands (-0.878), France (-0.852), Luxembourg (-0.82), Denmark (-0.815), the strongest positive correlation in case of (Czechia (0.986), Lithuania (0.944), Hungary (0.88), Poland (0.817). Romania is still situated on the upward part of the EKC with a correlation coefficient of 0.574 while Finland, Latvia and Bulgaria have almost no correlation between the GDP per capita and GHG or a very small correlation.

Similar findings are noticed in case of the variable R&D per capita, where developed countries with higher level of expenditures in research, development and innovation generate less anthropogenic GHG emissions the more expenditures with R&D they have. The negative correlation coefficients vary between -0.961 in case of Germany and -0.504 in case of Estonia and positive correlation coefficients between 0.57 in case of Latvia and 0.938 in case of Czechia. Portugal and Slovakia register very small correlations between the R&D expenditures and GHG emissions volumes.

Table no. 1. Correlations between the anthropogenic GHG emissions and their most important determinants (Pearson coefficient and clusters)

Country	GDP_per capita	R&D_per capita	Fossil_energy_materials_ per capita	Red_meat_ production_ per capita	CL4	CL3	CL2
Belgium	-0.612	-0.594	0.247	0.632	1	1	1
Denmark	-0.815	-0.780	0.778	0.813	1	1	1
Germany	-0.953	-0.961	0.964	0.916	1	1	1
Ireland	-0.224	-0.475	0.376	0.061	1	1	1
Greece	-0.629	-0.865	0.939	0.877	1	1	1
France	-0.852	-0.844	0.932	0.160	1	1	1
Italy	-0.273	-0.414	0.921	0.493	1	1	1
Malta	-0.880	-0.301	-0.284	0.910	1	1	1
Austria	-0.476	-0.568	0.533	0.326	1	1	1
Sweden	-0.426	-0.494	-0.336	0.854	1	1	1
Bulgaria	0.103	0.320	0.968	0.252	2	2	2
Poland	0.817	0.735	0.552	0.848	2	2	2
Romania	0.574	0.646	0.703	0.714	2	2	2
Croatia	0.494	0.342	0.200	0.053	2	2	2
Cyprus	0.402	0.301	0.621	-0.217	2	2	2
Latvia	0.120	0.570	-0.051	0.143	2	2	2
Lithuania	0.944	0.773	0.799	0.666	2	2	2
Portugal	0.275	0.189	0.813	0.133	2	2	2
Slovakia	0.299	0.093	-0.061	0.141	2	2	2
Finland	0.048	0.288	0.546	-0.220	2	2	2
Czechia	0.986	0.938	-0.609	-0.872	3	2	2
Hungary	0.880	0.739	-0.720	0.905	3	2	2
Slovenia	0.487	-0.610	-0.884	0.680	3	2	2
Estonia	-0.318	-0.504	0.808	-0.558	4	3	1
Luxembourg	-0.820	-0.919	-0.494	-0.866	4	3	1
Netherlands	-0.878	-0.899	0.819	-0.803	4	3	1
Spain	-0.359	-0.481	0.931	-0.312	4	3	1

Source: authors' calculation based on EUROSTAT database, extracted on 26.02.2022

Regarding the red meat production per capita and fossil energy materials per capita we can notice there are mostly positive correlation coefficients or small correlations with GHG emissions, strong negative correlations occurring in case of only 3 countries as to the fossil energy materials per capita, Slovenia (-0.884), Hungary (-0.72) and Czechia (-0.609) and also only 3 countries as to the red meat production per capita: Luxembourg (-0.866), Czechia (-0.872) and Estonia (-0.558). Almost no correlations occur for Latvia (-0.051, fossil energy materials per capita), Croatia (0.053, red meat production per capita), Ireland (0.061, red meat production per capita) and Slovakia (-0.061, fossil energy materials per capita). The strong positive correlation coefficients vary between 0.533 (Austria) and 0.964 (Germany) regarding the fossil energy materials per capita and between 0.632 (Belgium) and 0.916 (Germany) regarding red meat production per capita. This finding demonstrate that increasing the consumption of fossil energy materials and the production of red meat will generate more volumes of GHG emissions for the most part of countries.

According the resulted Dendrogram using the Ward Clustering the authors identified 4 significant clusters (cutting the tree at a distance of 5, fig. no. 1 and fig. 2).

There is a cluster of high developed countries (Germany, France, Denmark, Ireland, Greece, Italy, Belgium, Austria, Sweden, Malta) which showed negative correlations between GDP per capita, R&D per capita and GHG emissions per capita, we have a second cluster with Bulgaria, Poland, Romania, Croatia, Cyprus Latvia, Lithuania, Portugal, Slovakia and Finland, where we can notice almost only positive correlations between all variables and GHG emissions, with the exception of Latvia, Slovakia (almost no correlation between fossil material consumption per capita and GHG emissions), Cyprus and Finland (small negative correlation between red meat production per capita and GHG emissions), the third cluster formed by Czechia, Hungary and Slovenia, a less homogeneous cluster with a negative correlation between the fossil material consumption and GHG emissions and the fourth cluster with Estonia, Luxembourg, Netherlands and Spain where there are strong negative correlations between 3 or 4 variables and GHG emissions, In case of Luxembourg all analyzed variables have negative correlations with GHG emissions.

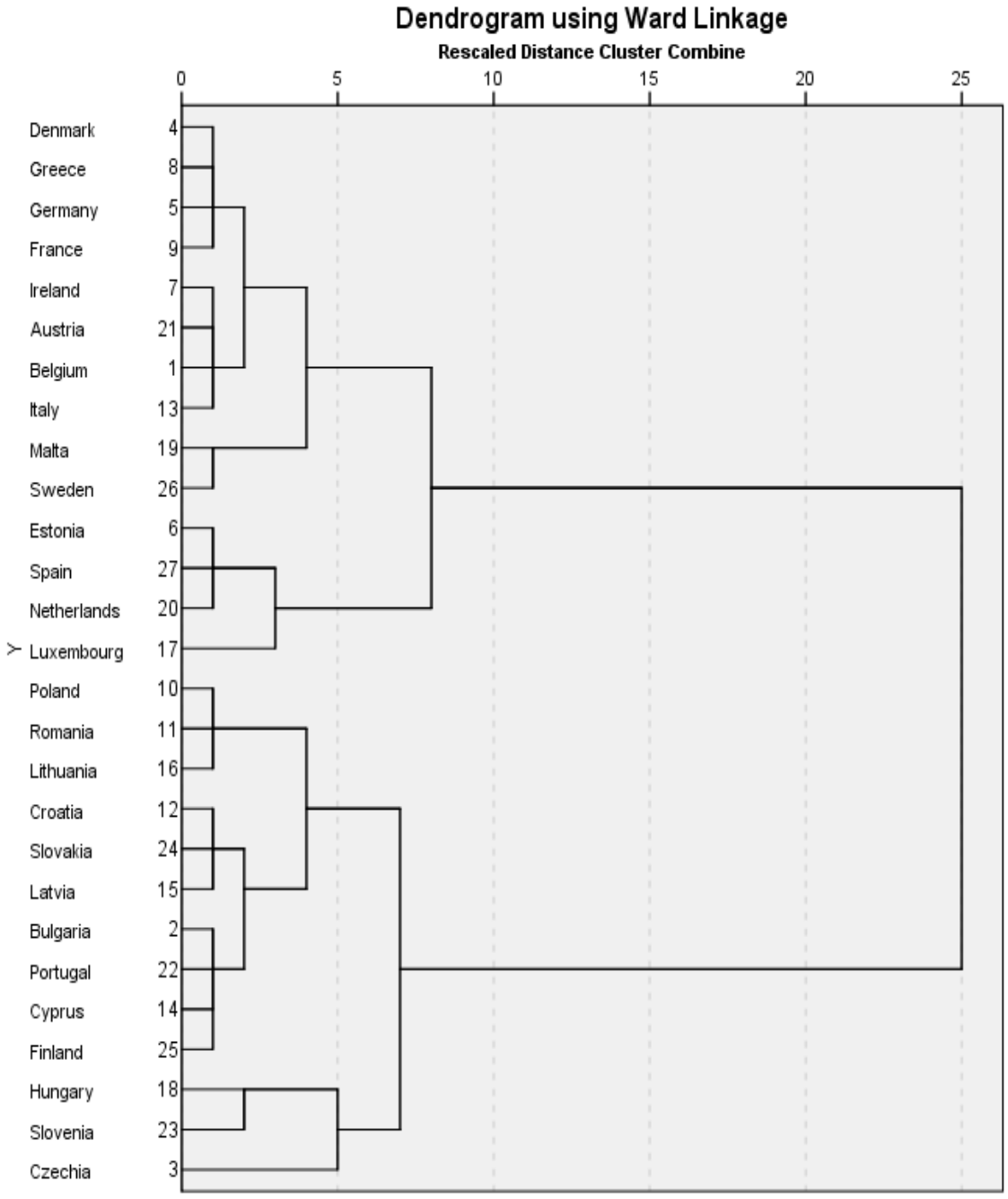

Figure no. 1. Grouping similar countries in clusters
Source: authors' calculation based on EUROSTAT database, extracted on 26.02.2022

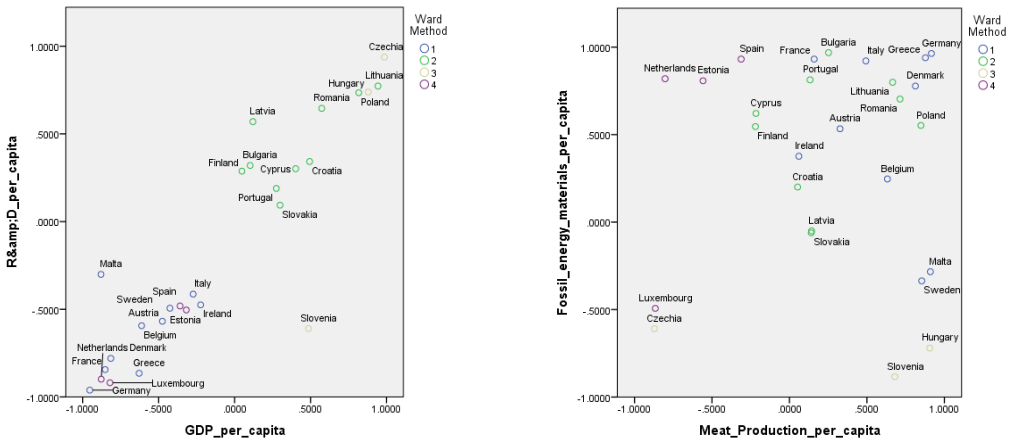

Figure no. 2. Projection of countries on the 4 indicators used in clustering
Source: authors' calculation based on EUROSTAT database, extracted on 26.02.2022

Conclusions

Starting from the scientific hypothesis and applying the announced research methodology, the authors found that H1 hypothesis is confirmed, countries with a high level of income per capita and R&D expenditures per capita generate less GHG emissions and vice versa, confirming also the validation of the U-inverted EKC, which is acknowledged by environment specialists.

The H2 hypothesis is partially confirmed as with only a few exceptions our findings show medium or strong correlations between both variables (domestic fossil material combustion and red meat production) and the level of GHG emissions. Given the fossil material price increase beginning with 2021 and the effect of pollution countries should look after renewable energy sources with no impact on the environment and better use of waste as a secondary material (Bran et al., 2021). Regarding the red meat influence on the GHG emissions and population health – carcinogenic risk (prostate, breast, hepatocellular and colorectal cancer), diabetes, chronic kidney, cardiovascular and metabolic diseases, abdominal obesity, shorter life expectancy in high and middle income countries, the authorities and private actors should move their interest into producing more fish, poultry, fruits and vegetables in order to satisfy the need for food (González et al., 2020). This can be eventually achieved supplementary to the market demands by retargeting the funding, releasing barriers or strict regulations.

Unfortunately, data drawn from EUROSTAT regarding the GHG emissions does not contain details on 2020 and 2021, which might have been very helpful in measuring also the impact of COVID on pollution and the evolution of variables. Our research might be further extended taking into consideration this relevant period and last but not least in order to analyze more thoroughly the unfavorable influence of other important GHG determinants so that climate change effect is reduced as possible.

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