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CLIMATE CHANGE IN THE EU: ANALYSIS BY CLUSTERING AND REGRESSION

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Abstract

Climate change is often seen as the most global and complex problem the world has been facing during its current development. The emissions of harmful gases, rising temperatures, variable amounts of precipitation, the occurrence of extreme weather conditions affect all countries regardless of their geographical position and level of development. The subject and goal of this paper is to examine the impact of economic, technological and demographic determinants on CO_2 emissions in 18 EU countries in the period from 2011 to 2020. In the research are used k-means clustering and panel regression analysis. By the application of k-means clustering, 18 EU countries were grouped into 2 clusters according to the level of emissions of selected greenhouse gases (CO_2, CH_4, HFC, PFC, SF_6) per capita. In the "green cluster", there are the following countries: Czech Republic, Germany, Austria, Poland, Belgium, Ireland, and Netherlands. The "red cluster" includes the other analyzed EU countries. The results of the panel regression model in the "green cluster" showed that CO_2 emissions are statistically significantly and positively influenced by Energy efficiency and Production of electricity by solid fossil fuels. On the other hand, the results of the analysis in the "red cluster" suggested that Research and developments costs turn out to be the most important predictor of CO_2 emissions.

Keywords: carbon dioxide emissions, social factors of climate change, energy efficiency, modern technologies, renewable energy sources, demographic trends

1. INTRODUCTION

Climate changes more general way represent the implications of abiotic and biotic set of processes and are reflected in statistically significant changes in climate parameters over longer periods. Various determinants cause climate changes. Biotic determinants coming from eco-system processes (non-anthropogenic factors), or from indirect and direct world population activities (anthropogenic factors). Current

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public view of climate change is that occur as a result of world population activities in the biosphere, that is, change of climate in more narrow sense. The article 1 of the United Nations Framework Convention on Climate Change (UNFCC) defines climate change "as changes in the climate, directly or indirectly related to human activities, which change the composition of the air and which can be detected in the observed period, independently of natural variations of climate parameters" (United Nations, 1992).

Research shows that extreme weather events, such as droughts or heavy rainfall and floods, have become much more frequent in recent decades. According to the official report of the Intergovernmental Panel on Climate Change (IPCC), by the end of the 21st century, the global temperature will rise from two to five degrees. The change in temperature will cause the increasing the number of weather difficulties, numerous biological species will disappear, ecosystems will be exposed to changes under the influence "environmental shock" (IPCC, 2007) etc. Such climate changes require serious adaptation.

High-income countries must take the lead in reducing greenhouse gas emissions. They cannot continue to unsustainably exploit a large part of the shared atmospheric wealth. On the other hand, low-income countries need growth in areas such as: energy and transportation systems, agriculture, etc. If this extremely necessary growth is achieved with high-carbon technologies, it will cause an increasing carbon dioxide emissions, and therefore climate change. Fossil fuels are hardly irreplaceable, because not enough efforts have been made to find alternatives. At a time when in the world, subsidies for fossil fuels – motor gasoline, diesel fuel, petroleum gas, etc. amount about 150 billion dollars per year, public expenditures for research and development in the field of energy are, for decades, around 10 billion, except for a short growth after the oil shock of 1974. On the other hand, private consumption (or private expenditures) for research and development in the field of energy, goes from 40 to 60 billion dollars annually, and accounts for 0.5 percentages of the total costs of research and development of the private sector in the world (IEA, 2008a).

The commitment of high-income countries to reduce emissions of harmful gases into the atmosphere and to control them could encourage the development of new technologies in energy, transport, and industry. A big and foreseeable demand for alternative technologies will decrease prices and improve competitiveness. The use of modern technologies at competitive prices can climate change be stopped without sacrificing economic development. Realistically, there is space for the transition of underdeveloped countries to the trajectory of a carbon-neutral economy (Kukla-Gryz, 2009). However, these countries do not have equal opportunities in the area of climate change mitigation and adaptation. They depend on the ability of rich states to give adequate financial and technical aid. The providing such support would be fair, because low-income countries contribute only slightly to global warming; they must be given the opportunity to develop even if it means increasing the emission of harmful gases (Giddens, 2009).

The aim of this paper is to investigate which demographic, economic and technological factors have the greatest impact on climate change in selected countries. The paper is organized as follows. After the introduction, the second part of the paper provides an overview of the literature on the subject of research. The third part describes the theoretical framework of the research. In the fourth part, the methodology, that is, the theoretical assumptions of the panel regression model, is presented, the variables and statistical-econometric tests, that will be used for data analysis, are defined etc. The fifth part presents the results of the research. In the conclusion, recommendations for economic policy makers and further research are given.

2. RELATED LITERATURE

Climate change as a subject of scientific research, mostly focused on weather observations, has a history of several centuries. The first data on a global scale, collected by meteorological observations, comes from ships of the Royal Navy of the United Kingdom. In a certain sense, the works of art created in the medieval period give a rough picture of the phenomenon of climatic influences at that time. For the man of the Renaissance period, climate was a physical phenomenon whose mechanism of action had to be deciphered. However, the work of figuring it out was not done systematically until 1719, when Charles Montesquieu sent invitation to scientists from different states to conduct a research to determine the physical history of the planet, including natural history, geography, geology and climate. The goal was to investigate the changes that occur because of human activities (Bok, 2018).

The first scientist who linked widespreaded effect of greenhouse and the carbon is the Svante Arrhenius (1859-1927) – the scientist from Sweden. Arrhenius foresaw shining upcoming days for world population, thanks to the changes that occur due to the greenhouse effect. According to the views of this scientist, expressed in the book "The Evolution of the Worlds" in 1910, the increasing the emission of carbon dioxide into the air gives the hope to humanity for times with higher temperatures, especially in the colder parts of the Earth, whereby these periods will lead to better crop which will allow the population to grow faster than ever (Wisniak, 2002).

Scientific observations came to the fore thanks to maritime ventures to the North and South Pole, whose discussions fascinated a large part of the world's population, especially the population of the Northern Hemisphere. Scientists from Europe mostly dealt with these issues. However, climate changes have global characteristics and rising temperature affect the occurrence of droughts not only in Africa but also in the Northern Hemisphere, affecting the possibilities of economic prosperity of Scandinavian and Siberian regions. The earliest attempts to model change of the global climate date back to the establishment of the Intergovernmental Panel on Climate Change at the United Nations. The complexity of the project continuously led to efforts to create a universal model of climate change, but each model, that was created, was limited to a certain set of criteria (Auffhammer et al., 2020; Dosio & Panitz, 2016).

In the continuation of the literature review, an overview of empirical papers that have already investigated the determinants, that are the subject of observation in this paper, is provided. We focus on papers that investigate the connection between carbon dioxide emissions, which represents the dependent variable of the econometric model and an indicator of climate change, on the one hand, and various deterministic variables such as: electricity production, population size, social policy measures, and so on, on the other hand.

Voumik et al. (2022) investigated the impact of electricity production sources on CO_2 emissions in member countries of the Association of Southeast Asian Nations, for the period from 1971 to 2020. They used the ordinary least squares method, panel models with fixed and random effects, and generalized methods of moments. The result of a panel model with a fixed individual effect shows that the Electricity produced by coal has the strongest influence on CO_2 emissions, followed by the variable Electricity generated by hydroelectric sources. The variable Electricity produced by oil has a somewhat weaker influence, while CO_2 emissions are least affected by Electricity produced by renewable sources and Electricity produced by natural gas.

In a similar empirical work, Mahapatra & Irfan (2021) examine the impact of energy efficiency on the carbon dioxide emissions of 28 developed countries and 34 developing countries in the short and long term. For this purpose, the autoregressive distributed lag model was used. The asymmetry between developed and developing countries regarding the impact of energy efficiency on carbon dioxide emissions in the long term is evident (statistically significant). Regression coefficients indicate that if energy efficiency increases by 1%, carbon dioxide emissions will decrease on average by 1.24 and 1.1 in developed and developing countries, respectively. If energy efficiency decreases by 1%, carbon dioxide emissions will increase by an average of 0.37% and 1.06% in developed and developing countries, respectively. Finally, the authors conclude that there is no statistically significant asymmetry between developed and developing countries when it comes to the influence of efficiency of energy on emissions of CO_2 in short term.

Numerous research have analyzed the impact of demographic trends on CO_2 emissions. Thus, Petrović et al. (2018) discovered a statistically strong positive impact of population growth on CO_2 emissions in 28 EU member states. This research was conducted on the basis of the logarithmic and incrementally extended STIRPAT model by estimating standard models with random error components on an unbalanced panel sample. According to the results of this analysis, the increasing population by 1% leads to increasing CO_2 emissions between 0.74% and 1.02%. In addition to the mentioned demographic variable, this study also uses economic determinants: GDP per capita and energy intensity. The obtained results show that in the short term, a partial increasing GDP per capita and energy intensity by 1% leads to increasing the growth rate of CO_2 emissions in the range between 1.10% - 1.15% and 1.07% - 1.09%, respectively.

Hashmi and Alam (2019) conducted a similar study in a sample of 29 industrialized countries for the period from January 1999 to November 2004. The using multiple regression, they showed that population was statistically significant and positive for every country in the sample. Real GDP per capita was positive and statistically significant for 12 countries in the sample, environmental tax revenue per capita was negative and statistically significant for 16 countries in the sample, while the variable non-environmental patent count was statistically significant and positive for five countries in sample.

Other authors explore the connection

between social policy and climate change. For example, Bergquist et al. (2020) assess the impact of 40 different climate, social, and economic policies on support for climate reform. They find that climate policy packages that include social and economic reforms, such as a minimum wage of $15 an hour or a safe workplace, increase public support for climate change mitigation in the United States. Energy standards, application of modern technology, also, increase the popularity of climate policy.

3. THEORETICAL FRAMEWORK OF RESEARCH

In the last few decades, we have witnessed more and more obvious climate changes. Previously, the climate changed exclusively as a result of changes in natural circumstances, while with the development of industry and population growth, human factors take over the primacy. It is believed that in the near and further future the influence of human factors will increase and that its consequences will be mostly unfavourable for people's lives. In the continuation of the paper, the most important economic, demographic and technological determinants of climate change, that we analyse in the empirical part of the paper, are presented.

3.1. Emissions of greenhouse gases

Global greenhouse gas emissions resulting from human activities have been increasing since pre-industrial times. The current level of greenhouse gases in the atmosphere is equal to approximately 430 parts per million (ppm) of CO_2, compared to only 280 ppm before the industrial revolution. This concentration has already caused the warming of the planet by more than half a degree Celsius, and due to inertia in the climate system it leads to further warming of at least half a degree over the next few decades.

Consider Figure 1. Global warming of 2 degrees relative to pre-industrial times corresponds to level (or concentration) of greenhouse gases in the atmosphere of 450 ppm CO_2e. As we can see, we are slowly approaching to the current level (450 ppm CO_2e). If the goal is to stabilize greenhouse gas concentrations at 450 ppm CO_2e, then greenhouse gas emissions, starting from today until 2100, must be lower than 2,100 Giga (billion) metric tons of carbon dioxide (Banuri & Opschoor, 2007).

Given that total emissions of carbon dioxide (from fossil fuel use, deforestation and other human activities) alone amount 35 GtCO_2 (today), the level of greenhouse gases in the air of 450 ppm CO_2e will be reached for 60 years, if CO_2 emissions continue to grow at the current rate. If we choose a higher target, say the concentration of 550 ppm CO_2e, then total greenhouse gas emissions will reach 3700 GtCO_2 by the end of this century (21st century) (Stern, 2006).

To consider the challenges of stabilizing greenhouse gas concentrations at the level of 450 ppm CO_2e, it is advisable to use the equation 1 (Bierbaum et al., 2007):

$$C = P\,(Y/P)\,(E/Y)\,(C/E) \tag{1}$$

where is:

C - carbon dioxide emission,
E - energy consumption,
Y - gross domestic product,
P - number of population,
E/Y - energy intensity of GDP,
C/E - carbon intensity.

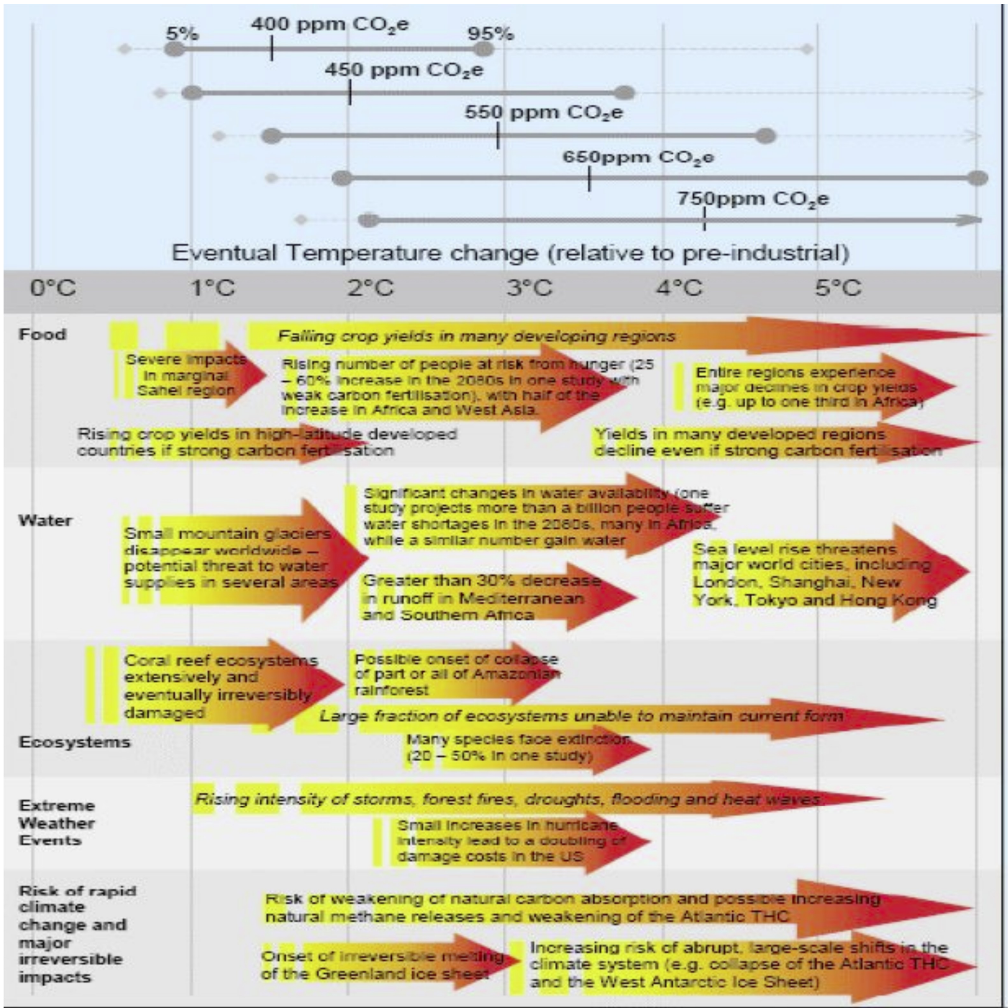

Figure 1. Possible consequences of climate change (Source: Stern, 2006)

From the equation, it follows that for the reduction CO_2 emissions in the atmosphere is necessary to decrease in one or more listed items (indicators):

1. Number of inhabitants. Reducing the growth of population will lead to a proportional decrease in carbon dioxide emissions, and not to affect consumption (welfare individuals), energy efficiency or carbon intensity.

2. Gross domestic product. A slowdown in the growth of gross domestic product would also lead to a proportional reduction in CO_2 emissions.

3. Energy and carbon intensity. Investments in energy-efficient production, switching to alternative fuels, changes in the way of land cultivation, and so on would implicate the decrease in CO_2 emissions both per unit of energy produced and per unit of energy used. Also, where possible, the consumption and production patterns, that characterized lower energy and carbon intensity, would contribute to achieving a balance between economic growth and carbon dioxide emissions (Bierbaum et al., 2007).

3.2. Economic, technological and demographic factors of climate change

Climate change causes huge costs. Lower costs of climate change mitigation mean high costs of adaptation to climate change and high losses. Also, people must compare the cost of our actions with the cost of our inaction. Such comparisons are complex due to the high degree of uncertainty, because it is not known: what technologies will be available in the future?, what will their prices be?, what will be the ability of ecosystems to adapt to changing climate conditions (and at what cost)?, and, finally, which degrees of temperature have the meaning of a critical threshold (or limit value) that humanity must not exceed if it wants to develop in a safe ecosystem, i.e. to avoid sudden, non-linear, potentially catastrophic and hard-to-predict changes in the environment.

Both problems, climate change mitigation and adaptation to climate change, are very serious. However, these problems can be solved with a smart, inclusive and sustainable climate policy that requires from us to act fast, together and in a different way. It is necessary to act quickly, because the climate system is characterized by great inertia. We need to act jointly to decrease expenditures and save the most vulnerable. Also, we need to significantly change our way of life and adapt it to "climate-smart world" that seeks for restructuring of energy systems, food production systems and risk management systems.

Climate is an internal system. When carbon dioxide and most other harmful gases enter the atmosphere, they remain in it for a long time, and it takes time for the reduction of emissions to affect the concentration of harmful gases. Also, there is a time lag between the concentration of gases in the atmosphere and the temperature. The temperature will continue to rise in the coming centuries after the concentrations of greenhouse gases stabilize (Barnett et al., 2015).

The dynamics of the climate system do not allow delaying mitigation and adaptation measures. Namely, in order not to increase the temperature by more than 2 degrees (which is considered an excessive increase in order to avoid the catastrophic consequences of global warming), it is necessary that the global emission of gases be reduced by approximately 1.5 percentages per year. On the other hand, if we delay a large reduction in emissions for five years, that delay must be compensated by faster reductions. Longer delays are generally not refundable (World Bank, 2010).

3.2.1. Inertia in the human environment

Inertia is also present in the human environment, the so-called "third nature", which has practically nothing to do with the habitats of animals and plants. This is an anthropogenic environment built by humans. It includes residential and non-residential premises, industrial complexes and other facilities. Investments in infrastructure require huge resources; they are concentrated in time, not uniformly distributed. Infrastructure objects have a long lifetime: from 15 to 40 years for factories and power plants, from 40 to 75 years for highways, railways and power distribution networks (Shalizi & Lecocq, 2009).

The inertia of physical capital cannot be compared to the inertia of the climate system. The possibilities of transition from high-carbon to low-carbon funds of (physical) capital are unevenly distributed in time (Shalizi & Lecocq, 2009). The number of thermal power plants that will be built all over the world in future is so large that the volume of CO_2 that will be emitted due to the exploitation of these thermal power plants can be compared with the volume of gas emissions from all forms of activity that are related to the burning of coal since the beginning of the industrial era. Thermal power plants that are located close enough to the storage (carbon dioxide) can subsequently be equipped with technology for sequestering carbon and storing it.

Inertia is also present in the area of research and development. For new technologies to be quickly released and introduced to the market in the near future, significant investments in research and development are necessary. This will require an additional 100 to 700 billion dollars per year (Nemet & Kammen, 2007). Also, it is necessary to introduce innovations in transport, construction, water resources management, organization of the economy and in many other areas that are threatened by the impact of climate change. Also, innovation is an important factor in adaptation to climate change.

When estimating the costs of mitigating the consequences of climate change, many economic models assume that emissions reductions occur "where" and "then" costs are lowest. "Where" means the possibility of choosing the most energy-efficient and economical measures for mitigating and adapting to climate change (in an economic sector or in a country). "Then" refers to choosing the right timing for investments in equipment, infrastructure or projects, for example, in agriculture and forestry that would minimize environmental costs (World Bank, 2010).

3.2.2. Insurance in conditions of climate change

Analysts agree that countries have enormous benefits from climate change mitigation and adaptation. In the case that a country or group of countries refuses to take such measures, all others will have to choose expensive financial instruments in order to achieve the main goal of the UN Framework Convention on Climate Change: the reduction of global emissions of harmful gases by at least 5% compared to the emission of 1990 year. Furthermore, delaying the mitigation of the consequences of climate change due to a lack of financial resources will only increase the costs of stabilizing global warming at 2 degrees Celsius (Hoegh-Guldberg et al, 2019).With mitigation costs estimated to add up to $4 trillion to $25 trillion over the next century, the losses due to delaying mitigation are so significant that it exists obvious utilities for developed states from financing projects in underdeveloped countries that reduce greenhouse gas emissions (Franta, 2022).

However, active action to reduce risk will never lead to its complete elimination, because the new residual risk always appears, which can also be controlled with the help of improved instruments for responding to the consequences of global warming. From this follows the conclusion that the development of countries, regions, etc. should be approached differently, emphasizing climate and weather risks. In this sense, greater efforts aimed at improving the quality of climate information and spreading experiences that are important in limiting and mitigating an increasingly variable and unpredictable climate are necessary.

Insurance is another climatic risk

management instrument, but it has its own limitations. Climatic risks influence while regions or big social entities at the same time, which, of course, makes insurance more difficult. Those risks depend on the magnitude and rate of warming, geographic location, level of development and vulnerability, as well as the selection and implementation of adaptation and mitigation measures. Future climate-related risks could be reduced by increasing and accelerating far-reaching climate change mitigation implemented at more levels and across more different sectors simultaneously, and through both the incremental and transformational adaptation.

However, even with insurance, specific individuals, local communities, companies, etc. they cannot cover damage caused by catastrophic natural events. In the conditions of climate change, governments will increasingly have the function of "insurance company of last instance" as well as implicit responsibility for eliminating the consequences of emergency situations and implementing reconstruction after natural disasters. Therefore, governments need to preserve their own liquidity in times of crisis.

Insurance can be provided by the mechanisms of regional integration groups and reinsurance funds. For example, 16 Caribbean countries have established the Caribbean Disaster Risk Insurance Fund. However, such funds need the assistance of the leading governments of the world. In other words, states with high incomes have a decisive role in repairing damage from natural disasters in countries with low income through the support of such funds or through direct financing.

3.2.3. Social policy and energy efficiency

Social policy reduces economic and social vulnerability and increases the resilience of the region, community, household, economic sector, etc. to the impacts of climate change. A healthy, educated and well-organized population that has access to large financial resources can fight climate change more easily (Iqbal et al., 2019). Already existing social policy measures should be improved and also implemented if not present. The establishing a social protection system in countries where it does not yet exist is a vital necessity. Development agencies could help spreading successful models of social safety nets and adapt them to the new needs created by the changing climate.

Even when financing is available, the question is: can emissions be reduced enough without the risk of slowing economic growth? Many models show that this is possible (Barnett et al., 2015). A significant increase in energy efficiency, more rational management of energy consumption, widespread use of existing energy sources with low CO_2 emissions can lead to a 50 percent reduction in gas emissions, which is necessary to prevent climate change.

Already known technologies and methods (practices) can enable us to gain time, only in case of their wide application. That is why it is absolutely necessary to introduce appropriate electricity prices. Further, reducing subsidies and increasing taxes on petroleum products is a politically unpopular "move", but the recent explosion in oil and gas prices indicates that the present moment is just the right time to do so. Really, states of Europe took advantage of the second oil shock from 1974, to impose high taxes on fuel (Kilian & Vigfusson, 2017). As a result, demand for fuel was half of what it might have been if prices had been similar to those in the United States.

The price determination is only one of the instruments that can improve the energy efficiency program. Legislative reform and financial incentives are also necessary and cost-effective. Efficiency standards and classification or label programs that confirm the source of energy that homes used in their consumption cost only around 1.5 cents per kilowatt-hour. It is much cheaper than any other electricity supply option. Let's also say that energy efficiency goals in industry stimulate innovation and increase competitiveness (Zhou, 2018).

3.2.4. Technology

All energy models indicate that it is impossible to achieve the 2°C trajectory only with energy efficiency and the diffusion of existing technologies (World Bank, 2010). New technologies, which are under development, such as: technologies for extracting CO_2, second generation biofuels, etc. are also important.

Current technologies for capturing and storing carbon dioxide from the air only store about 4 million tons (per year). In order to prove the efficiency and sustainability of these technologies, about 30 plants with the biggest capacity will be needed. It is necessary to provide storage capacities of 1 billion tons of CO_2 per year by 2030 in order to limited global warming to 2 degrees Celsius (IEA, 2008b).

It is also necessary to invest in research into second-generation biofuels. The expansion of production that uses first-generation biofuels can lead to the destruction of large forest areas and threaten the production of food products. On the other hand, second-generation biofuels can compete less with agriculture if less fertile land is cultivated in the production of this product. However, the production of second-generation biofuels leads to the destruction of pastures, village meadows, water resources, and so on (Đokić, 2022).

The development of new technologies for mitigating and adapting to the consequences of climate change requires higher costs for research and development. As pointed out in introduction, global public and private spending on research and development new energy is humble, both in relation to estimated needs and in relation to large government investments in innovation in areas such as: telecommunications, pharmaceutical industry and so on. Only 0.4 percent of patents in the world refer to renewable energy (World Bank, 2010). Moreover, countries with low income need access to these innovations (climate-smart technologies). This will require the strengthening of national capacities for the discovery and adaptation of technologies, as well as the strengthening of international mechanisms for technology transfer. It is essential to allow countries with low income to avoid the pattern regulations.

3.2.5. Demographic factors - population growth, poverty and education

The daily activities of all people, local communities, regions, country are related to demographic changes, the structure and level of use of natural resources, the state of the environment, and the dynamics and qualitative aspects of economic and social development (UNPF, 2014). Widespread and persistent poverty and serious challenges related to social inequality and gender inequality significantly affect the growth, structure and distribution of the population.

Regardless of the indicators that indicate that the birth rate has decreased in many countries, an increase in the number of inhabitants is unavoidable. Due to the young age structure, the coming decades will bring a significant increase in the population of many countries. Population mobility within and across states, including the quick growth of towns and the uneven dispensation of people in regions, will continue and increment in the upcoming times.

The goal of the state should be the full inclusion of demographic factors or determinants: 1) in strategy, planning, making decisions in the area of development and distribution of limited resources at all levels in order to meet the demands and increase the standard of living of current and future world population, 2) in all spheres of social and economic development planning, which would affect the achievement of social justice and the elimination of poverty through sustainable economic growth.

In addition to high demographic growth, widespread poverty remains a leading challenge to development. It is associated with unemployment, malnutrition (poor nutrition), illiteracy, exposure to environmental risks, etc. All of these mentioned factors affect fertility and mortality, and cause a low rate of productivity. Poverty is also closely related to uneven spatial distribution of population, uneven distribution of natural resources such as land, water, etc., as well as serious environmental degradation (UNPF, 2014).

Investments in areas important for poverty reduction, such as schooling, sanitary conditions, water, food, and infrastructure that are needed for rapid population growth, are a serious burden on a country with low income and limit development opportunities. An unusually high share of youth in the total population in some countries, as a result of rapid population growth, requires the creation of new jobs. The number of old people will grow faster and will require state support. That is why sustainable economic growth is needed in the context of sustainable development.

Education and demographic changes are interdependent (Gawel & Krstić, 2021). Education is also closely related to: the average age at marriage, the births, the mortality and the like. The increasing the level of education among women and girls improves gender equality, reduces the average age at marriage and reduces the number of family members. The reducting family size has a positive impact on CO_2 emissions that cause climate change (Cole & Neumayer, 2004). Larger families can achieve benefits in terms of transportation, use of space and energy consumption (Petrović et al., 2018). In general, demographic trends are among the most important factors of climate change and greenhouse gas emissions. Thus, empirical testing of the impact of demographic trends on greenhouse gas emissions resulted in different findings. Many analyses point to the conclusion that the elasticity of the emission of the most important gas – carbon dioxide in relation to the number of inhabitants is almost unity (Dietz & Rosa, 1997; York et al., 2003; Cole & Neumayer, 2004).At the same time, Cole and Neumayer draw attention to the fact that the influence of population on CO_2 emissions has the shape of a U curve (Cole & Neumayer, 2004).

After theoretical considerations and identification of various determinants that are assumed to have a significant influence on changes of climate, the following is verified by panel econometric analysis for selected determinants.

4. METHODOLOGY

4.1. Data

Considering the availability of data, as well as the literature from the research area, the following variables were selected for the purposes of this paper: 1) Carbon dioxide emission represents climate change, because this gas is the key generator that causes the greenhouse effect and leads to the climate crisis, 2) Production of electricity by solid fossil fuels is an indicator of the inertia of physical capital in empirical analysis, 3) Expenditures for social protection illustrate the importance of social policy for the protection of citizens from the pressures and dangers associated with climate change, 4) Non-life insurance enterprises illustrate the importance of this sector in the context of the impact of climate change on the occurrence of increasingly frequent and harmful events, 5) Energy efficiency as a measure of efficient energy management, 6), Average population is a variable that approximates the impact of demographic trends on carbon dioxide emissions, and finally, 7) Research and development costs is an item in the research which symbolizes the influence of modern technology (Table 1). Since economic theory assumes constant elasticity models, log-log models are used (Tijanić, 2010).

The units of observation are 18 countries of the European Union: Greece, Spain, France, Croatia, Italy, Portugal, Slovenia, Bulgaria, Romania, Czech Republic, Germany, Hungary, Austria, Poland, Slovakia, Belgium, Ireland, Netherlands. The reason for the omission of other member countries of the European Union in the empirical analysis is the lack of official data on certain variables on the website of the European statistics office - Eurostat. The time series taken into consideration is the period from 2011 to the "the freshest" year 2020.

4.2. Constructing and selection of model

The model with we will start the regression analysis is the fixed effects

Table 1. Overview of variables

Variables	Labels	Description	The type of the variable
Carbon dioxide Emission	$lnCO_2$	Total carbon dioxide emissions in thousand tonnes (annual)	Dependent
Production of electricity by solid fossil fuels	lnEPSFF	Gross electricity productionby solid fossil fuels in gigawatt-hour	Independent
Expenditures for social Protection	lnESP	Total, expenditure in million euro (annual)	Independent
Non-life insurance Enterprises	lnCP	Turnover or gross premiums written - million euro	Independent
Energy efficiency	lnEE	Primary, annual energy consumption in million tonnes of oil equivalent	Independent
Research and development costs	lnGERD	Annual research and development costs in million euro - all sectors	Independent
Average population	lnAP	Average population - total (in million)	Independent

Source: Author's calculation

model. There are two basic variations of this model, depending on the initial assumptions, and they are: 1) the slopes of the coefficients are constant and free term (or intercept) varies across the observed units, and 2) the slopes of the coefficients are constant, and free term varies over time and depending on the individually observed units. When the free term is allowed to vary for each observed country, and the restriction is imposed by the slopes of the coefficients so that each slope is constant for the individually observed country, then the regression equation, representing this type of fixed effects model in this paper, has obtained in the following way.

$$\widehat{lnCO}_{2it} = \hat{\beta}_{1i} + \hat{\beta}_2 lnEPSFF_{it} + \hat{\beta}_3 lnESP_{it} + \hat{\beta}_4 lnCP_{it} + \hat{\beta}_6 lnEE_{it} + \hat{\beta}_6 lnGERD_{it} + \hat{\beta}_7 lnAP_{it}. \quad (2)$$

Thus, the index i stands next to the free term (more precisely, estimation of free term $\hat{\beta}_{1i}$) to suggest that the free terms (and the same is true for their estimations) for the observed countries may be different. The question is, now, how do you allow the intercept to vary the between countries? By introducing artificial variables (dummy variables), the intercept allowed to vary through the observed units. Therefore, the regression equation (2) can be written as:

$$\widehat{lnCO}_{2it} = \hat{\alpha}_1 + \hat{\alpha}_2 D_{2i} + \hat{\alpha}_3 D_{3i} + \cdots + \hat{\alpha}_{18} D_{18i} + \hat{\beta}_2 lnEPSFF_{it} + \hat{\beta}_3 lnESP_{it} + \hat{\beta}_4 lnCP_{it} + \hat{\beta}_5 lnEE_{it} + \hat{\beta}_6 lnGERD_{it} + \hat{\beta}_7 lnAP_{it}, \quad (3)$$

where D_{2i}, D_{3i}, ... , D_{18i} represent artificial variables such that if:

1) the observation belongs to the country "Spain", then D_{2i}=1, otherwise D_{2i}=0,

2) the observation belongs to the country "France", then D_{3i}=1, otherwise D_{3i}=0, and so on.

Since artificial variables are used in the the fixed effects model, in the literature this model is also called Least-Squares Dummy Variable Regression Model (Schmidheniy, 2018; Eloriaga, 2022). In order to make difference between analyzed variants of the fixed effects models (that rely on dummy variables), we used numbers. This, first variant of the model is marked the LSDV I. The results of the regression analysis in the LSDV I model showed that the value of R^2=0.9936. Also, out of 6 regressors, 3 variables are statistically significant ($P_{lnEPSFF}$=0.005, P_{lnEE}=0.023, P_{lnCP}=0.073, see the Suplement).

The next variation of the fixed effects model, which is analyzed in this paper, is called the Least-Squares Dummy Variable Regression Model II (LSDV II) (Eloriaga, 2022). In the LSDV II, it is allowed to free term vary across the countries, which was previously shown, but it is also allowed to it vary over time.

Given that all beta parameters next to the independent variables are constant, while the free terms are variable by both countries and time periods, the LSDV II is presented the following regression formula:

$$\widehat{lnCO}_{2it} = \hat{\alpha}_1 + \hat{\alpha}_2 D_{2i} + \hat{\alpha}_3 D_{3i} + \cdots + \hat{\alpha}_{18} D_{18i} + \hat{\lambda}_0 + \hat{\lambda}_{2011} A_{2011t} + \hat{\lambda}_{2012} A_{2012t} + \cdots + \hat{\lambda}_{2019} A_{2019} + \hat{\beta}_2 lnEPSFF_{it} + \hat{\beta}_3 lnESP_{it} + \hat{\beta}_4 lnCP_{it} + \hat{\beta}_5 lnEE_{it} + \hat{\beta}_6 lnGERD_{it} + \hat{\beta}_7 lnAP_{it} = \hat{\alpha}_1 + \hat{\lambda}_0 + \sum_{j=2}^{18} \hat{\alpha}_j D_{ji} + \sum_{l=2011}^{2019} \hat{\lambda}_{lt} A_{lt} + \hat{\beta}_2 lnEPSFF_{it} + \hat{\beta}_3 lnESP_{it} + \hat{\beta}_4 lnCP_{it} + \hat{\beta}_5 lnEE_{it} + \hat{\beta}_6 lnGERD_{it} + \hat{\beta}_7 lnAP_{it}, \quad (4)$$

where are:

$$D_{ji} = \begin{cases} 1, for\ j = i \\ 0, for\ j \neq i \end{cases}$$

j=2, … , 18.
i=1, 2, … , 18.

$$A_{lt} = \begin{cases} 1, for\ l = t \\ 0, for\ l \neq t \end{cases}$$

l=2011, 2012, ... , 2019.
t=2011, 2012, ... , 2020.

The obtained results of the LSDV II model point to the following conclusions. Given that $F(31,148)=721.82$ ($Prob>F=0.0000$), it can be concluded that the LSDV II is a good model. Additionally, $R^2=0.9955$ has increased compared to the previous model (the LSDV I). However, the increase in R^2 coefficient is not surprising, given the increase in the number of predictors in the model. Of the independent variables, only one in the LSDV II has a coefficient that is statistically significant ($P_{lnCP}=0.007$, see the Suplement).

Given that the number of statistically significant variables has decreased in the LSDV II, it can be said that LSDV I is better. Also, the results of comparing the LSDV I and the OLS model (the standard, multiple regression model where the model parameters are estimated using the least squares model) show that LSDV I is much better ($F(17, 113)=27.89$, $Prob>F=0.0000$). We now know that the LSDV I is better than the LSDV II and that the LSDV I is better than the OLS model.

After the creation and selection of representatives of the fixed-effect model, a panel regression analysis of the random-effect model was conducted. The obtained results showed that the coefficient of determination that refers to whole set of data is 0.9433 (see the Suplement). This means that the stochastic effects model describes 94% of the variability of the dependent variable and this is a good model because the R^2 value is greater than 0.5. Finally, the Hausman test was used, which showed that the fixed effects model with a free term that varies across the observed countries, that is, LSDV I is more adequate than the random effects model and that LSDV I should be used as the final ($\chi^2=35.15$, $Prob>\chi^2=0.0000$). However, the results of this model suggest that there is a high degree of explanation of the dependent variable with the independent variables. Also, the expected sign were not obtained for all variables (lnCP).

The correlation matrix of independent variables showed that there are correlation coefficients that are greater than 0.8 (pairs of variables are lnEE and lnESP, and lnGERD and ln ESP). All this suggests the possibility of multicollinearity in the LSDV I model. The next step is to exclude disputed variables (ln CP and ln ESP) from the model.

The relationship between the variables can now be described by the LSDV I' model:

$$\widehat{lnCO}_{2it} = \hat{\alpha}_1 + \hat{\alpha}_2 D_{2i} + \hat{\alpha}_3 D_{3i} + \cdots + \hat{\alpha}_{18} D_{18i} + \hat{\beta}_2 lnEPSFF_{it} + \hat{\beta}_3 lnEE_{it} + \hat{\beta}_4 lnGERD_{it} + \hat{\beta}_5 lnAP_{it}. \quad (5)$$

The new fixed effects model (LSDV I') was subject of appropriate diagnostic tests, and it was shown that it does not satisfy the assumption about homoscedasticity (Table 2). This leads to the conclusion that there is heteroskedasticity in the model.

In order to answer the problem of heteroscedasticity, we applied a procedure that determines HAC (heteroskedasticity and autocorrelation consistent) standard errors that are robust to the presence of heteroskedasticity. Also, this procedure gives other estimates that are, also, reliable, despite the problem of heteroskedasticity. Therefore, this procedure does not eliminate the problem of heteroskedasticity , but provides more robust estimates (Newey & Westm, 1987; Wooldridge, 2013; Greene, 2018).

4.3. Cluster analysis

The next step in statistical analysis is cluster analysis. The software clustered data refer to the emission of the most significant greenhouse gases (GHG_S) per capita in selected EU countries in 2020. For each chose greenhouse gases, the average emission per capita was determined based on the sample of analyzed countries (Table 3).

The grouping of countries into 2 clusters was performed using the k-means method. The condition for the application of the k-means method is the creation of a binary matrix "Countries-average emissions greenhouse gases", where values of fields of the matrix receive the values 0 (if the i-th country has emission (per capita) less than the average emission of the j-th GHG per capita which is determined based on the sample of selected countries) or 1 (if the i-th country has emission higher than the average emission of the j-th GHG per capita obtained based on the sample of selected countries).

Table 4 represents binary matrix "Countries-average emissions greenhouse gases". Table 5 shows the results of the k-means method in the PAST3 software.

We can see that the K-means method grouped the countries into 2 similar groups

Table 2. Testing assumptions of linear regression

Assumptions	Results
The assumption about multicollinearity Problem	The VIF coefficients of all independent variables are less than 10.
The assumption about linearity of panel data	Scatter plots (see charts 1.-4. in the Supplement) showed that there is a linear relationship individual independent variables and the dependent variable.
The assumption about normality of relational errors	The p-value in the Jarque Bera test is 0.853673 and is greater than level ofsignificance of 5%.
The assumption about homoscedasticity	The results of the Breusch-Pagan test showed that the LSDV I' model is characterized by heteroskedasticity (χ^2 = 89.01, Prob > χ^2 = 0.0000; p value is less than 0.05, so the null hypothesis of homoscedasticity was rejected).

Note: See VIFs, Scatter plots, the Jarque Bera test, and the Breusch-Pagan test in the Suplement. Source: Author in STATA 14, Eviews, and OriginPro 8.5

Table 3. Average emissions of selected GHGs per capita at level of the sample of selected EU countries in 2020

Gases with the greenhouse effect	Average emission of the GHG per capita (thousand tonnes)
CO_2	0.0057171194
$CH4\_CO_2e$	0.001029645
HFC_CO_2e	0.0002207564
PFC_CO_2e	0.000005133358
$SF6\_CO_2e$	0.0000094815

Source: Author's calculation

Table 4. Binary matrix "Countries-average emissions greenhouse gases"

	Average Emissions CO_2 per capita	**Average emissions CH_4_CO_2e per capita**	**Average emissions HFC_CO_2e per capita**	**Average emissions PFC_CO_2e per capita**	**Average emissions SF_6_CO_2e per capita**
Greece	0	0	1	1	0
Spain	0	0	0	0	0
France	0	0	0	1	0
Croatia	0	0	1	0	0
Italy	0	0	1	1	0
Portugal	0	0	1	0	0
Slovenia	0	0	0	0	0
Bulgaria	0	0	0	0	0
Romania	0	1	0	0	0
Czechia	1	1	1	0	0
Germany	1	0	0	0	1
Hungary	0	0	0	0	1
Austria	1	0	0	0	1
Poland	1	1	0	0	0
Slovakia	0	0	0	0	0
Belgium	1	0	1	1	0
Ireland	1	1	0	1	0
Netherlands	1	1	0	0	0

Source: Author's calculation

Table 5. Result of K-means clustering

Countries – Cluster 1	**Countries – Cluster 2**
	France
Germany	Italy
Poland	Spain
Netherlands	Romania
Belgium	Greece
Czech Republic	Portugal
Austria	Hungary
Ireland	Bulgaria
	Slovakia
	Croatia
	Slovenia

Source: Author in Past3

or clusters. Cluster 1 includes: Czech Republic, Germany, Austria, Poland, Belgium, Ireland and the Netherlands. We named group 1 "green cluster". Cluster 2 includes the following countries: Greece, Spain, France, Croatia, Italy, Portugal, Slovenia, Bulgaria, Romania, Hungary and Slovakia. We can name this group as the "red cluster".

5. RESEARCH RESULTS

In the continuation of the statistical analysis, a panel regression procedure was carried out over clusters 1 and 2 in the STATA software. Selected regression parameters in clusters, obtained by running the LSDV I' model through STATA software, are shown in Table 6.

In cluster 1, it can be seen that the

Table 6. Results of the LSDV I' model (with robust standard errors) for clusters 1 and 2 (selected regression parameters)

Clusters	Variables	Coef.	P > | t |	(95% Conf. Interval)	
Cluster 1	Intercept	10.66964	0.024	1.454089	19.8852
	lnEPSFF	.0175703	0.009	.004597	.0305436
	LnEE	.006501	0.000	.0049232	.0080788
	LnGERD	-.0063081	0.767	-.0487273	.0361111
	LnAP	.0301975	0.916	-.5410982	.6014933
Cluster 2	Intercept	.5437191	0.02	-47.67284	46.76028
	lnEPSFF	.0748105	0.042	.002877	.146744
	LnEE	.0054167	0.067	-.0003777	.011211
	LnGERD	-.1834652	0.085	-.3926398	.0257094
	LnAP	.6883392	0.637	-2.199952	3.576631

Note: The dependent variable is CO_2 emissions ($lnCO_2$).Source: Author in STATA

variables Production of electricity by solid fossil fuels (or by non-renewable sources), Energy efficiency and Average population have a positive sign, which is expected. Therefore, with the increase (decrease) of these regressors, there is an increase (decrease) in CO_2 emissions. On the other hand, Research and development costs have a negative sign, and it can be said that the increase or decrease of the technological variable affects the decrease or increase of CO_2 emissions, respectively. Furthermore, it is necessary to take into account the statistical significance of the independent variables. Observing the column $P>| t |$, it can be concluded that the independent variables Research and development costs and Average population are not statistically significant, given that their value from the column $P>| t |$ (in cluster 1) is greater than 0.05. The same conclusion could be drawn with a 95% confidence interval. As the coefficients of the mentioned variables have confidence intervals that include zero, it can be said that they are not statistically significant in cluster 1.

In the cluster 2, we see that Production of electricity from non-renewable sources is statistically significant at a significance level of 5%. Next, the value $P>| t |$ of Energy efficiency and Research and development costs is very close to the threshold level of significance of 5%. Also, we see that in cluster 2 Production of electricity from non-renewable sources, Energy efficiency and Average population have a positive impact on CO_2 emissions, while the technology variable has a negative impact. The LSVD I' model suggests relationships between CO_2 emissions and independent variables that are expected.

It should be pointed out that the STATA program automatically takes the first unit (country) as the reference unit, so in the LSDV I' the intercept represents the actual effect of country 1, while for the others it gives the distance from the intercept. If we want the country with the lowest CO_2 emissions to be the reference, we add the auxiliary variable Di to the LSDV I' model for every country except for the reference (country) (Table 7).

The estimated model for Ireland as a reference country in cluster 1 is:

$$\widehat{lnCO}_{2it} = 10.0467 + 0.0175703\ lnEPSFF_{it} + 0.006501\ lnEE_{it} - 0.0063801 lnGERD_{it} + 0.0301975\ lnAP_{it} \quad (6)$$

Table 7. Results of the LSDV I' model (with robust standard errors) for cluster 1 (Ireland as a reference country)

Clusters	**Variables**	**Coef.**	**P > | t |**	**(95% Conf. Interval)**	
	Intercept	10.0467	0.025	1.317987	18.77542
	lnEPSFF	.0175703	0.009	.004597	.0305436
Cluster 1	LnEE	.006501	0.000	.0049232	.0080788
	LnGERD	-.0063801	0.767	-.0487273	.0361111
	LnAP	.0301975	0.916	-.5410982	.6014933
	D1	.6229405	0.014	.0669471	1.178934
	D2	.8764463	0.320	-1.085741	2.838633
	D3	.25415	0.140	-.1258249	.6333248
	D4	1.215078	0. 055	-.2070761	2.637232
	D5	.604422	0.017	.0547778	1.154666
	D7	.9240621	0.016	.0808985	1.767226

Source: Author in STATA

For Czech Republic:

$$\widehat{lnCO}_{2it} = (10.0467 + 0.6229405) + 0.0175703\, lnEPSFF_{it} + 0.006501\, lnEE_{it} - 0.0063801 lnGERD_{it} + 0.0301975\, lnAP_{it} \quad (7)$$

From the Table 7, it can be seen that all other countries in cluster I have higher estimated CO_2 emissions compared to Ireland. Poland has the largest emission, and this result is statistically significant. After that, Netherlands, Germany, Czech Republic, Belgium and Austria follow. The estimated parameters in cluster 1 for Germany and Austria were not statistically significant.

6. CONCLUSION

The emission of gases that lead the effect of greenhouse and the phenomenon of worldwide spreaded changes of the climate have long been at the top of the priority agenda of public policy makers at the highest level. Global climate changes related to the warming of the surface of the earth, oceans and atmosphere, melting of snow and ice and so on, impose as a priority urgent and effective action in the direction of limiting and gradually reducing the emission of harmful gases.

In this paper, 18 EU countries were grouped according to the amount (level) of greenhouse gas emissions in 2020. The k-means method divided the countries into 2 clusters. Cluster 1 consists of the following countries: Czech Republic, Germany, Austria, Poland, Belgium, Ireland and the Netherlands. Cluster 2 includes 11 countries, namely: Greece, Spain, France, Croatia, Italy, Portugal, Slovenia, Bulgaria, Romania, Hungary and Slovakia.

The results of the regression analysis in cluster 1 showed that the impact of Production of electricity by solid fossil fuels is positive and significant at the 5% level. An increase in electricity production from solid fossil fuels of 1% results in an increase in the growth rate of CO_2 emissions by 0.0175703%, assuming ceteris paribus. The effect of Energy efficiency or primary energy consumption is also statistically significant. Namely, increment in the energy efficiency growth rate of 1% causes an increase in the CO_2 emission growth rate by 0.006501%, if other variables are unchanged. According to the results of this research, Research and development costs and Average population size do not have a statistically significant impact in cluster 1.

The calculations of conducted regression analyses in cluster 2 showed that Research and developments costs turn out to be the most important predictor of CO_2 emissions. It is noted that Production of electricity by solid fossil fuels and Energy efficiency have a positive effect on CO_2 emissions, as well as a statistically significant effect at the level of 5% (more precisely, Energy efficiency is very close to becoming statistically significant at the 5% level ($P>| t |=0.067$)). So, an increase in Production of electricity by solid fossil fuels by 1% would lead to an increase in CO_2 emissions by 0.0748105%, according to the fixed individual effects model.

One can speculate about the reasons for the lack of results in panel regression models. The technical specification of the LSDV I model, which implies a relatively short period of observation and a relatively large number of variables in the starting model (6 variables) can certainly be taken as the most acceptable. Problems related to the specification of certain quantities taken as input for the formation of variables can also be taken into consideration.

A fixed-effects model can be "expensive", because including auxiliary (or artificial) variables reduces the degrees of freedom. The fixed effects model is adequate when differences between individual countries can be seen as parameter shifts in the fixed effects model. In this sense, results obtained by the fixed effects model are applicable only to the units that were selected for observation, i.e. they cannot be applied to the entire population.

Based on the above research results, certain recommendations for economic policy makers in the observed countries that can contribute to mitigating the negative influence of climate change can be formulated. First of all, in order to increase energy efficiency, we advise the policy makers in the observed countries the following: the using more modern and energy efficient technology, the improvement of energy efficiency of business facilities, greater reduction of carbon dioxide in the domestic energy sector, business as much as possible according to the principle of "green economy", and so on.

In order to reduce the production of electricity from non-renewable sources and improwed technologies, we suggest to policy makers in cluster 2: the increasing total investments in renewable sources of energy, the application of incentives for domestic power engineering that guarantee the return of the costs of today's technologies, the application of incentives to support the growth of the domestic clean energy market, establishment of new centers for the research of energetic limits at universities and so on. The above recommendations for policy makers are relevant for managers as well

Future research in the area may be expanded to the level of individual countries depending on the availability of data necessary for such research. It is also possible to substitute some variables with adequate variables for better performation of analysis, longtermly.

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КЛИМАТСКЕ ПРОМЕНЕ У ЕУ: КЛАСТЕР АНАЛИЗА И РЕГРЕСИЈА

Милош Крстић

Извод

Климатске промене се често посматрају као најглобалнији и најкомплекснији проблем са којим се свет суочио у досадашњем развоју. Емисије штетних гасова, пораст температуре, променљиве количине падавина, појава екстремних временских прилика утичу на све земље независно од њихове географске позиције и нивоа развоја, детерминишући њихове производне потенцијале и квалитет животних услова становништва. Предмет и циљ овог рада је да испита утицај економских, технолошких и демографских детерминанти на емисију CO_2 у 18 држава Европске Уније у временском периоду од 2011. до 2020. године. У истраживању су коришћени метода кластер анализе к-средњих вредности и панел регресиона анализа. Применом метода к-средњих вреднсти, извршено је груписање 18 земаља Европске уније у 2 кластера, према висини емисија одабраних гасова стаклене баште (CO_2, CH_4, HFC, PFC, SF_6) *per capita*. У "зеленом кластеру" налазе се следеће земље: Чешка, Немачка, Аустрија, Пољска, Белгија, Ирска и Холандија. "Црвени кластер" укључује остале анализиране земље Европске уније. Резултати панел регресионог модела у "зеленом кластеру" показали су да на емисију CO_2 статистички значајно и позитивно утичу Енергетска ефикасност и Производња електричне енергије из необновљивих извора. С друге стране, резултати анализе у "црвеном кластеру" сугерисали су да Трошкови истраживања и развоја представљају најважнији предиктор емисија CO_2.

Кључне речи: емисије угљен-диоксида, друштвени фактори климатских промене, енергетска ефикасност, савремене технологије, обновљиви извори енергије, демографска кретања

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