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EMISSIONS, TEMPERATURE AND ECONOMIC GROWTH: AN EMPIRICAL ANALYSIS OF EUROPE

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ABSTRACT

This Paper looks at the economic and ecological behavior behind the release of greenhouse gas emissions by thirty-three countries in Europe over a time interval from 1990-2016. We use a time-series clustering analysis on the data. We find significant results between average temperature, the average change in temperature over the years, and the level of economic growth as against greenhouse gas emissions between clusters. The above exercise further helps to analyze the policy implications of different countries and the economic development in the region by proving the environmental Kuznets curve hypothesis using clustering results.

KEYWORDS: ***European Union, Time Series, Clustering, Carbon Emissions, Economic Growth, Temperature***

1. INTRODUCTION

The United Nations remark that climate change is the defining issue in today's world. Several calls have been made for immediate and drastic action to save the future. While several factors like changing weather patterns and rising sea levels have been focal points, economics and environmental policy lie at the core of addressing solutions towards climate change. With increasing population and industrialization, there has been a significant increase in greenhouse gas emissions, causing severe damage to the environment and livelihoods. On the policy front, this Paper aims to give a comprehensive review and analysis of core variables of environmental and economic behavior such as temperature and gross domestic product per capita vis-a-vis emission levels in Europe.

Specific Objectives:

- To assess the performance of countries in Europe from the period 1990-2016 on the indicators as mentioned earlier.
- To group countries based on their emission data to observe trends and behavior economically and environmentally.
- To understand the development patterns around different parts of Europe.

The Paper is organized as follows: Section 2 reviews the literature; section 3 discusses our data and methodology; section 4 explains our results and analysis, and section 5 concludes.

2. LITERATURE REVIEW

The relationship between temperature data, greenhouse gas emissions, and economic development is the focus of literature under the environmental policy regime. The Paris agreement says that emissions must

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be cut by 7.6 percent to keep the temperature increase at 1.5 degrees ("Rise in global temperature will bring more destructive climate impacts: UN report," 2019). Another study remarked that pollutants in the air increased with increased temperatures, particularly during heat waves with ozone increase of more than 50% due to an increase in temperature (Kalisa et al., 2018). On the economic front, there is a positive relationship between economic growth and CO2 emissions in sectors like electricity (Ntanos et al. 2015). Chalikias & Ntanos (2015) conducted a clustering analysis for around 140 countries and concluded that the developed countries are significant polluters where they find a high positive correlation between economic development and carbon emissions. Lapinskienė et al. (2014) give insights on the EKC hypothesis in European regions- We found that the EKC hypothesis holds for GHG and GDP from 1995-2010 in twenty-nine countries using a regression framework.

The originality factor of this research lies in the addressing of the above-reviewed indicators through time series clustering. We focus on Europe, establishing research on the correlation between the above-discussed variables and particular analysis of the environmental policy of the EKC hypothesis through time series clustering helps us to arrive at growth clusters. Mainly we look at relative change in temperature (delta) and cluster the data around it to gain more insights.

3. DATA AND METHODOLOGY

Our exercise to analyze the impact and behavior of ecological and economic variables surrounding our crucial concept of greenhouse gas emissions has been done through a time series clustering analysis using agglomerative and K-means techniques. We look at how different pockets in the region are performing by helping us to group similar performing countries. It gave us a clear indication of the different development stages in Europe and geographical development. The exercise further explains the relationship between the variables in focus. Variables for economic value assessment are GDP per capita, temperature, and change in average temperature for ecological assessment and greenhouse gas emissions as the primary variable of analysis.

The dataset comprises a time series of emission data of 33 countries in Europe from 1990 to 2016. 1990 is taken as the base year (marked as 100), and every year is a relative figure of 1990. The data source for the same is from Eurostat. The dataset also comprises the data for temperature comprising over the same timeframe taken from the European environmental agency. Data for GDP per capita (for measuring economic value impact) is from World Bank statistics for the same period.

4. RESULTS AND ANALYSIS

We perform two levels of cluster analysis to look at the behavior of emissions and temperature variables:

1. To look at the effect of temperature data, we conduct a clustering analysis of the average temperature change from 1990 to 2016. Using the hierarchical clustering process and the elbow method, we fix 3 clusters as optimal K to employ the K-means clustering method. The following were the clustering results:

Cluster	No of countries	% of the total
Cluster A	19	60%
Cluster B	7	21%
Cluster C	6	19%

The names of the countries are as follows:

Cluster A: Belgium, Czech Republic, Denmark, Germany, Ireland, Spain, France, Croatia, Italy, Luxembourg, Hungary, Netherlands, Austria, Poland, Portugal, Slovenia, Slovakia, United Kingdom, Liechtenstein

Cluster B: Bulgaria, Greece, Cyprus, Malta, Iceland, Switzerland, Turkey

Cluster C: Estonia, Latvia, Lithuania, Finland, Sweden, Norway

The following are the characteristics of the cluster profile:

	Avg Change in Temp (Delta)	Avg Temperature
Cluster A	0.048	9.99
Cluster B	0.057	14.14
Cluster C	0.021	4.37

The first cluster has the maximum number of countries followed by the second and third. Most of the European countries exhibit an average temperature of around 10 degrees with ranges from 8-12 degrees. At the same time, some countries lie above the specified range (Cluster B), and cluster C lies below the range. Clusters overall that show a greater average change in temperature over the period also show the higher average temperature in the region. Hence, a hotter area experiences comparatively higher variance in the temperature over the years. A good point of observation in the case of an outlier, Iceland. Iceland is one of the coldest countries in Europe, but the average change in temperature (marked by delta) is on the higher side leading to the position in cluster B. There can be external reasons for this behavior. In the next section of the analysis, we introduce the clustering of emissions and examine its behavior concerning temperature data.

2. Cluster Analysis of the time series data is performed on the greenhouse gas emissions variable, analyzed along with the temperature and GDP per capita as substitutes for ecological and economic indicators. We fix the appropriate number of clusters to the data after employing the hierarchical clustering process and the elbow method. We find that 3 clusters exist for the data clustered on emissions. With three as the optimal number, we do K-means clustering to arrive at clusters. The following were the results:

Cluster	No of Countries	% of Total
Cluster 1	8	24%
Cluster 2	19	58%
Cluster 3	6	18%

The names of the countries are as follows:

Cluster 1: Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Romania, Slovakia
Cluster 2: Belgium, Denmark, Germany, Ireland, Greece, France, Croatia, Italy, Luxembourg, Netherlands, Austria, Poland, Slovenia, Finland, Sweden, United Kingdom, Liechtenstein, Norway, Switzerland
Cluster 3: Spain, Cyprus, Malta, Portugal, Iceland, Turkey

Cluster 1 comprises all east European countries. Cluster 2 comprises West European countries and Scandinavian countries. Cluster 3 is a mix of countries from different regions, which will be essential in our further analysis. The following is the characteristic of clusters' emissions and temperature:

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Cluster Profile (Temperature and Emissions):

Clusters	GHG Emissions		Temperature	
	Mean	Std. Deviation	Mean	St.Deviation
Cluster 1	62.69	10.88	8.42	2.06
Cluster 2	98.27	8.7	9.15	4.48
Cluster 3	133.23	14.72	13.72	6.39

The first cluster has the lowest average emissions, and the third cluster has the maximum. The six countries in the third cluster almost emit twice as the countries in the first. Another clear relationship we see from the table is the hypothesis between emissions and temperature data. As per literature reviews implying on the positive correlation between emission and temperature, we can see a similar behavior wherein higher average emissions correspond to higher average temperatures over the three decades in Europe. We can observe that almost twice the amount of emissions produced has led to a 1.5 times higher temperature in countries in the third cluster compared to the first.

The next step of the analysis between temperature and emission is the analysis of economic growth across clusters. Economic growth analysis across clusters will give a detailed account of how production and consumption-based emissions are impacted by the increasing value of goods and services from economic activities that impact temperatures.

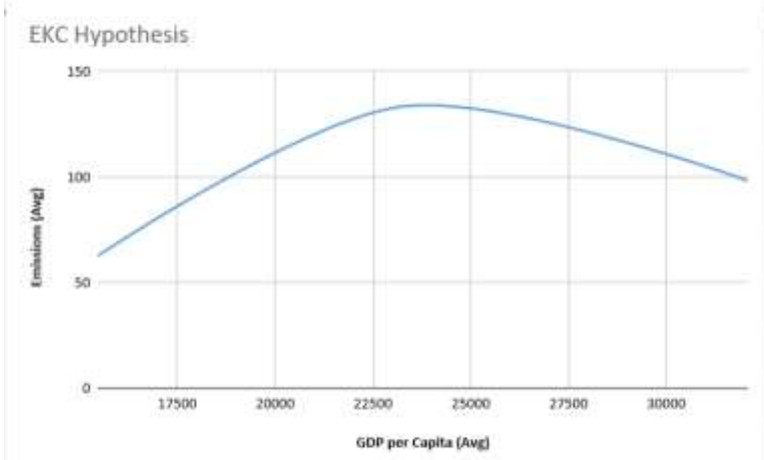
The following is the **GDP Cluster Profile**:

Clusters	Average GDP per capita
Cluster 1	15471.76
Cluster 2	320709.18
Cluster 3	23205.23

The above table is an inquiry into the development aspect of the countries' emission data. The above table shows us the GDP per capita of each cluster averaged over the years of study. From the data, Eastern Europe, comprising countries mostly in the first cluster, has a lower GDP compared to the other clusters over the years. We note that these countries have lower emissions compared to other clusters. The poorer countries in the European region have the least GDP and, in correlation, have the lowest temperature in the region. The developed world comprises the second cluster with the highest GDP in the region on an average (almost twice as the first cluster) but still does not form the worst emitters in the EU. The previous statement is a significant result in terms of the ecological and economic impacts of carbon emissions.

Out of them all, Turkey is the worst-performing country in this GDP to emission index comparison, and Luxembourg in the second cluster is one of the best performing countries comparatively on the GDP to emission index. Third cluster countries do not represent countries with high GDP as the developed world. They fall in between underdeveloped Eastern Europe and the developed West and Scandinavian Europe. Therefore, this shows that in the development process, these developing countries face drastic environmental degradation due to the release of high amounts of emission and temperature, as seen through the clusters.

The above analysis leads us to an essential hypothesis of the Environmental Kuznets Curve. We can prove using time series clustering analysis on the validity of the analysis, as we learned from our review about the validity of the EKC hypothesis. The following is the EKC curve plotted using clusters data of GDP per capita vs Emissions(Avg) taken from above tables:



We have seen that environmental degradation rises for around twenty-six years (third cluster) before falling in an inverted U shape (second cluster). More developed countries can effectively flatten their level of emissions by employing effective scientific and technological measures, whereas, in the starting stages of development, countries face a tradeoff with environmental causes. Poorer countries emit least emissions and express lower temperature, with gradual economic expansion and development, they face more substantial degradation due to the lack of efficient technology and tools to control carbon emissions. As a result, they face an overall rise in temperature.

5. CONCLUSION

A European study shows the validity of the EKC hypothesis. We can find significant results concerning the relationship between variables of economic growth and environmental impact from carbon emissions in the last 26 years. More significant changes in temperature is a result of a higher temperature in the regions. On the one hand, we find that environmental factors like temperature are correlated with emissions and as well as affect the emissions level in the ecosystem. Using clustering on emissions, we extend our argument on the impact it has on economic variables like GDP per capita. We can divide the whole region into three parts- lower development stage countries (Cluster 1) lies on the lower rising part of the curve. Developing countries (Cluster 3) lie above the Cluster 1 countries- produce highest emissions with increasing GDP per capita (closer to the turning point) and highly developed countries (Cluster 2) lie on the falling part of the curve signifying efficiency. Policy-wise, we can conclude that "grow now, clean up later" has proven to be consistent with the data over the timeframe.

We have seen the recent implementation of mechanisms like carbon tax employed by countries in an attempt towards a cleaner Europe. So, the question is if this approach will prove to be useful in the future. With the advent of different market mechanisms under drastic changes in the economic world, countries face a significant tradeoff where the turning point from the third to the second cluster might not be the same under the "grow now, clean up later" approach. Different factors are holding the key to the control of environmental degradation from literacy, governance, rights, trade. (Jacoby et al., 2019). Internal and external conditions complicate environmental policy. We raise the question of looking at environmental policy and regulations away from the economic value of it and more towards socio-economic variables, which can create a shift from the consistent approach observed in the European region.

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