Countries Clustering with Respect to Carbon Dioxide Emissions by Using the IEA Database

Miltiadis Chalikias[1], Stamatis Ntanos[2]

[1]Technological Educational Institute of Piraeus, Department of Business Administration, Egaleo, 122 44, Greece, e-mail: mchalik@teipir.gr
[2]Democritus University of Thrace, Department of Forestry and Management of the Environment and Natural Resources, Orestiada, 68200, Greece, e-mail: sdanos@mycosmos.gr

Abstract. The purpose of this study is to use clustering variables according to the Kaya identity, an equation involving energy consumption, economic growth and carbon dioxide emissions. By using aggregate data from the International Energy Agency for a dataset of developed and developing countries, we perform clustering according to variables such as population, gross domestic product (GDP), total primary energy supply (TPES) and total CO_2 emissions. We use the estimated clusters to have an overview of the relationship between economic development and carbon dioxide emissions.

Keywords: Carbon emissions, Kaya identity, cluster analysis

1 Introduction

Rapid economic development during the last century led to an increase in the concentration of greenhouse gases in the atmosphere, especially carbon dioxide (hence CO_2). Carbon emissions are a negative byproduct of burning fossil fuels mainly for energy and transportation purposes. Global carbon emissions from fossil fuels follow a rising pattern since 1900. Emissions increased by over 16 times between 1900 and 2008 and by about 1.5 times between 1990 and 2008 (EPA, 2015).

Data for energy consumption provided by the International Energy Agency concerning the year 2012, reveal that North America has a mean energy consumption of about 6.8 toe / person (toe stands for tons of oil equivalent), the EU 3.46 toe / person, while for non-OECD countries the index is 1.34 toe / person. These important differences confirm that the level of prosperity and the development rate of the countries associate positively with energy consumption. A higher standard of living means more energy consumption and hence more CO_2 emissions. European Union countries have stabilised energy consumption during the last decade due to Kyoto Protocol commitments. China on the contrary shows an impressive energy consumption increase, due to intense industrialization. Carbon emissions on a global scale reached 31.7 billion tons in 2012, from 14.08 in 1971, an increase of 125%. Analyzing further in OECD and Non-OECD countries, we notice that emissions increase in Non-OECD countries is significant higher. Specifically, while in OECD countries there is a 30% CO_2 emissions increase between 1971 and 2012, the

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emissions have tripled in non-OECD countries during the same time period (IEA 2014).

2 Literature Review

According to the International Energy Agency, an equation, proposed by Kaya (1990; 1997) can be used in order to estimate the level of human effect on earth's atmosphere. This index, known as Kaya identity states that aggregate CO2 emissions can be estimated as the result of four inputs: Carbon content of the energy consumed (or carbon efficiency), Energy intensity of the economy, Production per person (per capita GDP), and population.

$$CO_2 = \frac{CO_2}{TOE} * \frac{TOE}{GDP} * \frac{GDP}{POP} * POP \quad (1)$$

By using this basic index, CO_2 emissions can be calculated for a country, region or on a global scale and we can also test different greenhouse gas emissions scenarios scenarios.

According to a recent paper by Ntanos et al. (2015), the relation between economic growth and CO_2 emissions was tested by using One Way ANOVA. The results indicated that there is a positive correlation between GDP, energy consumption and CO_2 emissions for the electricity sector and a negative correlation for the transportation sector. According to Zafeiriou et al. (2011) economic growth is linked with energy use while the uneven distribution of fossil fuels around the globe may lead to countries conflict. The turn to renewable energy sources can help in countries energy security and help environmental protection. More specific it was found that the substitution of fossil fuels with biomass can potentially contribute to the reduction of the greenhouse effect.

In an interesting study concerning CO_2 emissions and financial performance of firms, it was found that the performance of environmentally responsible firms is negatively related to an increase of global CO_2 emissions. This implies that there is a category of "green" investors that are interested in the environmental attitude of corporations. In our opinion this approach can be applied not only for firms but also for countries evaluation (Sariannidis et al. 2013).

Concerning the contribution of renewable energy sources (RES) in reducing CO_2 emissions there is a plethora of publications. In a paper revealing the attitudes of Greek citizens on environmental issues, it was found that citizens are willing to invest in RES, especially for residential applications. The public's high level of awareness on RES can reduce national carbon dioxide emissions and contribute to GDP growth, by creating jobs and increasing people's income (Tsantopoulkos et al, 2014).

3 Results

Cluster analysis was performed by using variables of CO_2 emissions in tons per capita, GDP in USD per capita and Total Primary Energy Supply (TPES) in tons per capita. Firstly hierarchical cluster analysis was used and from the Agglomeration schedule the number of clusters where estimated (it was found that 3 clusters exist). With K-Means Analysis for the three clusters the following results were obtained:

Table 1. Cluster distribution with number of countries included in each cluster

Cluster Distribution

		Number of countries	% of Combined	% of Total
Cluster	1	91	65.0%	65.0%
	2	36	25.7%	25.7%
	3	13	9.3%	9.3%
	Combined	140	100.0%	100.0%
Total		140		100.0%

Three clusters were estimated as we can see in table 1. The countries names included in the clusters are given below.

First Cluster In the first cluster 91 developing and underdeveloped countries are included.

Second Cluster: Australia, Israel, Japan, Korea, New Zealand, Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Poland, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, Belarus, Cyprus, Kazakhstan, Malta, Russian, Federation, Turkmenistan, Malaysia, Singapore, Chinese Taipei, Hong Kong, China, Islamic Rep. of Iran.

Third Cluster: Canada, United States, Iceland, Luxembourg, Brunei, Netherlands Antilles, Trinidad and Tobago, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates.

Table 2. Cluster profiles (mean of GDP/cap, CO2 emissions/cap and energy consumption/cap)

		GDP per capita in USD		CO2 Emissions in tons per capita		Total Primart Energy Supply in toe per Capita	
		Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Cluster	1	7784.3	5095.6	2.29	1.93	1.07	.69
	2	28942.5	10546.1	8.45	2.67	3.79	1.15
	3	50515.0	26529.0	20.57	7.47	10.52	4.14
	Combined	17192.9	17410.6	5.57	6.26	2.65	3.14

In table 2 we can see the average GDP/cap, the average CO_2 emissions/cap and the average energy consumption in toe/cap for each cluster. We observe that the 3d cluster includes countries with the highest GDP which are the main world oil producers, while the 2nd cluster includes developed countries and the 1st cluster included undeveloped countries. We observe that CO_2 emissions and energy supply are positively related to economic development as expressed by GDP per capita.

4 Results

Using a database from IEA, we found that there is a correlation between economic development and CO_2 emissions. We observe that the clusters effectively divide countries mainly depending on GDP per Capita criterion. Clusters depict rich countries with a high production of oil, developed countries and undeveloped countries. The results reveal that economic development is associated with intense energy consumption and CO_2 emissions and reinforce the conclusion that developed countries are the major CO_2 polluters.

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