Categorization of countries according to CO2eq emissions per capita

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Abstract

This paper provides an *ad-hoc* classification of countries using available World Bank values of 2019 CO2eq emissions (metric tons per capita). Countries are classified as: extremely high, very high, high, upper middle, middle, lower middle, low, and very low emitters. Categorization is validated through an ANOVA analysis that confirm the statistical differences between defined categories.

Introduction

The total CO2eq emissions of a country are relevant in the global fight against climate change. However, it is also important to consider the approach of the analysis of the CO2eq emissions per capita of a country. Under the per capita perspective, and not total CO2eq emissions, India goes from being the emitter No. 3 in the world in 2019 to be the emitter No. 115, from 191 countries.

This paper is organised as follow: The first section shows the CO2eq emissions per capita approach. The second section depicts the categorization framework; it will present how categories where defined and validated. The third section reveals the results obtained through a map. The last section provides conclusions.

CO2eq emissions per capita

Equivalent carbon dioxide (CO2eq) emissions into the atmosphere comes mainly from human activity, and the abrupt reduction of the number of inhabitants of a country is not feasible. In fact, the United National projects an annual growth of the planet's population of 0.74% between 2022 and 2050, from 7.9 billion people to 9.7 billion people.[1]

Therefore, in order to reduce CO2eq emissions per capita a country has three simplistic scenarios under a change in population and a change in emissions:

• increase population at a lower level of emissions (↓↓ CO2eq per capita = ↓ Total CO2eq emissions / ↑ Total Population). For example, EEUU reduced MtCO2eq per capita emissions from 16.8 in 2009 to 14.7 in 2019, where population increased from 306.7 mm to 328.3 mm and emissions reduced from 5,156 mm to 4,817 mm.

• increase population at a higher level of emissions but the effect of the increase in population is higher that the effect of the increase in total emissions (↓ CO2eq per capita = ↑ Total CO2eq emissions / ↑↑ Total Population). For example, South Africa reduced MtCO2eq per capita emissions from 8.0 in 2009 to 7.5 in 2019, where population increased from 50.5 mm to 58.5 mm and emissions increased from 404 mm to 439 mm.

• decrease population at a lower level of emissions but the effect of the decrease in total emissions is higher that the effect of the decrease in population (↓ CO2eq per capita = ↓↓ Total CO2eq emission / ↓ Total Population). For example, Japan reduced MtCO2eq per capita emissions from 8.6 in 2009 to 8.5 in 2019, where population decreased from 128.0 mm to 126.6 mm and emissions reduced from 1,100 mm to 1,081 mm.

Categorization

Using the World Bank database[2] an initial inspection of the CO2eq per capita values for the year 2019 for 191 countries was carried out. These values recorded a maximum value of 32.47 (Qatar), a minimum value of 0.04 (Somalia), and a mean value of 4.12.

Through an interactive process, we proceeded to define particular ranges that determined a number of categories (e.g., 3 categories: high, medium, and low; 4 categories: high, medium high, medium low, and low, etc.) that were later contrasted with an ANOVA analysis.

Taking into consideration the desire to incorporate a large number of validating categories, we proceeded to define eight categories determined by the following ranges: <1.0 very low, from 1.01 to 2.0 low, from 2.01 to 4.0 lower middle, from 4.01 to 6.0 middle, from 6.01 to 8.0 upper middle, from 8.01 to 12.0 high, from 12.01 to 20.0 very high and >20.01 extremely high.

In order to validate the statistical significance of the differences between the defined categories, the ANOVA analysis was execute using the LSD test of the agricolae package in R.[3]

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[1] https://population.un.org/wpp/

[2] https://data.worldbank.org

[3] R commands:

```
library(readxl)
library(agricolae)
CO2.data <- read_excel(file.choose())
Model<-aov(Emissions~Category, data=CO2.data)
Df<-df.residual(Model)
MSerror<-deviance(Model)/Df
# comparison <- LSD.test(Emissions,Category,Df,MSerror)
LSD.test(Model,"Category",console=TRUE)
```

Results

The ANOVA analysis confirmed that all the formulated categories corresponded to groups with statistically significant differences at a 95% confidence level.

	Emissions	groups
extremely high	24.9209960	a
very high	15.0137982	b
high	9.5375222	c
upper middle	7.1042274	d
middle	4.8483485	e
lower middle	3.1168424	f
low	1.5020198	g
very low	0.4181526	h

Thus, the next map shows the CO_2eq emissions per capita category by country:

The oil nations of Qatar, Kuwait and Bahrain are the countries classified as extremely high emitters.

For their part, the countries of UEA, Brunei, Canada, Luxembourg, Saudi Arabia, Oman, Australia, United States, Trinidad and Tobago, and Turkmenistan are classified as very high emitters.

In Africa, countries classified as very low emitters predominate, highlighting the particular exceptions of Libya classified high and South Africa classified upper middle.

In Latin America, countries classified as lower middle and low emitters predominate, highlighting the cases of Chile and Suriname classified as middle, and the aforementioned Trinidad and Tobago (very high).

Conclusions

We have conducted a category analysis of CO_2eq emissions per capita for the year 2019.

Future lines of research could apply the category analysis over time to follow countries transitions from one category to other, or the estimation of alternatives categories.