Forecasting CO2 emissions using ARIMA models in Brazil, China, EU, India and US

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Motivation

Increasing evidence has shown that human emissions of carbon dioxide and other greenhouse gases are a primary driver of climate change (IPCC, 2013). This makes worldwide emissions one of the world's most pressing challenges and has provoked various international agreement, like the Paris Agreement on emission reduction and other climate goals. Three of the largest current emitting regions are China, the US and the EU.

Introduction

The main topic of this term paper is to analyze and model the trends of CO2 emissions in some of the countries of the European Union, the United States of America and China (and perhaps comparing them with emerging economics such as Brazil and India). Current actions to mitigate the climate effects of such steep rise of CO2 emissions over the last 50-60 years (citation needed) are not enough to reach the goals set in the Paris Agreement by 2030. Such is the slowed response from the governing institutions and international organizations that the current trends indicate that the temperature increases (and all the consequences behind it) will be irreversible in less that 5 years(citation needed). This paper will analyze the trends of CO2 emissions of the above-mentioned countries and will design a fitting econometric model. Lastly, a forecast for the next periods based on the model will be presented.

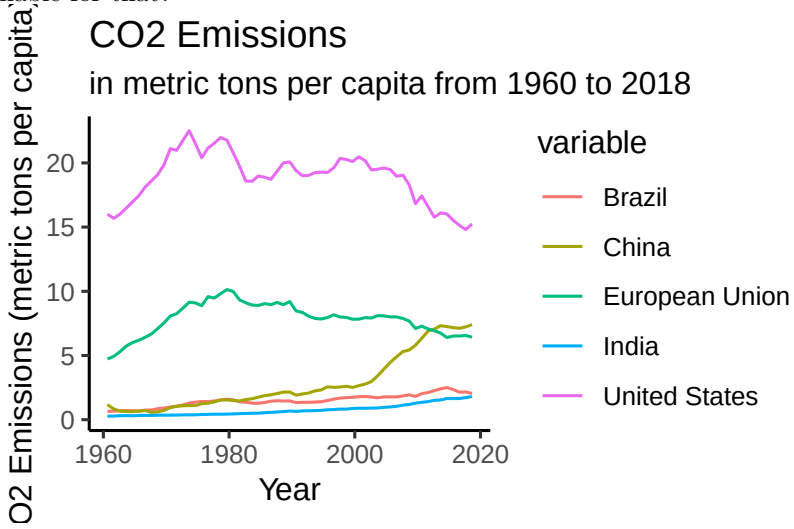
- What do we already know about the subject (literature review)? Use citations: **?** shows that… Alternative Forms of the Wald test are considered [**?**].

Literature review

Exploratory data analysis

What kind of data do we use? C02 emissions per capita, why? Arguments for using that measure -> Although all 3 regions are really big, the population density is different and thus "spreading" the CO2 emissions by population gives us more sensible data and accounted

for the different sizes of population. Maybe disaggregate countries in the EU (high income vs low income), same in the USA with big states (California, Texas) vs poorer states such as (Mississippi, Alabama, Arkansas in Continental USA). Kind of panel data, is there data available for that?



Plot description

As seen above, CO2 emissions of the countries of interest are showing different trends and magnitudes.

The econometric and economic theory is briefly described and related literature is presented

Idea: compare with GDP or GNP

For this section, we compare the trends of CO2 emissions with the GDP (per capita or growth??) to test our hypothesis that up until some point in the last 30 years, GDP and CO2 emissions were highly correlated.

Include kyoto and paris agreement and other historical events (fukushima, fridays for future?)

Some other factors that could prove to be pivotal in the slow decline of CO2 emissions in the European Union and USA could be historical events like the Kyoto Agreement in 20XX and the Paris Agreement, and some natural distasters, like the 2011 tsunami in Japan that caused the explosion in the nuclear factory in Fukushima. This event led to a chain of events that ended with Germany's (and some other European countries) abandonment (?) of atomic energy.

The model and data

In this section, we go over the data, its characteristics, sources and reliability. Moreover, we introduce the ARIMA (Auto Regressive Integrated Moving Average) model in a formal way, next, we run the model on our data to then set up all the insights to analyze in the following section.

The econometric model and the data applied are described, a first descriptive analysis of the data is shown

All data is taken from the World Bank's Database. This database has proven to be reliable for industrialized countries, not su much for developing countries, since data from these countries might not be recollected or administered correctly by the corresponding authorities. (Get a source on that).

- How was the data sample selected?

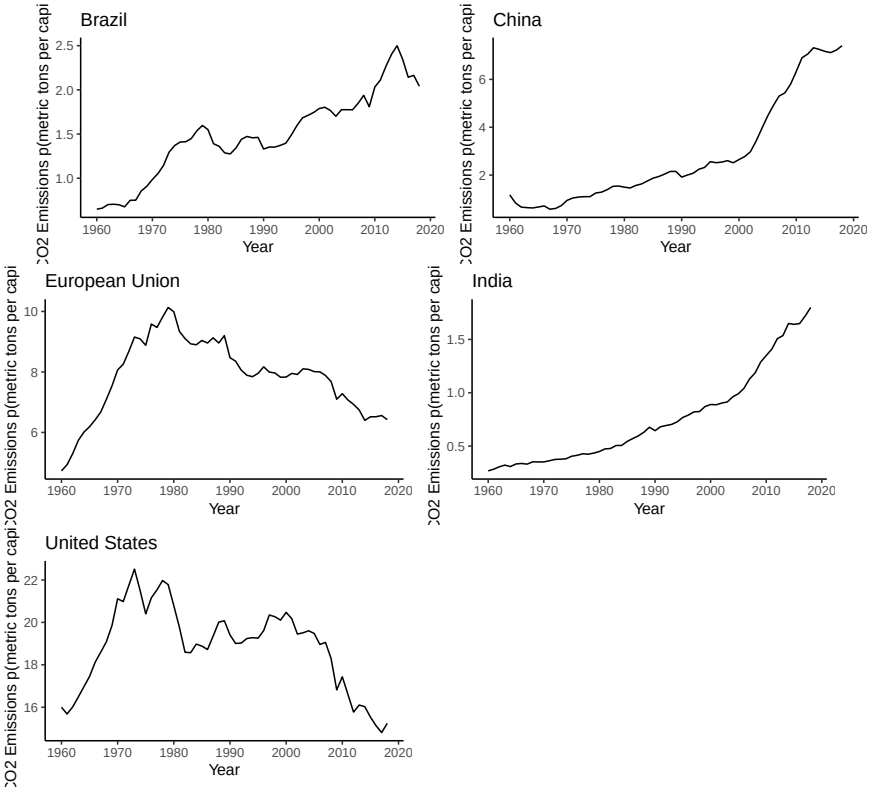
As stated in the Introduction, our interest here is to analyze the trends of the 3 biggest emitters of CO2 in the world: the United States of America, the European Union and China [quote on that]. Additionally, we compare those trends and forecast, with trends and forecast of emerging economies such as Brazil and India, as those countries display worrying trends on CO2 emissions that are the product of contamination and deforestation due to their growing industries.

- Provide descriptive statistics such as:
  - time period,
  - item number of observations, data frequency,
  - item mean, median,
  - item min, max, standard deviation,
  - item skewness, kurtosis, Jarque–Bera statistic,
  - item time series plots, histogram.

	Brazil	China	European Union	India	United States
	Min. :0.6499	Min. :0.5742	Min. : 4.729	Min. :0.2676	Min. :14.81
	1st Qu.:1.2913	1st Qu.:1.2103	1st Qu.: 7.000	1st Qu.:0.3929	1st Qu.:17.44
	Median :1.4577	Median :2.0384	Median : 7.966	Median :0.6441	Median :19.24
	Mean :1.4862	Mean :2.8182	Mean : 7.845	Mean :0.7551	Mean :18.86
	3rd Qu.:1.7758	3rd Qu.:3.6886	3rd Qu.: 8.914	3rd Qu.:0.9382	3rd Qu.:20.14
	Max. :2.4994	Max. :7.4052	Max. :10.133	Max. :1.7998	Max. :22.51

Here we present some initial descriptive statistics for the different countries:

- Time series plots for each country or region separately:



Recall the autocorrelation function formula: $\rho\_k = \frac{\gamma_k}{\gamma_o} = \frac{Cov[y_t, y_{t-k}]}{Var(y_t)}$

ACF plots and correlograms

- Allows the reader to judge whether the sample is biased or to evaluate possible impacts of outliers, for example.
- Here tables can be easily integrated using the `kable()` function in the `knitr` package (with perhaps some additional help from the `kableExtra` package). `kable()` will automatically generate a label for the table environment. That way you don't have to manually enter in the table in LaTex, you can embed tables from R code.

Methodology

- How was the data analyzed ?
- Present the underlying economic model/theory and give reasons why it is suitable to answer the given problem[1].
- Present econometric/statistical estimation method and give reasons why it is suitable to answer the given problem.

[1] Here is an example of a footnote.

– *Equation* @ref(eq:SpecDens) *represents the ACs of a stationary stochastic process:*

$$f_y(\lambda) = (2\pi)^{-1} \sum_{j=-\infty}^{\infty} \gamma_j e^{-i\lambda j} = (2\pi)^{-1} \left(\gamma_0 + 2 \sum_{j=1}^{\infty} \right. \tag{1}$$

where $i = \sqrt{-1}$ is the imaginary unit, $\lambda \in [-\pi, \pi]$ is the frequency and the γ_j are the autocovariances of y_t.

– Equations can be referenced with `\@ref(eq:<name>)`, where name is defined by adding `(\#eq:<name>)`

- Allows the reader to judge the validity of the study and its findings.
- Depending on the topic this section can also be split up into separate sections.

Estimation and results

The model choice is reasoned well in statistical and economic terms, the estimation results are presented, the results are interpreted and connected to the economic theory and literature from point 1.

Find an appropriate ARIMA model to describe the three series. Base your decision on (P)ACFs, unit root tests, AIC and further diagnostic checks. What limits the validity of these results? 4. Forecast the CO2 emissions one period ahead and for 2030 based on the chosen model. Evaluate the forecast in comparison to an alternative prediction method. 5. Discuss the economic consequences of your results and suggest different techniques how your model and a potential long-term forecast could be improved.

- Do the results support or do they contradict economic theory ?
- What does the reader learn from the results?
- Try to give an intuition for your results.
- Provide robustness checks.
- Compare to previous research.

Conclusion:

Summary of the main results and outlook on further interesting research directions

- Give a short summary of what has been done and what has been found.
- Expose results concisely.
- Draw conclusions about the problem studied. What are the implications of your findings?
- Point out some limitations of study (assist reader in judging validity of findings).
- Suggest issues for future research.

References

?{owidco2andothergreenhousegasemissions, author = {Hannah Ritchie and Max Roser}, title = {CO and Greenhouse Gas Emissions}, journal = {Our World in Data}, year = {2020}, note = {`https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions`} }

?{nyoni2019modeling, title={Modeling and forecasting carbon dioxide emissions in China using Autoregressive Integrated Moving Average (ARIMA) models}, author={Nyoni, Thabani and Mutongi, Chipo}, year={2019} }