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CO2 emissions

Final assignment Data Analysis with Python

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1. Introduction

The rise of carbon dioxide (CO2) emissions is the main cause of climate change. Emissions will have to be reduced to slow down climate change and its devastating consequences. In 2016 the Paris Agreement was signed by 196 countries.
"*The Paris Agreement's long-term temperature goal is to keep the rise in mean global temperature to well below 2 °C (3.6 °F) above pre-industrial levels, and preferably limit the increase to 1.5 °C (2.7 °F), recognising that this would substantially reduce the impacts of climate change. Emissions should be reduced as soon as possible and reach net-zero by the middle of the 21st century.*"(https://en.wikipedia.org/wiki/Paris_Agreement).
Human activities such as the burning of fossil fuel are the primary cause of increased CO2 concentrations in the atmosphere. Countries need to reduce their CO2 emissions drastically.

In relation to CO2 emission and the reduction of CO2 emission three questions have been formulated:

1. What is the biggest predictor of a large CO2 output per capita of a country?
2. Which countries are making the biggest strides in decreasing CO2 output?
3. Which non-fossil fuel energy technology will have the best price in the future?

Question 1 will be discussed in chapter 3, question 2 in chapter 4 and chapter 5 will handle the third question. The last chapter (6) will summarize the conclusions.

2. Data collection

All data have been collected from "Our World in Data": https://ourworldindata.org. This is a project of the Global Change Data Lab, a non-profit organization based in the United Kingdom. Their website contains a large collection of data, obtained from many researche(r)s over the world. Their goal is to make the knowledge on the big problems in the world accessible and understandable.

3. What is the biggest predictor of a large CO2 output per capita of a country?

Annual production-based emissions of carbon dioxide (CO2), measured in tonnes, have been collected from countries all over the world. The timespan is 1750-2019.

A selection of possible biggest CO2 predictors has been made:

1. GDP per capita
2. Fossil fuel consumption
3. Land use (change)
4. Cattle livestock count
5. Daily meat consumption
6. Motor vehicle ownership
7. CO2 emission by aviation per capita
8. CO2 emission by transport per capita (excl. aviation and shipping)

The Pearson correlation coefficient has been calculated to find the relation between the CO2 output per capita of a country and possible predictors.

3.1. Results

Predictor	Pearson Correlation Coefficient
Fossil fuel consumption	*0.82*
Gas	*0.71*
Oil	*0.56*
Coal	*0.31*
CO2 emission by transport per capita	*0.73*
GDP per capita	*0.68*
Land use change	*0.64*
Motor vehicle ownership	*0.61*
Daily meat consumption	*0.55*
CO2 emission by aviation per capita	*0.46*
Cattle livestock count	*-0.0058*

Table 1. The Pearson Correlation Coefficients of the annual CO2 emission per capita and the selected possible predictors.

Table 1 shows the Pearson correlation coefficients of the annual CO2 emission per capita and the selected predictors. The biggest predictor is fossil fuel consumption with a correlation coefficient of 0.82. This type of fossil energy use that is mostly related to CO2 emission is gas. The second biggest predictor is use of transport per capita (correlation coefficient = 0.73), see also figure 1.

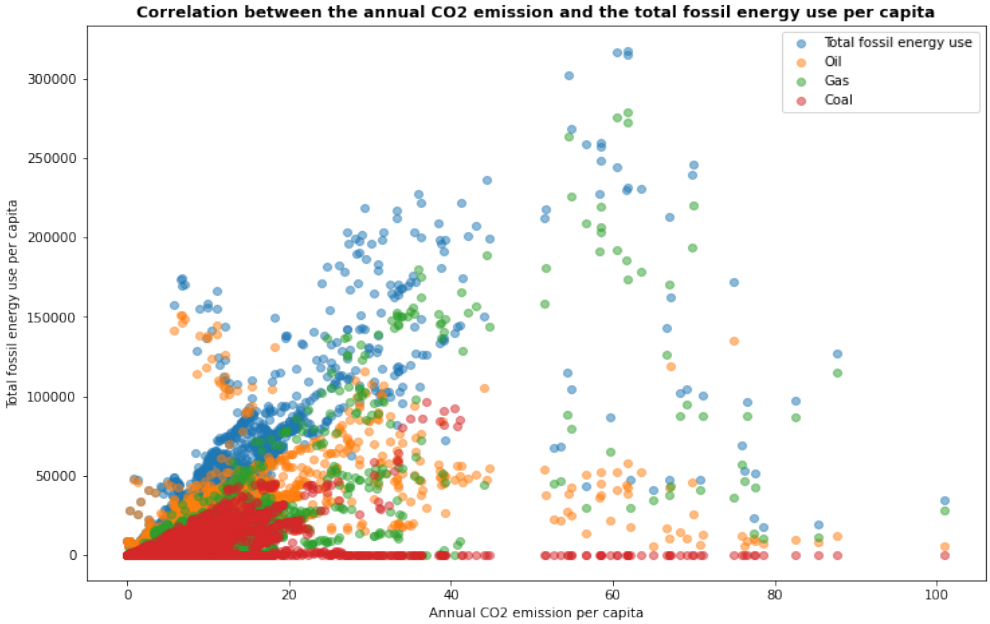

Figure 1. Scatter plot that shows the correlation between annual CO2 emission per capita and the different sources for fossil energy.

The GDP per capita is also moderate to highly correlated to the amount of CO2 emitted by a country. As can be seen in table 2 GDP is moderate to highly correlated to the majority of the other predictors. It is likely that in countries with a high GDP per capita there are more cars, people fly more and have more money to buy meat.

Predictor	**Pearson Correlation Coefficient**
Fossil fuel consumption	*0.63*
CO2 emission by transport per capita	*0.75*
Land use change	*0.64*
Motor vehicle ownership	*0.70*
Daily meat consumption	*0.72*
CO2 emission by aviation per capita	*0.67*
Cattle livestock count	*0.0083*

Table 2. The Pearson Correlation Coefficients of the GDP per capita and the other possible predictors.

3.2. Conclusion

The biggest predictor of a large CO2 output per capita of a country is the use of (total) fossil energy use.

4. Which countries are making the biggest strides in decreasing CO2 output?

To answer this question the change in annual CO2 emissions in the period 2016-2019 has been determined for countries of which data were available. This time period has been chosen, because in 2016 the Paris Agreement has been signed by many countries, marking the starting point of reducing CO2 emissions. The latest data that are available at this moment are from 2019.

4.1 Results

Table 3 shows that top 10 of countries that have made the biggest decrease in absolute CO2 emission in 2019 compared to 2016. Germany has the biggest reduction in CO2 emission, followed by Japan and Venezuela.

Country	Change in absolute CO2 emission (in million tonnes)	Country	Change in absolute CO2 emission (in million tonnes)
1. Germany	*-98.56*	**6. United Kingdom**	*-29.23*
2. Japan	*-96.50*	**7. Italy**	*-19.47*
3. Venezuela	*-46.50*	**8. France**	*-17.28*
4. Mexico	*-46.13*	**9. Brazil**	*-12.73*
5. United Arab Emirates	*-37.90*	**10. Argentina**	*-11.99*

Table 3. Top 10 biggest decreasers in absolute CO2 emission since 2016.

However, the size of the population has not been taken into account. Table 4 shows the change in absolute CO2 emission *per capita*.

Country	Change in absolute CO2 emissions per capita (in million tonnes)	Country	Change in absolute CO2 emissions per capita (in million tonnes)
1. United Arab Emirates	*-4.90*	**6. Venezuela**	*-1.37*
2. Estonia	*-2.72*	**7. Germany**	*-1.33*
3. Trinidad and Tobago	*-1.93*	**8. Bahrein**	*-1.09*
4. Curacao	*-1.67*	**9. Finland**	*-1.06*
5. British Virgin Islands	*-1.61*	**10. Anguilla**	*-1.03*

Table 4. Top 10 biggest decreasers in absolute CO2 emission per capita since 2016.

The change in CO2 emission per person is biggest in United Arab Emirates, followed by Estonia and Trinidad and Tobago.

But who made the biggest relative change in CO2 emission per capita? This is shown in table 5. The top 3 is: Venezuela, British Virgin Islands and Estonia.

Country	Change in absolute CO2 emissions per capita (in million tonnes)	Country	Change in absolute CO2 emissions per capita (in million tonnes)
1. Venezuela	*-0.251*	**6. Equatorial Guinea**	*-0.187*
2. British Virgin Islands	*-0.223*	**7. Gabon**	*-0.179*
3. Estonia	*-0.206*	**8. Ghana**	*-0.154*
4. United Arab Emirates	*-0.201*	**9. Cameroon**	*-0.150*
5. Eswatini	*-0.199*	**10. Denmark**	*-0.142*

Table 5. Top 10 biggest decreasers in relative CO2 emission per capita since 2016.

4.2 Conclusion

The country that makes the biggest strides in reducing CO2 emission in absolute numbers is Germany. When looking at CO2 emission per capita, the country that shows greatest reduction is United Arab Emirates. The country that has made the biggest relative step in reducing CO2 emission per capita is Venezuela. This means that in 2019 per person CO2 emission has been reduced with 0.25% compared to 2016.

5. Which non-fossil fuel energy technology will have the best price in the future?

Levelized cost of energy (LCOE) estimates the average cost per unit of energy generated across the lifetime of a new power plant. It is measured in 2019 US$ per kilowatt-hour. To predict which non-fossil energy technology will have the best price in the future a linear regression model has been fit, that included historical prices of the following renewable energy sources:

- Concentrated solar power (CSP)
- Solar PV
- Bioenergy
- Geothermal
- Hydropower
- Onshore wind
- Offshore wind

5.1. Results

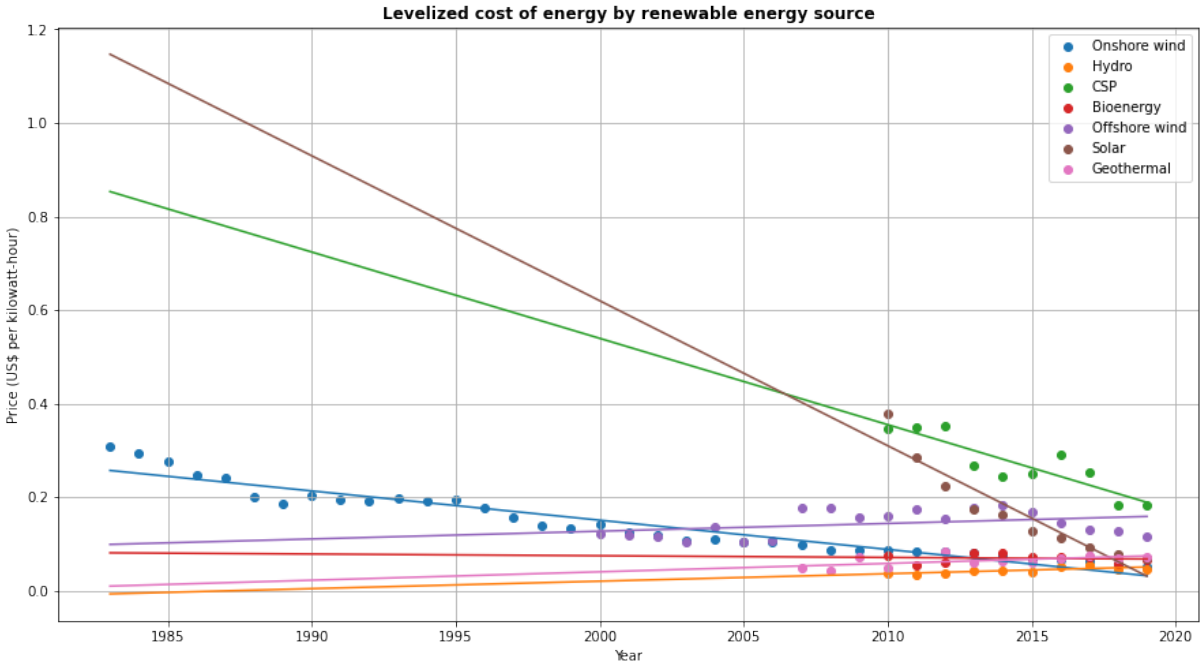

Figure 2. Levelized costs of energy by renewable energy sources with linear regression lines.

The 'levelized cost of energy by renewable energy source' graph shows the linear regression lines of all non-fossil energy sources. Energy produced by solar panels (solar) has been decreasing fastest over the years, so it is most likely that the price for solar energy will be lowest in the future.

6. Conclusions

Answers to the questions, asked in the introduction:

1. What is the biggest predictor of a large CO2 output per capita of a country?

   The biggest predictor of a large CO2 output per capita of a country is the use of fossil energy.

2. Which countries are making the biggest strides in decreasing CO2 output?

   Looking at change in absolute CO2 emission (unrelated to population size), the top 3 is:
   1. Germany
   2. Japan
   3. Venezuela

   Looking at the change in absolute CO2 emission per capita, the top 3 is:
   1. United Arab Emirates
   2. Estonia
   3. Trinidad and Tobago

   Looking at the change in relative CO2 emission per capita, the top 3 is:
   1. Venezuela
   2. British Virgin Islands
   3. Estonia

3. Which non-fossil fuel energy technology will have the best price in the future?

   The renewable energy technology that will have the best price in the future is solar panels.

APPENDICES

I. For detailed results, computer outputs and extra graphs of all the performed analyses of chapter 3 (What is the biggest predictor of a large CO2 output per capita of a country?), see:

https://github.com/Marieke-do/Final-assignment---CO2-emissions/blob/f5e4faeea8772f213efb275e56081e2fc7140c22/Final_assignment_CO2_emissions_part1.ipynb

II. For detailed results and computer outputs of all the performed analyses of chapter 4 (Which countries are making the biggest strides in decreasing CO2 output?), see:

https://github.com/Marieke-do/Final-assignment---CO2-emissions/blob/f5e4faeea8772f213efb275e56081e2fc7140c22/Final_assignment_CO2_emissions_part2.ipynb

III. For detailed results and computer outputs of all the performed analyses of chapter 5 (Which non-fossil fuel energy technology will have the best price in the future?), see:

https://github.com/Marieke-do/Final-assignment---CO2-emissions/blob/f5e4faeea8772f213efb275e56081e2fc7140c22/Final_assignment_CO2_emissions_part3.ipynb