Do Countries Follow Through on Climate Agreements?

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This paper investigates CO2 emissions before and after the Paris Climate Accord which was signed in December 2015 using data from The World Bank, finding that changes in CO2 emissions in the immediate years following the agreement varied significantly by country. In particular, in the 3 years following the agreement, Peru, Mexico, and Germany had the largest % decrease in CO2 emissions while Vietnam, Nepal, and Indonesia had % increases in their CO2 emissions. We also find that countries with high government effectiveness (e.g. Singapore, Switzerland, Norway) are associated with % decreases in CO2 emissions from 2016 to 2020, suggesting the importance of this factor in the ability of countries to reach climate outcomes. Lastly, we find that treaty-signing countries were not any more effective than non-treaty-signing countries at reducing CO2 emissions and that developed countries are significantly more effective at decreasing their CO2 emissions than developing countries.

I. Introduction & Background

Our project idea stems from the media coverage of climate accords and climate conferences, which act as the intersection of international politics and environmental policy. Politicians often cite their involvement with specific climate agreements to show their commitment to environmental issues. However, it remains to be seen how much of their claims are virtue signaling and how much signing a climate agreement constitutes tangible progress on climate goals. This research paper takes the first step in understanding the extent to which countries and politicians can take credit for changes in climate policy at the national level by investigating the CO2 levels of countries that signed the Paris Climate Accord in December 2015. The Paris Climate Agreement's primary target is to hold the increase in global average temperature to below 2 degrees Celsius by making global CO2 emissions net zero to prevent interference with the climate system and ensure sustainable food production and climate development (Rogelj, 2016).

While countries in these agreements set specific long-term targets for 2030 and 2050 within the Paris Climate Agreement, this paper hopes to investigate the progress of each country in the immediate years after the treaty signing. These initial years following treaty signing are important indicators because they provide a sense of the level of commitment of countries and the political will of these countries to meet their proposed climate goals.

One reasonable question is the efficacy of these policies and how these metrics stand relative to the rest of the world (non-treaty signing countries). After all, if non-treaty-signing countries are decreasing carbon emissions at a similar rate as treaty-signing countries, that could provide some evidence for the lack of impact of the treaty on CO2 emissions for treaty-signing countries. It is important to recognize that the metric of CO2 emissions at the national level is the result of decision-making at the industry and government levels: CO2 emissions are the product of the complex interaction of these two spheres. The challenges that come with international climate accords come from the fact that industries and governments may choose to deviate from their intended reduction target because it is costly to transition away from greenhouse gas emitting production, making decarbonization on a national level a tough challenge (Falkner, 2016). This is further complicated by domestic politics and limited political terms, which can drive politicians to act in terms of short-run interests because it is harder to take credit for commitment to long-term targets (Battaglini, 2020). Previous research finds that governments tend to make lofty promises to climate targets which they fail to follow through on (Falker, 2016). In this analysis, we try to better understand how well countries follow through on their commitments to international climate agreements. Specifically, we investigate countries that signed the Paris Climate Accord in 2015 and their progress on CO_2 emissions in the initial years following the treaty signing. From our analysis, we aim to provide evidence for our research questions through a case study of the Paris Climate Agreement. An outline for our analysis is provided below as a series of questions.

1. Do countries follow through on their commitment to CO_2 reduction in the Paris Climate Accord?
2. Is government effectiveness for treaty-signing countries related to a reduction in CO_2 emissions?
3. Were treaty-signing countries any more effective than non-treaty-signing countries at reducing CO_2 emissions?
4. Are there differences in post-treaty commitment to CO_2 emission reduction between developed and developing countries?

II. Data Description

The datasets selected for this project were chosen after the initial preparation phase, each relevant to the research topic of CO_2 emissions before and after the signing of the Paris Climate Accord. The datasets we use in our analysis are as follows:

- **The World Bank Climate Change Data** contains global data on various environmental and development indicators crucial for understanding and analyzing trends in CO_2 emissions and other climate-related factors (World Bank Group, 2024). This dataset provides data on emissions levels that allow us to analyze the progress towards the climate goals signed by the Climate Accord.

- **Climate Agreement Data** features the Nationally Determined Contributions and net zero targets of the countries that signed the Paris Climate Accord, including specific goals for reducing greenhouse gas emissions by 2030 and 2050 (Climate Action Tracker, 2024). This dataset helps us to understand how countries are committed to reducing their carbon footprint in accordance with the Paris Climate Accord.
- **ESG Data** shows current indicators for each country's performance and policies on environmental sustainability, social responsibility, and governance (World Bank Group, 2024). This dataset is crucial for evaluating whether a country is capable of implementing effective climate policies and achieving significant reductions in CO_2 emissions in line with the Climate Accord.

The selection of these exact datasets was influenced by several factors:

- **Relevance:** Each dataset is directly related to the research topic, offering specific data that is needed to investigate if countries follow through on climate agreements in the context of the Paris Climate Accord
- **Credibility:** The datasets were chosen from reputable sources, ensuring that the research is based on reliable and accurate information.
- **Comprehensiveness**: Combined, these datasets provide a comprehensive view of the issue, covering emissions data, international climate commitments, and factors that influence environmental governance.

III. Data Cleaning

We applied specific data-cleaning techniques to address inconsistencies and prepare each dataset for analysis.

World Bank - Climate Data and ESG Data

1. Missing Data Handling: We replaced placeholder values like "..." and empty entries with "NULL" (without quotes) to ensure consistent identification and handling of missing data points.
2. Column Selection: Irrelevant columns were removed to streamline the dataset and focus on the relevant information for our analysis.
3. Data Standardization: Inconsistencies within the dataset (typos, formatting variations, conflicting information) were identified and rectified. We mapped these inconsistencies to a single, consistent format across the data.

Climate Agreement Data

1. Text Preprocessing: As the data was initially unstructured text detailing each country's agreements, we began by separating the text into sentences using appropriate techniques. Regular expressions (regex) were then employed to extract relevant information due to the relatively consistent text format.
2. Data Type Conversion: Textual dates and numbers were parsed and converted into their respective numerical data types for further analysis.

IV. Data Analysis

In Figure 1, we show a line chart over time before and after the time of the policy in 2016 which gives us a rough idea of a before-after comparison of the CO2 emissions for the countries that signed the Climate Accord. We also get an idea of the highest CO2 emitting countries, which appear to be Australia, Canada, and Kazakhstan. More details of specific values for each year can be found by hovering over the graph in the Jupyter Notebook or .html file. Overall, we get the impression that before the policy and after the policy, most countries either maintain CO2 levels or decrease them slightly over time.

In Figure 2, we show a bar chart that allows us to isolate specific countries before and after the time of the policy in 2016 and gives us a rough idea of a before-after comparison of the CO2 emissions for the countries that signed the Climate Accord. By interacting with the graph and clicking on a specific country in the Jupyter notebook, the user can compare the specific CO2 emissions for 2016 and 2020 for a specific country. However, looking at changes in absolute terms is not fair for smaller countries since they emit less CO2 to begin with from year to year and absolute CO2 levels are highly related to the energy consumption of the population. As such, the optimal metric for changes in CO2 emissions would be % changes since it is proportional to each country's baseline CO2 emissions in 2016.

In Figure 3, a simple difference-in-means chart between emissions in 2020 and 2016 shows the countries that appear to have made the most progress on their CO2 emissions. We see that Peru, Mexico, and Germany all appear to have made the largest changes in their CO2 emissions proportional to their 2016 levels. Conversely, although Vietnam, Nepal, and Indonesia signed onto the Paris Climate Agreement intending to reduce their CO2 emissions, their CO2 emissions have increased relative to their 2016 levels! With this simple analysis, we find that these countries did not follow through with their commitment to the Paris Climate Agreement.

In Figure 4, we get an idea of the relationship between government effectiveness and the % change in CO2 emissions post-treaty. We see that countries with high government effectiveness (above 1.0 on this scale) also appear to have negative % changes in CO2 emissions post-treaty. This makes sense since governments are important for facilitating the reduction in CO2 emissions in the private sector: governments with high effectiveness more competently achieve their government objectives despite private interests in using existing technology that generates CO_2 emissions. Conversely, governments with low effectiveness are less able to consistently create change in the private sector and transition away from CO_2-emitting production.

The next portion of our analysis involves a more rigorous approach to seeing how treaty-signing countries compare to non-treaty-signing countries. Regression analysis is the best technique for this purpose because it allows us to control for several related variables that could impact CO_2 emissions, and fits a line through our data allowing us to estimate the change in CO_2 emissions over time. As such, the focus of our regression analysis is the coefficient on the "year" variable, In particular, this coefficient can be interpreted as follows: a one-year change is associated with an "x" Metric Ton increase/reduction in CO_2 emissions. We leave the CO_2 emissions in absolute terms since it does not affect the quality of the analysis. A subset of the data from 2016 to 2020 is used so it only reflects post-treaty progress on CO_2 emissions. We then compare the coefficient on year for treaty-signing countries vs. non-treaty-signing countries in the same period to see if signing the treaty has a substantial correlation with a reduction in CO_2 emissions. If even countries that do not sign the treaty also reduce their CO_2 emissions, this might imply that treaty-signing countries are on average not any better than non-treaty-singing countries.

The regression #1 output and regression #2 output imply that there is no substantial difference between countries that signed the Paris Climate Accord and those that did not! We see that the point estimate for the coefficient on "year" in the first regression is -0.0785 which uses data for treat-signing countries, while it is -0.0790 for the second regression which uses data from the rest of the non-treaty-signing countries. This means that after controlling for population density and government effectiveness, each subsequent year post-treaty is associated with a 0.0785 reduction in Metric Tons of CO_2 emissions for treaty-signing countries on average while each subsequent year is associated with a 0.079 reduction in Metric Tons of CO_2 emissions for non-treaty signing countries on average. Thus, countries who signed the agreement were no better off at reducing their CO_2 emissions than the rest of the world.

We extend our analysis to the heterogeneity between countries to better understand what groups of countries follow through or fail to follow through on their commitment to the Paris Climate Accord. Figure 5 and Figure 6 show us simple charts of % change in CO_2 emissions between 2016 and 2020 for Developed and Developing Countries. The results imply that Developed Countries did much better at following through on the Paris Climate Accord than Developing Countries, as all 7 developed countries (Germany, Switzerland, Japan, Canada, Norway, Australia, and Singapore) reduced their CO_2 emissions from 2016 to 2020. Conversely, we have mixed results for developing countries with 13 developing countries reducing emissions and 8 countries increasing their emissions relative to their baseline level in 2016.

Our analysis is substantiated by another set of linear regressions which uses data on CO_2 emissions 4 years post-treaty. In regression outputs #3 and #4, we find that the point estimate for the coefficient on year is -0.2863 for developed countries and -0.0092 for developing countries. This implies that on average after controlling for population density and government effectiveness, developed countries that signed the Paris Climate Accord reduced their emissions by -0.2863 Metric Tons of CO_2 on average, while developing countries that signed the Paris Climate Accord reduced their emissions by -0.0092 Metric Tons of CO_2 on average.

IV. Discussion

From our analysis, we find answers to our research questions.

1. Do countries follow through on their commitment to CO2 reduction in the Paris Climate Accord? We find that the answer to this depends on the specific country. Figure 3 shows which countries were the most/least effective at reducing their CO2 emissions from 2016 to 2020 (post-treaty).
2. Is government effectiveness for treaty-signing countries related to a reduction in CO2 emissions? Yes. We see in Figure 4 that countries with high government effectiveness also had proportional reductions in their CO2 emissions. While it seems like high government effectiveness is correlated with a reduction in CO2 emissions, low government effectiveness does not seem to be a good indicator of the level of CO2 emission reduction.
3. Were treaty-signing countries any more effective than non-treaty-signing countries at reducing CO2 emissions? No. We find evidence against this hypothesis from regression specifications 1 and 2 that treaty-singing countries reduced their CO2 emissions by as much as non-treaty-signing countries in the 4 years post-treaty.
4. Are there differences in post-treaty commitment to CO2 emission reduction between developed and developing countries? Yes. From Figures 5 & 6 and regression specifications 3 and 4, we find that developed countries are significantly more effective at decreasing their CO2 emissions than developing countries.

Overall, while climate agreements are important in unifying efforts to reach specific climate metrics like reduction in CO2 emissions, it is important to consider factors like government effectiveness and heterogeneity in country characteristics such as development when evaluating country follow-through on climate agreements. In particular, we find that looking at the performance of non-treaty-signing countries is highly informative in evaluating the performance of treaty-signing countries.

Our results in the effectiveness of treaty-signing and non-treaty-signing countries should also be taken with a grain of salt. In particular, although treaty-signing countries have a similar decrease in emissions on average as non-treaty-signing countries, there are various ways to interpret this. One way could be positive, where developed countries signing the climate agreements may have inspired some change in non-treaty-signing countries with the consequence being a decrease in CO2 emissions for treaty-signing and non-treaty-signing countries. Another possible interpretation is that developed countries are simply following global trends in technology and transitioning away from CO2 emissions at the same rate as the rest of the non-treaty signing countries. Further, as much as we would like to say that it is clear that treaty-signing countries reduce their CO2 emissions by about as much as non-treaty-signing countries in the case of the Paris Climate Accords, in reality, there is far more nuance in these results. Since non-treaty signing countries are the composite of all data points for all other countries, there may be specific countries driving these results. There may be some selection bias in the treaty-signing countries that makes them systematically different than the non-treaty-signing countries in a way that is not captured by our controls which could contribute to this result. Overall, our results are very preliminary, and further analysis and research would need to be done to thoroughly answer these questions.

With regards to the difference between developing and developed countries, questions of climate responsibility are relevant to this analysis: are developed countries only able to meet their climate targets because they are more well-off and can afford to reduce their CO_2 emissions in the short-term while developing countries cannot afford to do so? Understanding the historical contribution of each country to climate change and the unique economic and environmental challenges faced by each country is important to leading a well-balanced discussion of climate change today.

V. Future Directions

An issue we faced was that the data we could find about certain niche topics was understandably limited. As such we had to narrow the scope of our discovery and analysis in line with the data we had access to. While we were able to scrape some data to create our stores of information, it was not feasible to do so for other kinds of data. In the future, we would love to gather more interesting data related to climate agreements to better understand our research topic.

We could have also gone further with our quantitative methods of analysis. One next step would be to do more with the regression analysis. In particular, we could do a log transformation of our outcome variable, which would allow us to interpret the coefficient in percentage terms. Further, we could have incorporated some deep learning techniques, to extrapolate toward the long-term dates outlined in the Paris Agreement (i.e. 2030 and 2050). Specifically, using recurrent neural networks would be appropriate as the prediction of one year could be fed in as the input for the following to better inform the predicted trends.

Lastly, there is a lot of value to be found in a more qualitative analysis as well. We have found trends that help us answer the questions we posed, however, finding the patterns is only the first step. Understanding the reasons why certain countries have failed to stay on track with their goals would help inform further studies and initiatives to correct their course. Reaching out to organizations such as Climate Action Tracker who work in this space would likely help us answer the reasons for these global trends. Similarly, connecting with local governments or other such entities would allow for more in-depth case studies with a narrower scope.

VI. Data Concerns

Long-Term Data Storage Concerns:

- Data Format Obsolescence: Over time, file formats and storage technologies can become outdated. This could make our project data difficult or impossible to access with future software.
- Data Loss Events: There is always a risk of data loss due to hardware failures, storage media degradation, or unforeseen circumstances like natural disasters.

Preserving Data Provenance:

To address these concerns and ensure long-term data usability, we will implement the following strategies:

- Storage Format Selection: We will choose a widely supported data format SQL for the cleaned datasets. This reduces the risk of future incompatibility with data analysis tools.
- Data Archiving: We will back up the cleaned data on a reliable, redundant storage system (e.g., cloud storage with version control). Regular backups will mitigate data loss risks.
- Detailed Documentation: We will create comprehensive documentation that outlines the data sources, the cleaning steps applied, and the final data format. This documentation will be crucial for anyone trying to understand or reuse the data in the future.

VII. Relational vs. Non-Relational

Our project uses data that is highly structured and with only a couple of exceptions, non-hierarchical. Preserving integrity constraints and cascade deletes is also critical for maintaining the structure of our data. For example, entries in the Climate Data entity should be deleted if the country that corresponds to it is deleted. These actions do not occur too often so the overhead associated with it is negligible, but the guarantees it provides are important.

Since our queries are relatively simplistic we could have used a NoSQL approach to structure our project. However, this is likely the only feature of NoSQL databases that we would prefer over relational databases. Scalability and flexibility are two of the main value propositions of non-relational databases but this project does not require either of these aspects. We do not store tremendous amounts of data, nor do we value fault tolerance over consistency. Lastly, the queries we perform require few joins so using a relational database in the context of our project makes the most sense.

Appendix

Note: Most of these charts are interactive and display relevant details about specific countries and characteristics when you hover or click on them. For the full experience, please interact with the visualizations in the Jupyter notebook or .html file!

Fig 1. Total CO2 emissions for Paris Climate Accord Countries from 2012 to 2020

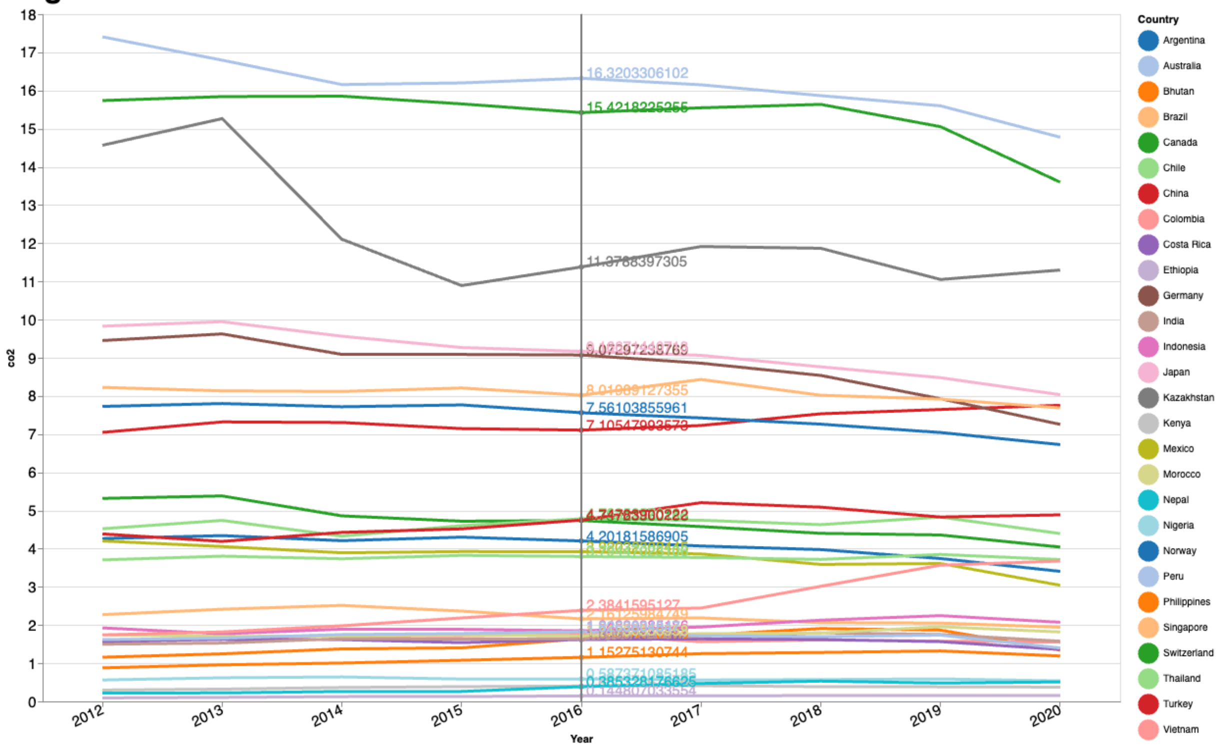
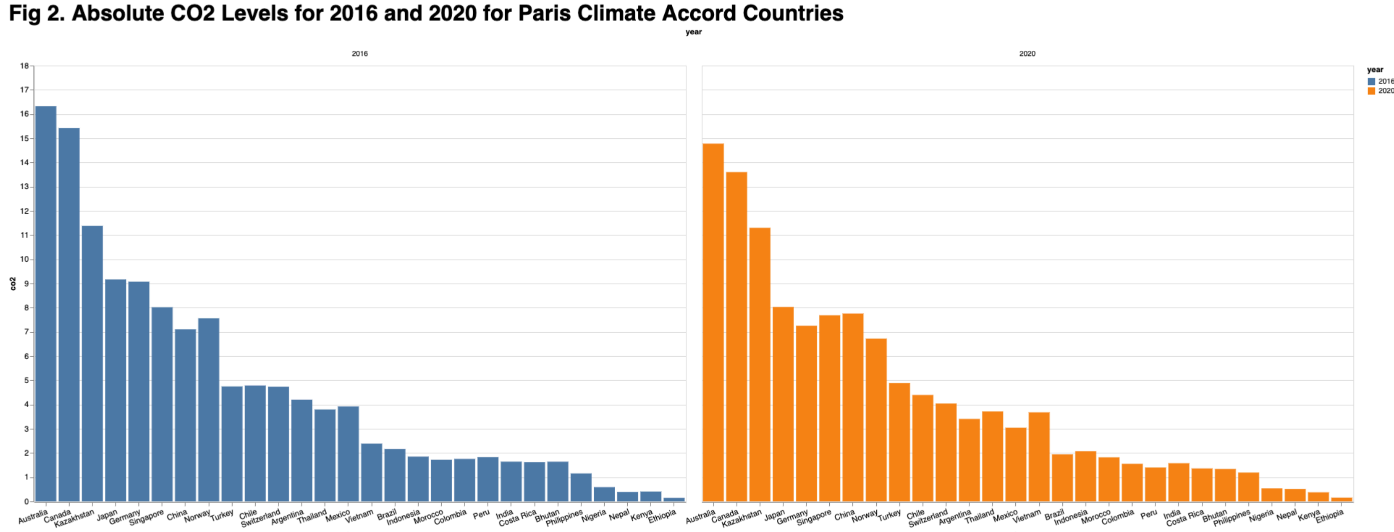


Fig 2. Absolute CO2 Levels for 2016 and 2020 for Paris Climate Accord Countries



For a full-size chart with visible country names, please see the accompanying .ipynb file or the .html file.

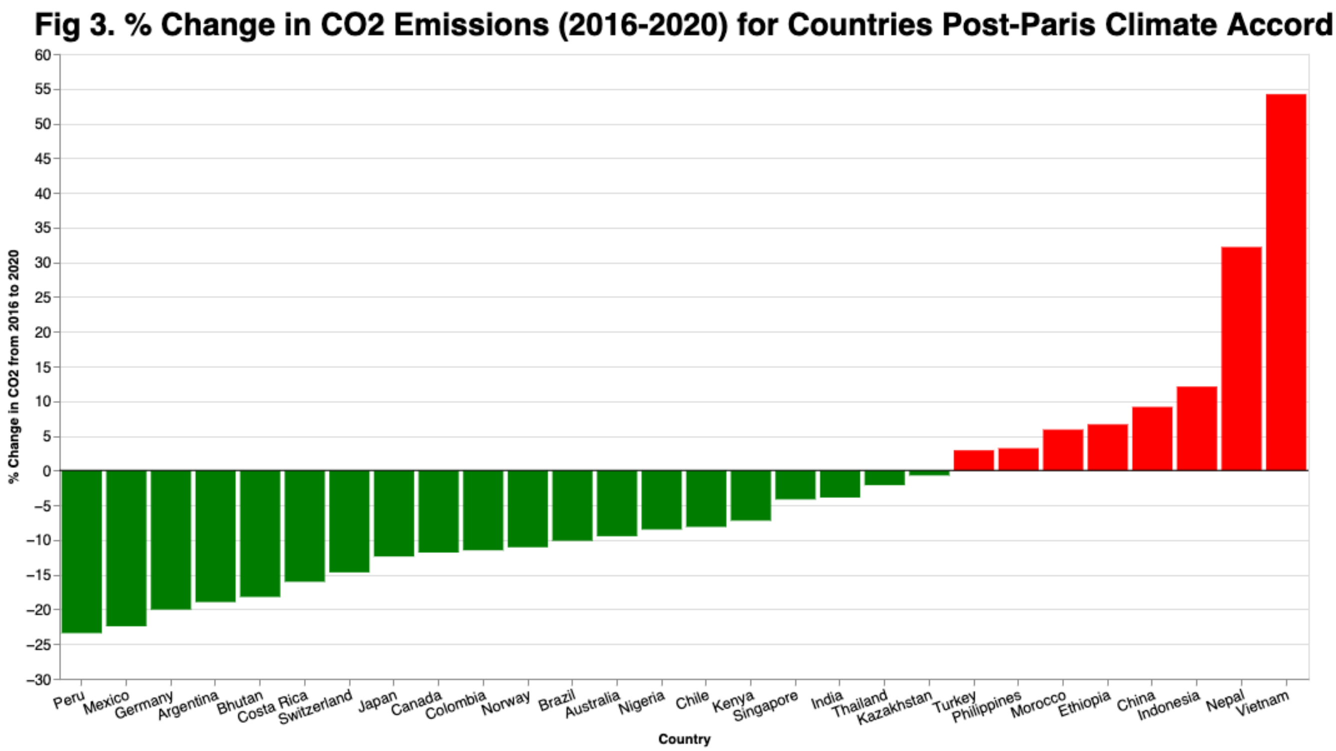


Fig 3. % Change in CO2 Emissions (2016-2020) for Countries Post-Paris Climate Accord
% Change in CO2 from 2016 to 2020
Country
Peru
Mexico
Germany
Argentina
Bhutan
Costa Rica
Switzerland
Japan
Canada
Colombia
Norway
Brazil
Australia
Nigeria
Chile
Kenya
Singapore
India
Thailand
Kazakhstan
Turkey
Philippines
Morocco
Ethiopia
China
Indonesia
Nepal
Vietnam

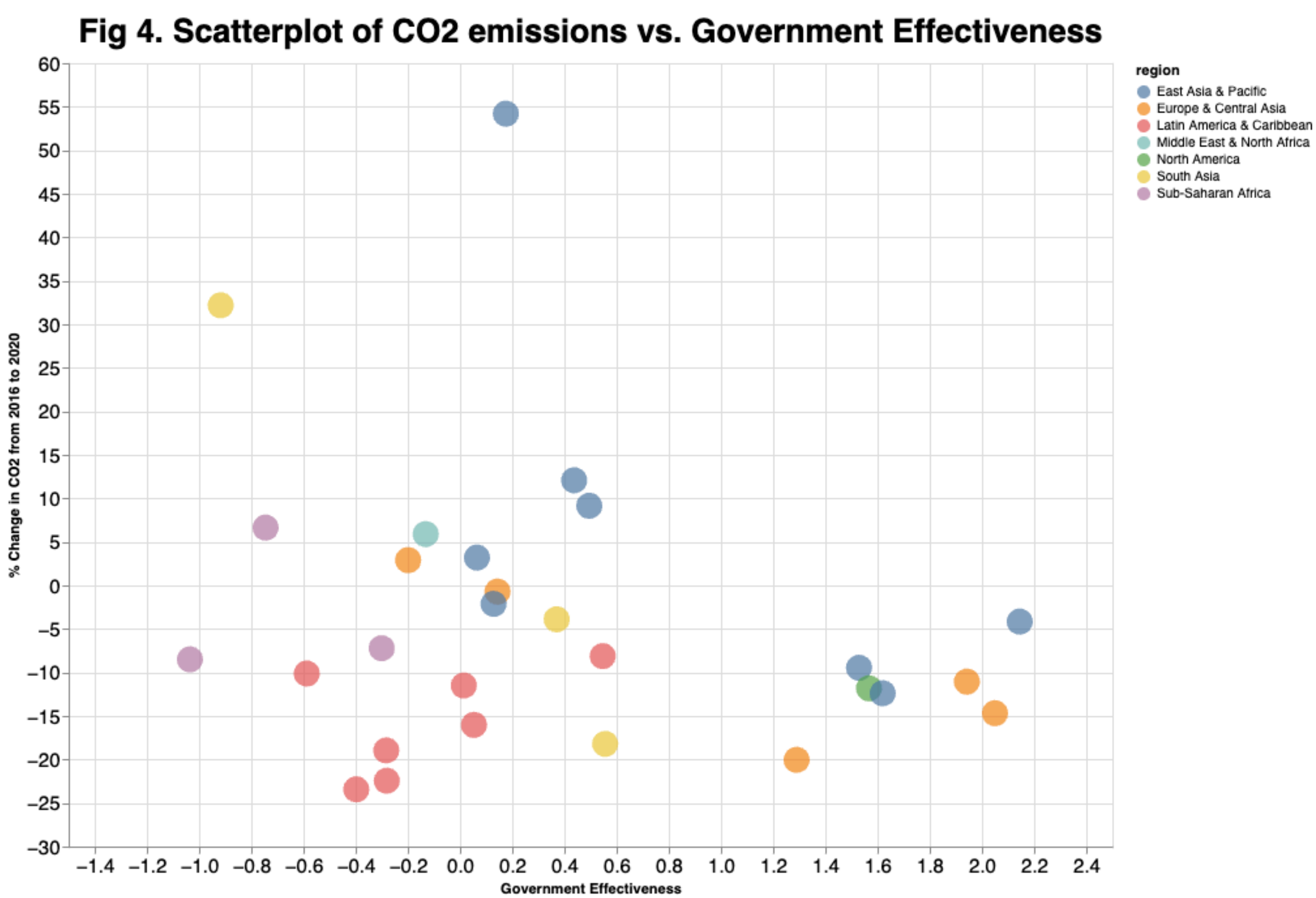


Fig 4. Scatterplot of CO2 emissions vs. Government Effectiveness
% Change in CO2 from 2016 to 2020
Government Effectiveness
region
East Asia & Pacific
Europe & Central Asia
Latin America & Caribbean
Middle East & North Africa
North America
South Asia
Sub-Saharan Africa

Regression #1 Output:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    co2   R-squared:                       0.478
Model:                            OLS   Adj. R-squared:                  0.467
Method:                 Least Squares   F-statistic:                     41.57
Date:                Fri, 22 Mar 2024   Prob (F-statistic):           3.94e-19
Time:                        00:22:34   Log-Likelihood:                -353.72
No. Observations:                 140   AIC:                             715.4
Df Residuals:                     136   BIC:                             727.2
Df Model:                           3
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const               161.8556    370.412      0.437      0.663    -570.656     894.367
year                 -0.0785      0.184     -0.428      0.670      -0.441       0.284
pop_density          -0.0004      0.000     -2.173      0.032      -0.001   -3.94e-05
gov_effectiveness     3.4358      0.314     10.942      0.000       2.815       4.057
==============================================================================
Omnibus:                       19.294   Durbin-Watson:                   0.487
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               22.819
Skew:                           0.880   Prob(JB):                     1.11e-05
Kurtosis:                       3.901   Cond. No.                     2.98e+06
==============================================================================
```

Regression #2 Output:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    co2   R-squared:                       0.262
Model:                            OLS   Adj. R-squared:                  0.259
Method:                 Least Squares   F-statistic:                     93.03
Date:                Fri, 22 Mar 2024   Prob (F-statistic):           1.58e-51
Time:                        00:22:34   Log-Likelihood:                -2253.0
No. Observations:                 790   AIC:                             4514.
Df Residuals:                     786   BIC:                             4533.
Df Model:                           3
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const               163.7456    213.303      0.768      0.443    -254.966     582.457
year                 -0.0790      0.106     -0.748      0.455      -0.287       0.128
pop_density           0.0013      0.001      2.328      0.020       0.000       0.002
gov_effectiveness     2.5551      0.159     16.027      0.000       2.242       2.868
==============================================================================
Omnibus:                      457.603   Durbin-Watson:                   0.416
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             3628.859
Skew:                           2.572   Prob(JB):                         0.00
Kurtosis:                      12.154   Cond. No.                     2.89e+06
==============================================================================
```

Regression #3 Output:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    co2   R-squared:                       0.320
Model:                            OLS   Adj. R-squared:                  0.255
Method:                 Least Squares   F-statistic:                     4.874
Date:                Fri, 22 Mar 2024   Prob (F-statistic):            0.00685
Time:                        00:22:34   Log-Likelihood:                -90.553
No. Observations:                  35   AIC:                             189.1
Df Residuals:                      31   BIC:                             195.3
Df Model:                           3
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const               601.9474    824.345      0.730      0.471   -1079.316    2283.211
year                 -0.2863      0.408     -0.701      0.489      -1.119       0.547
pop_density           0.0002      0.000      0.914      0.368      -0.000       0.001
gov_effectiveness    -8.5063      2.421     -3.514      0.001     -13.443      -3.569
==============================================================================
Omnibus:                        4.622   Durbin-Watson:                   0.164
Prob(Omnibus):                  0.099   Jarque-Bera (JB):                1.965
Skew:                           0.215   Prob(JB):                        0.374
Kurtosis:                       1.922   Cond. No.                     4.37e+06
==============================================================================
```

Regression #4 Output:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                    co2   R-squared:                       0.268
Model:                            OLS   Adj. R-squared:                  0.247
Method:                 Least Squares   F-statistic:                     12.35
Date:                Fri, 22 Mar 2024   Prob (F-statistic):           6.00e-07
Time:                        00:22:34   Log-Likelihood:                -233.45
No. Observations:                 105   AIC:                             474.9
Df Residuals:                     101   BIC:                             485.5
Df Model:                           3
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const                22.4988    317.395      0.071      0.944    -607.128     652.126
year                 -0.0092      0.157     -0.059      0.953      -0.321       0.303
pop_density          -0.0065      0.002     -3.582      0.001      -0.010      -0.003
gov_effectiveness     2.5045      0.489      5.124      0.000       1.535       3.474
==============================================================================
Omnibus:                       39.120   Durbin-Watson:                   0.441
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               80.692
Skew:                           1.499   Prob(JB):                     3.01e-18
Kurtosis:                       6.075   Cond. No.                     2.89e+06
==============================================================================
```

References

Battaglini, M., & Harstad, B. (2020). The political economy of weak treaties. Journal of Political Economy, 128(2), 544-590.

Climate Action Tracker (2024). https://climateactiontracker.org/data-portal/.

Falkner, R. (2016). The Paris Agreement and the new logic of international climate politics. International Affairs, 92(5), 1107-1125.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., ... & Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 C. Nature, 534(7609), 631-639.

World Bank Group, Climate Change Knowledge Portal (2024). https://climateknowledgeportal.worldbank.org/.

World Bank Group, Environment Social and Governance Data (2024). https://datacatalog.worldbank.org/search/dataset/0037651/Environment--Social-and-Governance-Data.