A Descriptive Analysis of Climate Change Accountability

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Data Sci W200 Section Th 630

Introduction

The United Nationals global warming conference in Glasgow, which ran for two weeks and ended Nov.12, has made headlines across all major newspapers. With scientists warning that every fraction of a degree of warming will lead to more intense heat waves, drought, floods, and wildfires and a 100,000-people rally on Global Day for Climate Justice, the world has come to recognize the severity and urgency of climate change. One of the largest debates during the summit is whether the world's wealthiest nations are disproportionately responsible for global warming, and whether they should compensate poorer nations for increasingly severe weather (Popovish and Plumer, 2021). To further explore the climate change phenomenon, our project is extending New York Times' analysis on current emissions by visualizing the occurrence of severe weather events. Our main research question is:

How does severe weather experience compare between high- and low- polluters in the world?

a. Are there more severe weather events over time?
b. Are rich countries polluting more than poorer countries?
c. Should rich nations compensate poorer nations for severe climate change?

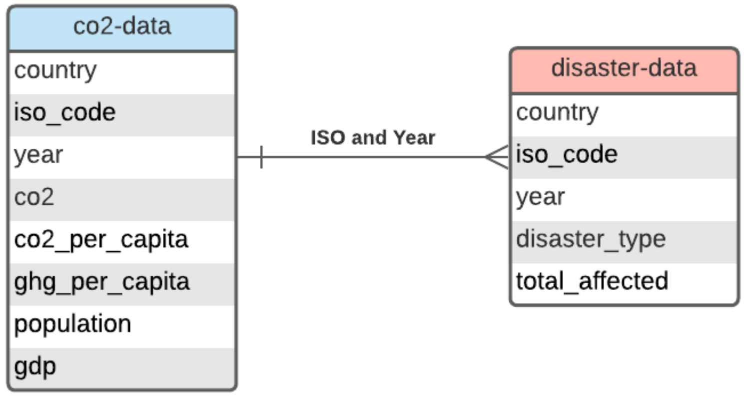
This project uses the frequency and impact of natural disaster events as an indicator of climate change. Carbon dioxide (CO2) and greenhouse gas (GHG) emission levels will be used to measure pollution. Since natural disasters and pollution come from separate datasets with different time ranges, each dataset will be observed individually. Next, datasets will be observed together during their overlapping year ranges. After our descriptive statistical analysis, we will discuss our research question and make recommendations on future steps.

Datasets

The primary dataset is *Data on CO2 and Greenhouse Gas Emissions* by *Our World in Data*. This dataset includes data on CO2 emissions (annual, per capita, cumulative, and consumption-based), other greenhouse gases, energy mix, and other relevant metrics. For our project, this dataset is saved as "co2-data.csv" and the following columns will be used: **country**, **year**, **co2**, **iso_code**,**co2_per_capita, population**, **gdp**, **total_ghg**, **ghg_per_capita.**

The supplemental dataset is EM-DAT by the Center for Research on the Epidemiology of Disasters - CRED. This is a public database that records disaster events around the world and is sourced from a combination of organizations, including multiple United Nations committees, National Governments, US Governments, IFRC, World Bank, and more. The date range of the dataset goes from 1956 to 2020. For our project, this dataset is saved as "disaster-data.csv" and the following columns will be used: **Year, Disaster Group**, **Disaster Type**, **Country**, **ISO**, **Start Year, Start Month, Start Day**.

The datasets were reviewed and slimmed down to include only the information that we required to help answer our research questions. We produced three distinct datasets for different use-cases. An emissions focused (co2-data), a disaster focused (disaster-data) and a merged dataset that involves aggregating the disaster events to the year and joining on **iso_code** and **year** (co2-disaster-data).



Assumptions

General
- All answers to our research question is from an observational statistics perspective.
- Pollution is measured by CO2 and GHG emissions.
- Wealth of a country is measured by its GDP per capita. While this relationship is not a perfect indicator of a country's wealth it does measure how much economic activity has occurred during a timespan and is commonly used as a metric for a healthy economy.
- Severe weather is a subset of natural disasters. E.g. Floods, storms, droughts.
- Collection of data is consistent over the years in the datasets. Any variation is not due to enhancements in tracking mechanisms and/or policies.
- Each country has unique variations in land mass, GDP, population, industries, and other metrics that may result in bias toward pollution, prosperity, or increased likelihood of disasters. There will not be a need to do robust normalization based on the context of countries because analysis will be executed on the full set of all countries.

Disaster data
- NaN values will be assumed as missing and not included in aggregations such as mean.
- Disasters with null values for "total_affected" means none affected. This is because there is no basis for assuming any other value.

CO2 data
- Data rows with ISO codes refers to CO2 and GHG emissions per individual country. In contrast, data rows with no ISO codes refer to CO2 and GHG emissions per continent. Total emissions for the world (i.e. country fields with 'World') are an exception with the ISO code 'OWID_WRL'.
- Remove rows with NaN and empty strings in relevant columns, i.e. ISO code, CO2
- CO2 emissions are calculated based on territorial production-based emissions, which do not account for embedded trade-based emissions.
- For the process of determining which countries' economies are most capable of contributing now and in the future, conclusions will be made using the most recent GDP values.

Descriptive Statistics

During the 2021 UN Climate Change Conference, poorer countries argue that wealthy countries are the largest contributors to high pollution levels due to mass production and consumption and should therefore compensate poorer nations affected by the ensuing climate change. In addition to rising temperatures, poorer nations claim that they are facing more natural disasters that are damaging their living environment, economy and government funds. To answer this question, we analyzed data across our three sub-questions.

a. Are there more severe weather events over time?

To answer this question, we analyzed the number of different natural disaster types over time, how disasters map geographically and the relationship between natural disaster types and CO2 emissions over time.

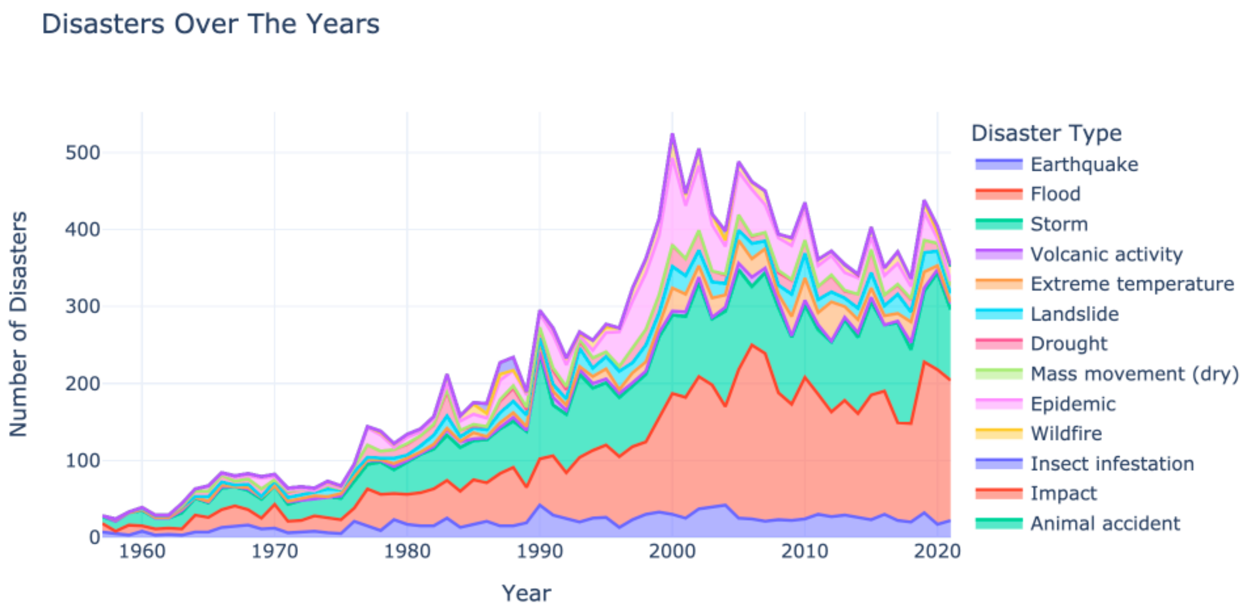


Figure 1. Natural disasters per year classified by disaster type (1956-2020). *Area chart depicting a steadily increasing count of natural disasters. Disasters from the original dataset that are not classified as Natural have been removed.*

Looking at trends from 1956 to 2020 we can see there is a trend of increasing storms, floods, and other natural disasters. Extreme weather events, the most common type of natural disasters, are widely considered to be increasing as a result of climate change (Ornes, 2018). We will further explore this rise in relation to rising emissions, who's being affected, and who may be to blame.

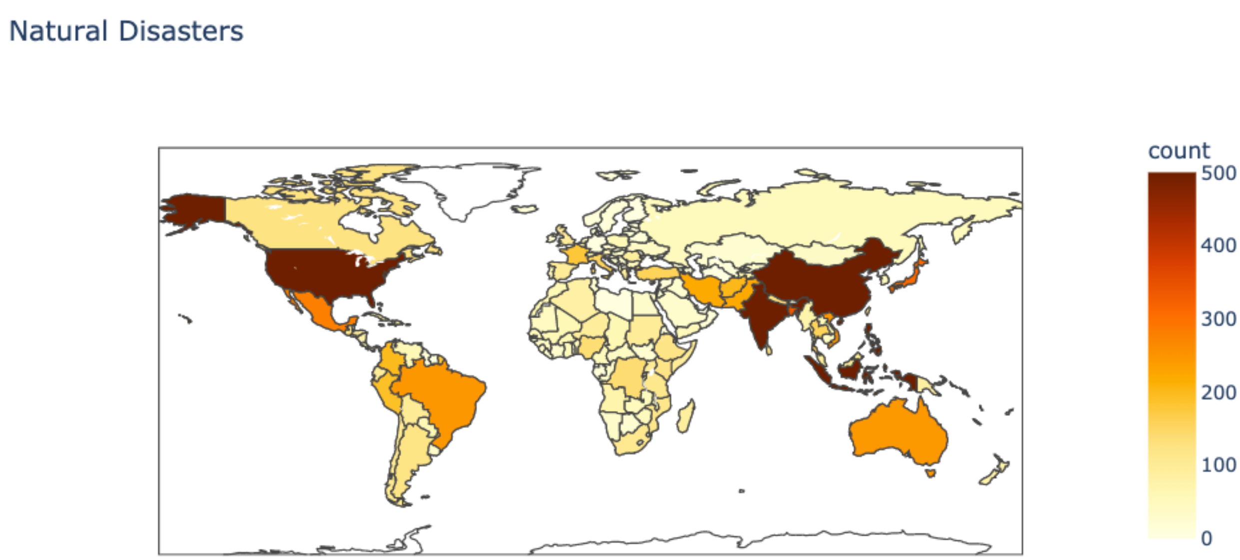


Figure 2. Where the natural disasters have occured geographically since 1956. *World choropleth map with coloring based on the number of disasters that have occured on each county. While the color range is 0-500, some of the outlier countries exceed that by almost double. (US-999, China-709)*

Starting out by taking a look at where severe weather events are primarily occurring will help determine if there is a geographical component to where disasters are occurring. For example around the equator, in clusters of different elevation, or those with the largest land mass. However, aggregation of the number of disasters by country suggests that there is no correlation between geographic location and the frequent occurrence of natural disasters. The same continent may include countries with both high and low numbers of natural disasters and there is no discernible pattern.

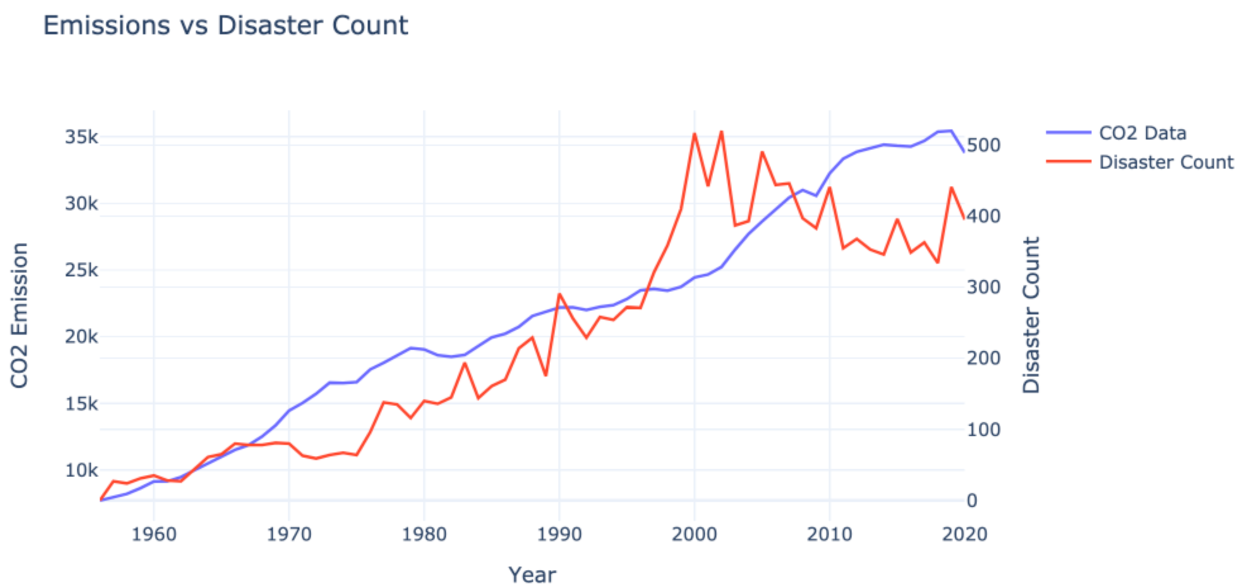


Figure 3. Relationship between the emission rate and natural disasters over time. *Dual axis line graph which represents the CO2 emissions in metric tonnes overlaid with the count of natural disaster events from 1956-2020.*

The trending of emissions and disaster events suggests there is a relationship between the rise in CO_2 emissions and the rise in the number of natural disasters. The results are consistent with findings of focused research that address the causes of increased weather events (AMERICAN METEOROLOGICAL SOCIETY, 2017). Asserting that this increase of weather events is due to man-made pollution is the first step in discussing who's culpable and in turn who should be held accountable.

Analysis

Overall, we see a strong relationship between the disaster types and CO_2 emissions over time. More natural disasters related to climate change, such as floods, are occuring in higher numbers over time. When we examine the volume of disasters geographically, there is no correlation between specific geographic locations (i.e. closer to the equator, continent). Additionally, we see a strong relationship between CO_2 emissions and natural disasters increasing over time.

To understand how this relates to CO_2 emissions and GDP more in-depth, we examine the overall CO_2 and GHG emissions across countries and relationships with GDP.

b. Are rich countries polluting more than poorer countries?

To understand this question better, we initially observed the top countries leading in CO2 emissions and also observed how these countries' CO2 and GHG emissions span over time. We then did analysis to examine the relationship between emission rates and GDP through observing emission rates of countries.

Charts

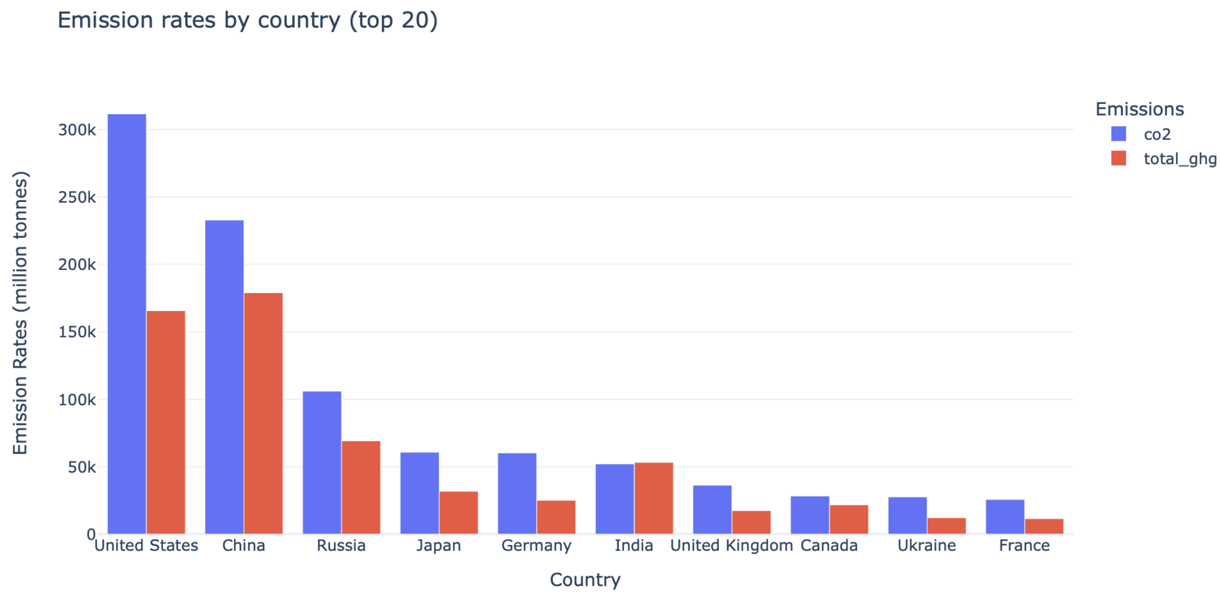


Figure 4. Graph for 10 countries with highest CO2, GHG emissions - *Annual production-based emissions of carbon dioxide (CO2), measured in tonnes per person. This is based on territorial emissions, which do not account for emissions embedded in traded goods. Total greenhouse gas emissions including land use change and forestry, measured in million tonnes of carbon dioxide-equivalents.*

Even among the top 10 countries with highest CO2 and GHG emission rates, the United States and China both have significantly higher emissions for CO2 and GHG levels compared to the other countries within the 10 countries with the highest CO2 and GHG emission rates. For example, the United States' CO2 emissions are almost 3x more than Russia's, while China's CO2 emissions are 2.2x higher than Russia's.

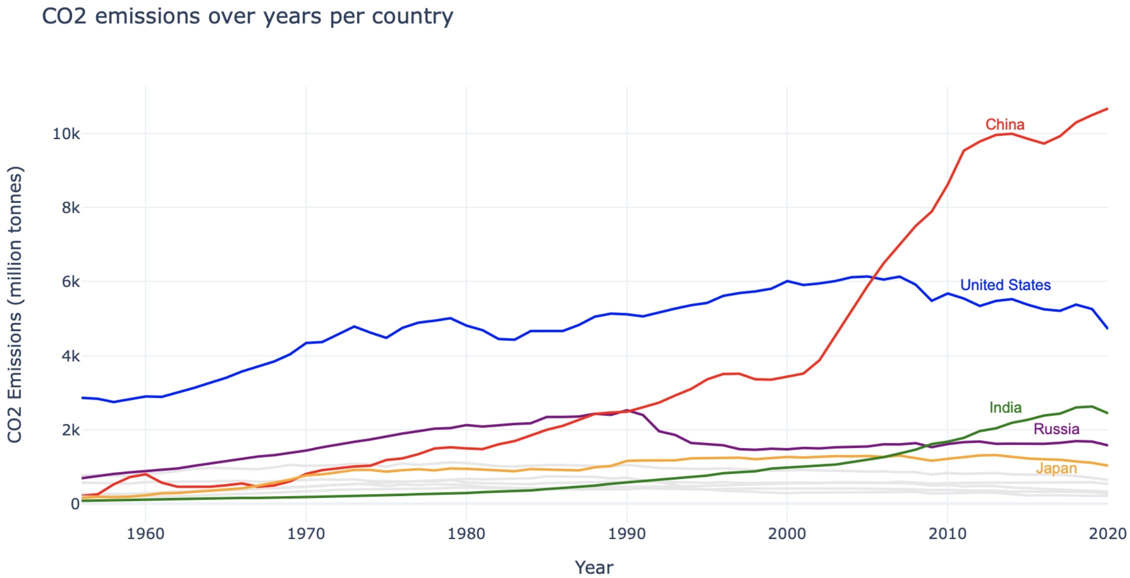


Figure 5. Increase in CO2 emissions over years per country - *Annual production-based emissions of carbon dioxide (CO2), measured in tonnes per person. This is based on territorial emissions, which do not account for emissions embedded in traded goods.*

Taking a deeper look at how CO2 emissions have evolved over time for countries, overall CO2 has increased linearly. CO2 levels increased from around 7720 million tonnes in 1956 to 33.8k million tonnes in 2020, which is 4x the amount in a 64 year period time frame. Among the 10 countries with highest CO2 emissions, India and China have seen the most rapid increase in emissions at exponential rates. The United States, Russia, and Japan continue to see increase throughout the years. This contrasts with other countries (i.e. Germany) that have not seen a high increase in emissions.

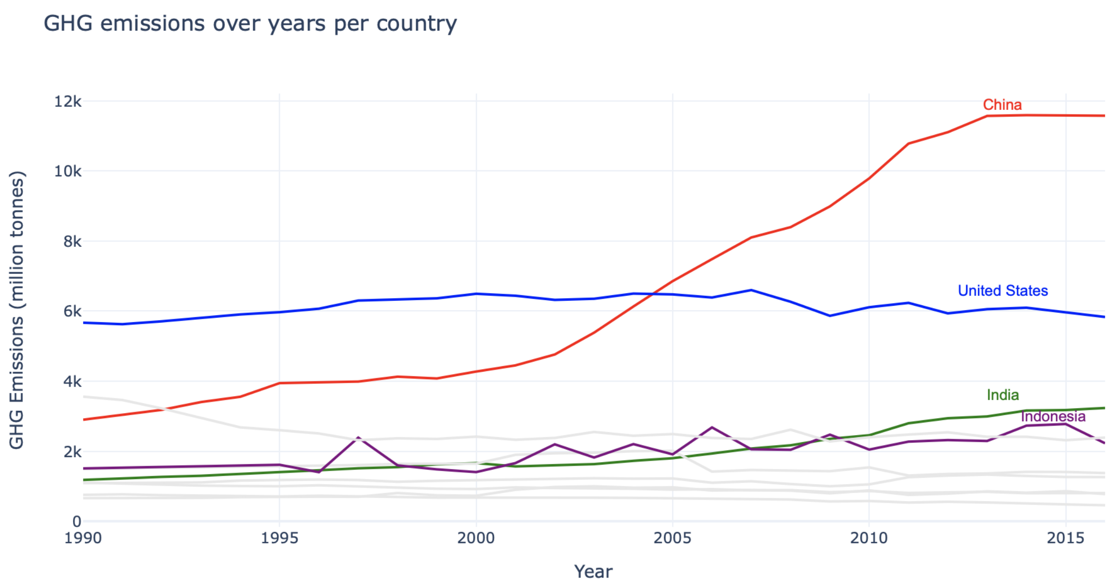


Figure 6. Increase in GHG emissions over years per country - *Total greenhouse gas emissions including land use change and forestry, measured in million tonnes of carbon dioxide-equivalents.*

Additionally, GHG levels have increased steadily from 33.8k million tonnes in 1990 to 47.5k million tonnes in 2016, which is a 1.4x increase over a 26 year period. Among the 10 countries with highest GHG emissions, China and India have seen the fastest growth in terms of increase in GHG emissions. Other countries, such as Indonesia and the United States continue to see linear increase in GHG emissions.

	Country	CO2 Emissions	GHG Emissions
1	China	232977.94	179061.84
2	United States	311737.12	165734.57
3	India	52063.32	53209.94
4	Japan	60824.13	31811.53
5	Germany	60250.35	25108.81
6	Russia	106056.13	69251.04
7	Indonesia	13746.35	53385.09
8	Brazil	15847.89	42729.29
9	France	25707.71	11467.98
10	United Kingdom	36257.64	17487.48

Figure 7A. CO2, GHG emissions for countries in top 10 GDP (ordered descending from highest GDP) - *Annual production-based emissions of carbon dioxide (CO2), measured in tonnes per person. This is based on territorial emissions, which do not account for emissions embedded in traded goods. Total greenhouse gas emissions including land use change and forestry, measured in million tonnes of carbon dioxide-equivalents.*

	Country	CO2 Emissions	GHG Emissions
1	Dominica	4.79	8.10
2	Sao Tome and Principe	3.35	4.82
3	Comoros	5.30	11.92
4	Saint Lucia	14.31	21.28
5	Guinea-Bissau	10.05	101.98
6	Seychelles	13.38	15.94
7	Djibouti	18.75	35.75
8	Barbados	54.21	97.61
9	Central African Republic	10.55	1671.03
10	Cape Verde	13.01	8.83

Figure 7B. CO2, GHG emissions for countries in bottom 10 GDP (ordered ascending from lowest GDP) - *Annual production-based emissions of carbon dioxide (CO2), measured in tonnes per person. This is based on territorial emissions, which do not account for emissions embedded in traded goods. Total greenhouse gas emissions including land use change and forestry, measured in million tonnes of carbon dioxide-equivalents.*

When we start examining the relationship between emission rates and GDP, in both tables we notice that countries with top 10 GDP, have much higher pollution rates than that of the bottom 10 GDP. For example, China, the country with the highest GDP, had 48.6k times more CO2 emission rates than Dominica, the country with the lowest GDP. Additionally, China's GHG emission rates were 22.1k times greater than that of Dominica.

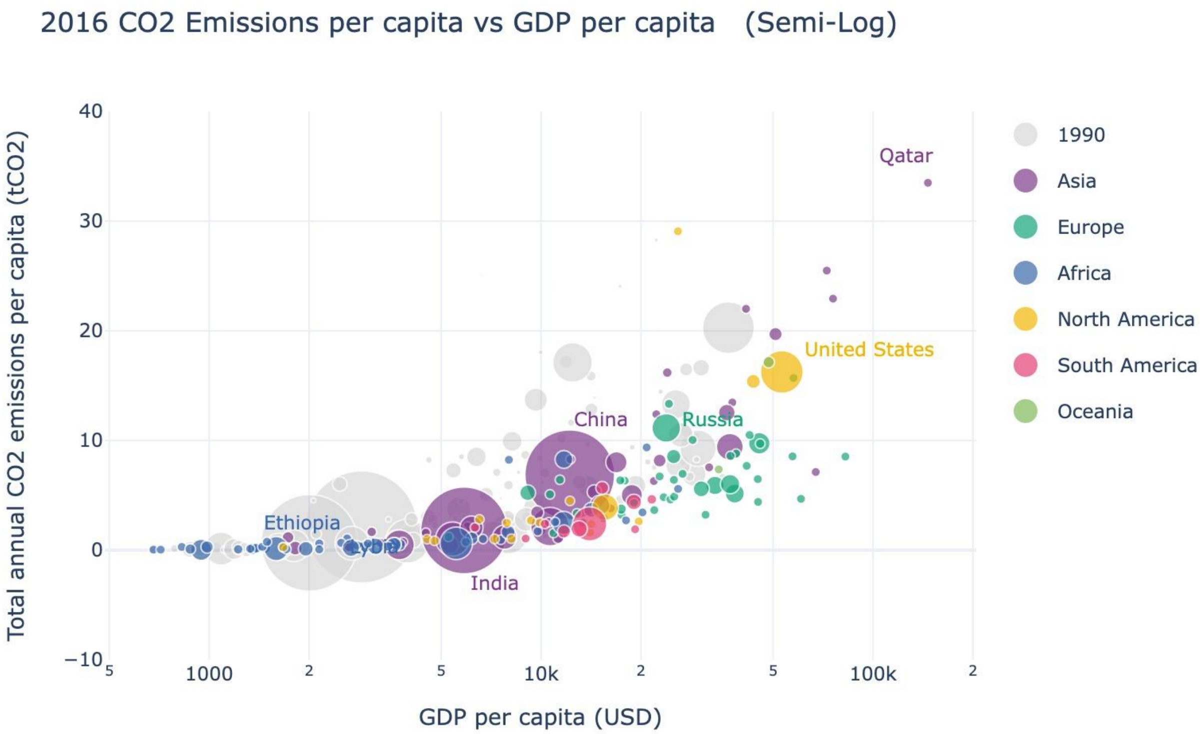


Figure 8. CO2 emissions per capita vs GDP per capita (Semi-Log): *Annual production-based emissions of CO2 is measured in tonnes of CO2. This is based on territorial emissions, which do not account for emissions embedded in traded goods. GDP per capita with population uses GDP measured in international-$ using 2011 prices to adjust for price changes over time (inflation) and price differences between countries. Size of markers represent population.*

To map the relationship further between CO2 emissions and GDP per Capita, above is a comparison of 1996 and 2016's annual CO2 emissions per capita vs GDP per capita. In the span of 20 years, several Asian countries have sky-rocketed in both CO2 emissions per capita and GDP per capita. Europe's emissions have concentrated in the range of 5 to 10 tonnes of annual CO2 emissions. These two graphs consistently demonstrate that most of Africa has the lowest emissions followed by South America and North America.

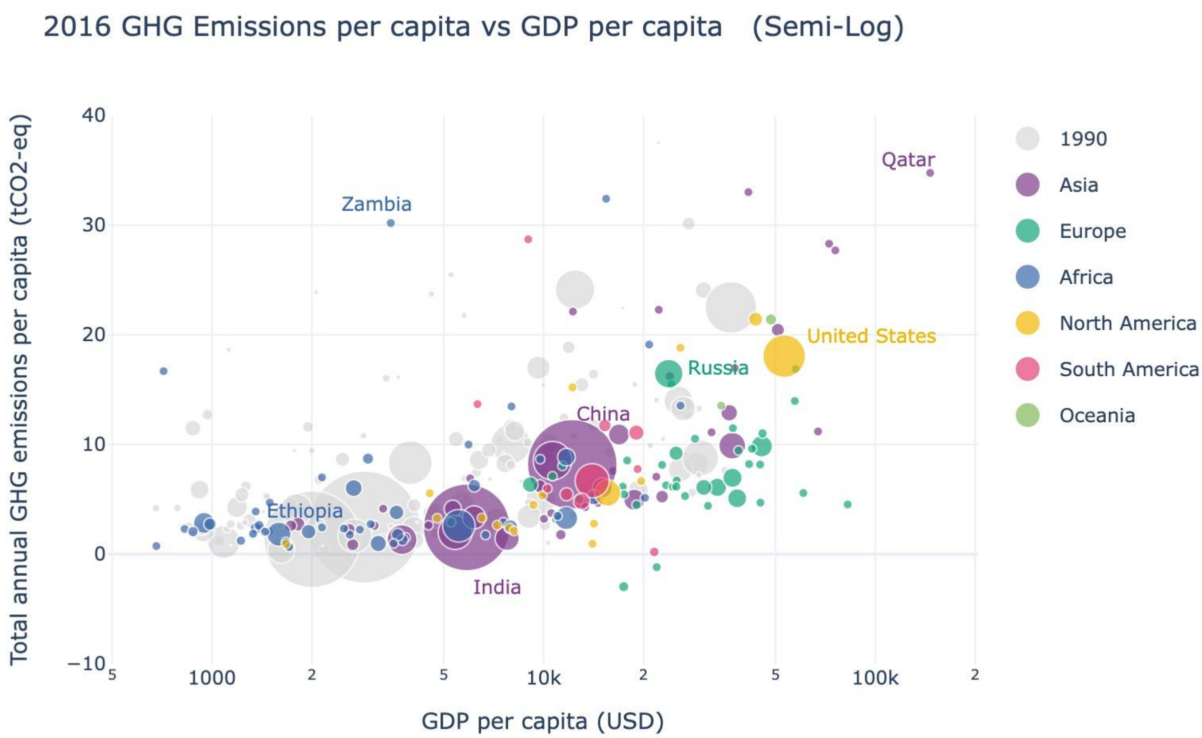


Figure 7. Total annual GHG emissions per capita vs GDP per capita (Semi-Log) in 1966 and 2016: *Total greenhouse gas emissions per capita including land use change and forestry, measured in tonnes of CO2-equivalents. GDP per capita with population uses GDP measured in international-$ using 2011 prices to adjust for price changes over time (inflation) and price differences between countries. Size of markers represent population.*

When observing pollution using total GHG emissions, the distribution is much more scattered compared to the CO2 emissions graph. Additionally, there are a handful of African and South American nations that have emission levels as high as wealthier nations in Europe and Asia.

Analysis

From our findings, we believe that richer countries are generally polluting more than poorer countries. One of the key graphs is 2016 GHG emissions vs GDP per capita. The total GHG emissions, which includes land use change and forestry. GDP per capita is used to measure the wealth of countries. In the graph, the size of the dots represent the size of the population. The majority of the countries are clustered around 10~25k GDP per capita and emit around 5~10 tCO2-eq. Compared to 1990 in grey, many countries in Asia became wealthier as they became the world's factory, but also increased in emissions. Europe maintained emissions around 5~10 tCO2. Most of Africa has both low emissions and GDP per capita.

However, it becomes apparent that rich and poor is a subjective phrase and GDP can be very misleading. UN Summit debates target this argument towards major countries such as China, Europe, and USA. However, China has a high GDP yet their per capita GDP is very low due to their large population. India also has among the highest GDPs, but their per capita GDP is very low. An interesting observation is Qatar, which is on the extreme end and has highest emissions AND GDP per capita due to having oil and gas as their main economic sector. But when considering their small population, their GDP would not be as high as the Big5 nations.

Secondly, the correlation between emissions and wealth is not as strong as the CO2 emissions graph as we see in Figure 6. There are countries such as Zambia that have extremely high emissions yet do not have a high GDP per capita. And the reason behind this is that there are many other factors independently influencing GDP and emissions. To have all high-polluters take monetary responsibility for their pollution may not be practical for all countries. And to only charge rich countries would not be very reasonable either.

c. *Should rich nations compensate poorer nations for severe climate change?*

To answer this question, we draw insights from the two previous research questions. For additional data, we examined how countries are negatively affected by climate change through understanding the number of disaster types across countries.

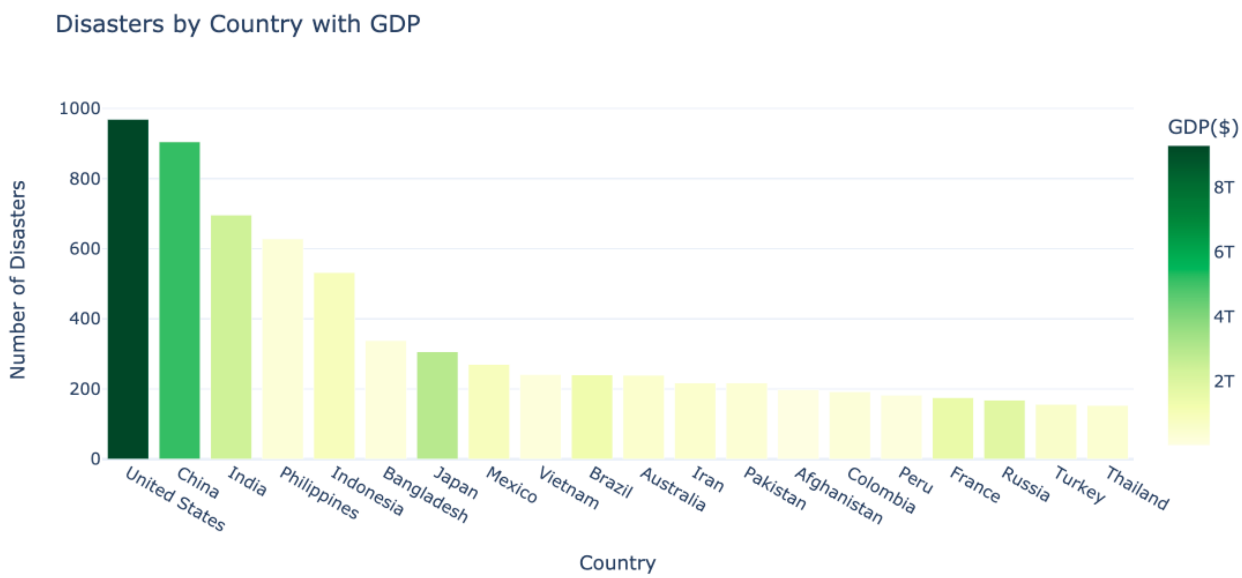


Figure 10. Accumulative disaster event count by country with GDP coloring from 1956~2020. *Gross domestic product measured in international-$ using 2011 prices to adjust for price changes over time (inflation) and price differences between countries. Calculated by multiplying GDP per capita with population.*

Countries with high GDP per capita, such as the United States, China, India, and Japan are ranked top in terms of the number of disasters. Many of these wealthy nations also have high emission rates based on earlier analyses. Even though many of these countries have high emission rates, other countries, such as the Philippines and Bangladesh, do not have high emission rates and are experiencing the brunt of disasters.

Analysis

Based on our above analyses, we have no definite answers, but have policy considerations. From the analysis in the research question “Are rich countries polluting more than poorer countries?”, we determined that nations with higher GDP are polluting more than the poorer countries. However, there are a number of factors that may evolve. The world is increasing in both GDP and CO2 emissions so the definition of wealth and high pollutants may change over time. For example, if countries with lower GDP increase CO2 and GHG emissions at what’s considered ‘high levels’, will they be accountable as well?

In terms of compensation, wealthy and poor (high vs. low GDP) are too general as categories. As shown in figures to answer “Are rich countries polluting more than poor countries?”, there are countries with low GDP and high emission rates such as Ukraine. Additionally, as shown in Figure 10, countries with highest GDP (i.e. The United States, China, India) also rank the highest in the number of natural disasters and also are feeling the pain of climate change. Thus, the variable, GDP, on its own does not define how much countries should contribute to climate change. As next steps, future research may include considering better factors for defining accountability.

Conclusion

To summarize, we found the following results to answer our research question, **"How does severe weather experience compare between high and low-polluters in the world?"** through analyzing the listed sub-questions. To answer "**are there more severe weather events over time?",** we conclude that severe weather is a good indicator for pollution. In our graphs, CO2 emissions rose with disaster counts. To summarize our findings from **"are rich countries polluting more than poorer countries?",** we found that high GDP countries were polluting more than lower GDP countries. Additionally, few high GDP countries, disproportionately drove the most emissions in the last 20 years. For example, countries such as China and India, had the most rapid growth in CO2 and GHG emissions. Finally, for "**should rich nations compensate poorer nations for climate change?**", we found that GDP was a too general variable to determine compensation. When we compared the disasters by country, high GDP countries were also experiencing more disasters. However, there were also low-GDP countries (i.e. Bangladesh) that were experiencing a high number of natural disasters. Thus, there is no direct tie between disaster and GDP. Additionally, there were countries with low GDP (i.e. Ukraine) that had high CO2 and GHG emissions.

Thus, we conclude that richer countries report higher CO2 and GHG emissions and that there is a strong relationship between CO2 emissions and natural disasters over 1956-2020. High GDP countries contributing to high pollution are the United States, China, Russia, Japan and India.

However, GDP should not be used as the sole variable in determining compensation as these same high GDP countries also feel large pain from climate change based on natural disasters, and there are low GDP countries such as Zambia that are also contributing high emission rates. Finally, definitions of high pollution rates and wealthy countries may evolve over time as the world is increasing in emissions and GDP. Thus, we recommend incorporating these observations to consider better factors for accountability in future studies.

References

AMERICAN METEOROLOGICAL SOCIETY. (2017, December 14). *Human influence on climate led to several major weather extremes in 2016 | NOAA Climate.gov*. Climate.gov. Retrieved December 9, 2021, from https://www.climate.gov/news-features/understanding-climate/human-influence-climate-led-several-major-weather-extremes-2016

Friedman, L. (2021, November 15). *What Is COP26? And Other Questions About the Big U.N. Climate Summit*. The New York Times. Retrieved December 10, 2021, from https://www.nytimes.com/article/what-is-cop26-climate-change-summit.html

Herring, S. (2016). *Explaining Extreme Events of 2016 from a Climate Perspective*. Explaining Extreme Events of 2016 from a Climate Perspective. Retrieved 12 08, 2021, from https://doi.org/10.1175/BAMS-ExplainingExtremeEvents2016.1

Ornes, S. (2018). *Core Concept: How does climate change influence extreme weather? Impact attribution research seeks answers*. PNAS.

Plumer, B. (2021, November 12). *Who Has The Most Historical Responsibility for Climate Change?* The New York Times. Retrieved December 10, 2021, from https://www.nytimes.com/interactive/2021/11/12/climate/cop26-emissions-compensation.html