Finding Sustainable Development

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Motivation

Economic development and quality of life are major factors that must be accounted for by leadership of the world's nations. Collectively, we must all face the consequences of greenhouse gas emissions produced as a byproduct of moving economies, contributing to global warming and climate change.

Studies indicate that the rapid development of China's economy was supported by the use of traditional fossil fuel energy sources that are harmful to the environment. However, in the case of the USA, there is strong evidence that some economic factors including economic growth, labor force, and capital could reduce emissions. (Yamaka et al., 2021)

We're hoping to discover how developing nations are weighing these tradeoffs between rapid economic expansion and damaging emissions. Could there be other examples of countries like the USA, which are mature enough to grow their economies sustainably? Understanding how economic factors contribute to climate change may shed light on how progress is made toward sustainable development goals.

Additionally, economic development is a driver for reductions in poverty. (Britz et al., 2022) We want to analyze the correlations between countries with increasing GDP and decreasing poverty in an attempt to gain insight into whether this is having a negative impact on the environment or if some countries are finding ways to develop in a sustainable manner.

We will collect data on **Greenhouse Gas Emissions** (CO2, CH4, N2O, etc.) for each country and compare it to the country's **Gross Domestic Product** (as a measure of economic output) and **Poverty Rate** (as a measure of quality of life outcomes).

Objectives

- How does a country's economic standing contribute to its greenhouse gas output?
- Can we identify countries with relatively high standards of living that also have minimal impact on the environment?
- Are developing countries increasing emissions (and increasing GDP?) as their population lifts out of poverty?

Data Sources

Methodology

Greenhouse Gas Emissions

Source: Climate Watch

Our **primary dataset** is gathered from the Climate Analysis Indicators Tool (CAIT). It consists of a compilation of carbon dioxide, methane, fluorine, and other greenhouse gas output for **195 countries** during the period **1990-2019**. This is also broken down by output from each sector, including manufacturing, transportation, agriculture, etc. The data also includes values for Land Use Change & Forestry (LUCF) practices which can **add or remove carbon** from the atmosphere. We'll be investigating how carbon offsets differ in countries based on development.

2.1MB | 109K records

climatewatchdata.org/data-explorer/historical-emissions

Global Poverty Data

Source: UN Sustainable Development Goals

The UN has accumulated a dataset of global poverty information. This dataset includes the proportion of population below the **international poverty line**, (currently $1.90 a day) and multidimensional poverty; a composite index with **indicators for health education and overall standard of living**. These measurements are also split by sex, age, and geographic location (urban/rural). This set includes over 40 years of complete data for 206 countries and regions worldwide which will be pared down to match our Greenhouse Gas Emissions data.

9.4MB | 113K records

unstats.un.org/sdgs/dataportal/database

World Development Indicators (GDP Data)

Source: The World Bank

The World Bank's DataBank includes many indicators of prosperity and government stability for countries and regions across the world. We have decided to pare this down exclusively to **GDP as a measure of economic output**. Within this scope the dataset provides measures of GDP in **constant currency** as well as **purchasing power parity**. Again, we are restricting this large dataset (1965-2021) to match the 30 years present in the Greenhouse Gas Emissions data.

208.4MB | 383K records

databank.worldbank.org/data/download/WDI_csv.zip

Data Manipulation

Methodology

Combining Datasets

All three of our datasets share dimensionality of country and year. This allows us to join by country name and append rows of all three datasets to a single common dataframe. In practice, this is not so simple.

Some countries do not share a common name between the datasets. We had to generate lists of unique country names not included in the other datasets. Since the **GHG data** is the (initially) smallest of our datasets and it is our primary source of correlation it was chosen as the **"source of truth" for country labels**.

Countries such as Iran, South Korea, and Turkey used different names in all three sources. We found **34 cases of mismatched country names** in total.

GHG	Poverty	GDP
Iran	Iran, Islamic Rep.	Iran (Islamic Republic of)
South Korea	Korea, Rep.	Republic of Korea
Turkey	Turkiye	Türkiye

Names like Saint Lucia/St. Lucia were simple enough to match, while others required a small amount of research into alternative names. Consequently, this was not a process that lent itself to automation and the 34 country names were manually mapped together. These lists were zipped into dictionaries to pass into the Pandas `replace` method resulting in common labelling between the datasets.

Pivoting

The year is stored in a single column in the poverty data, but it is broken into 30 different columns in the greenhouse gas and GDP sets. Since this format was more common, we chose to run a `pivot` on the poverty data, transforming it from long to wide format to match the other two datasets.

Filling in Missing Data

Additionally, we need to consider the prevalence of null data in these sets. We chose to interpolate data from surrounding years rather than omitting these null values. Emissions, GDP, and poverty rates generally don't swing wildly from year to year, they rise or fall in consistent trends that allowed us to make straight line inferences using a linear fill with the Pandas `interpolate` method. We chose to fill in up to 4 years both forward and backward from a true isolated data point.

Complete Dataset

Column	Description
`country`	Country name
`c_code`	Three letter shortcode for the country
`indicator`	Name for the value, for GHG data this describes the source of the emission
`i_code`	Shorthand code for the indicator
`gas`	Type of emission gas ("CO2", "CH4", etc.)
`1990..2019`	Range of years for the data

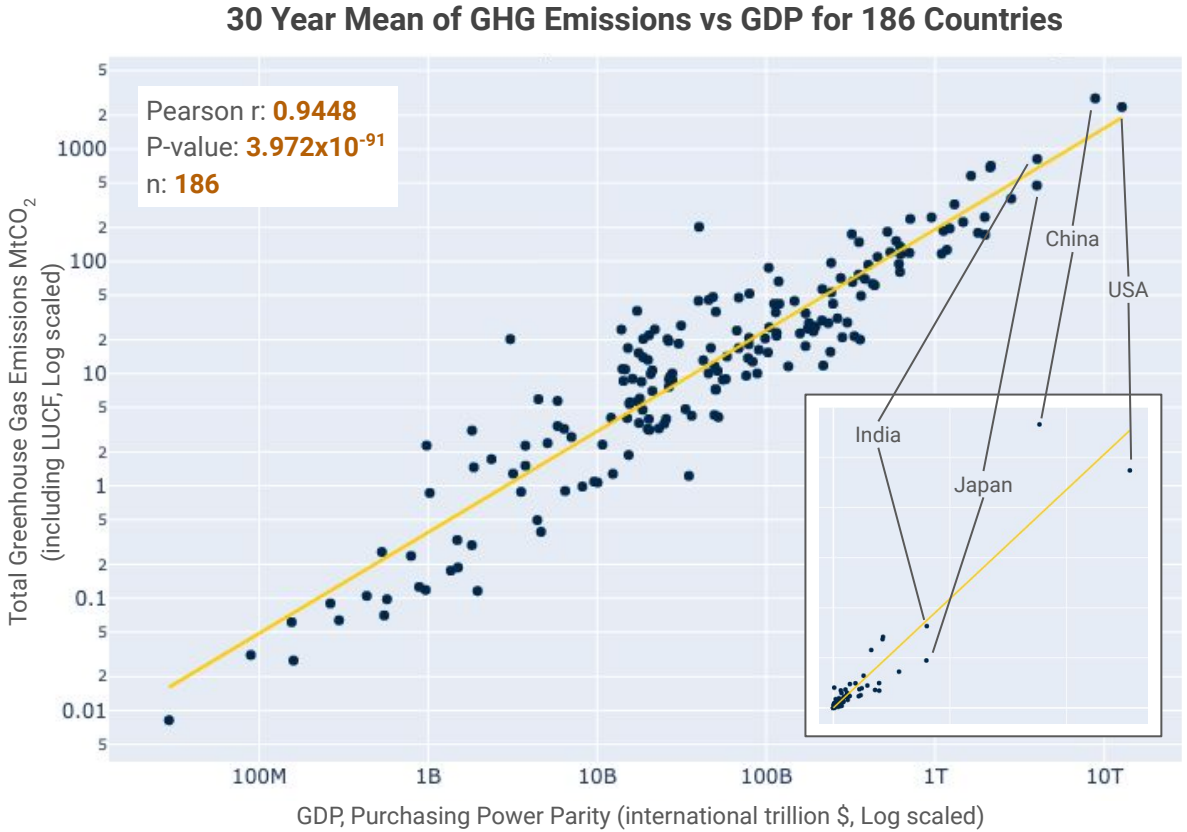
Strong Correlations

Analysis

The Strong Positive Correlation Between GHG Emissions & GDP

The dataset that was assembled brought this strong, positive, linear correlation right to the forefront and it serves as a basis for the rest of our analysis. We can say with very high confidence that countries with high GDP indicators also tend to produce more GHG emissions. Countries to the bottom right of this regression line are emitting less GHG than we would expect given this correlation.

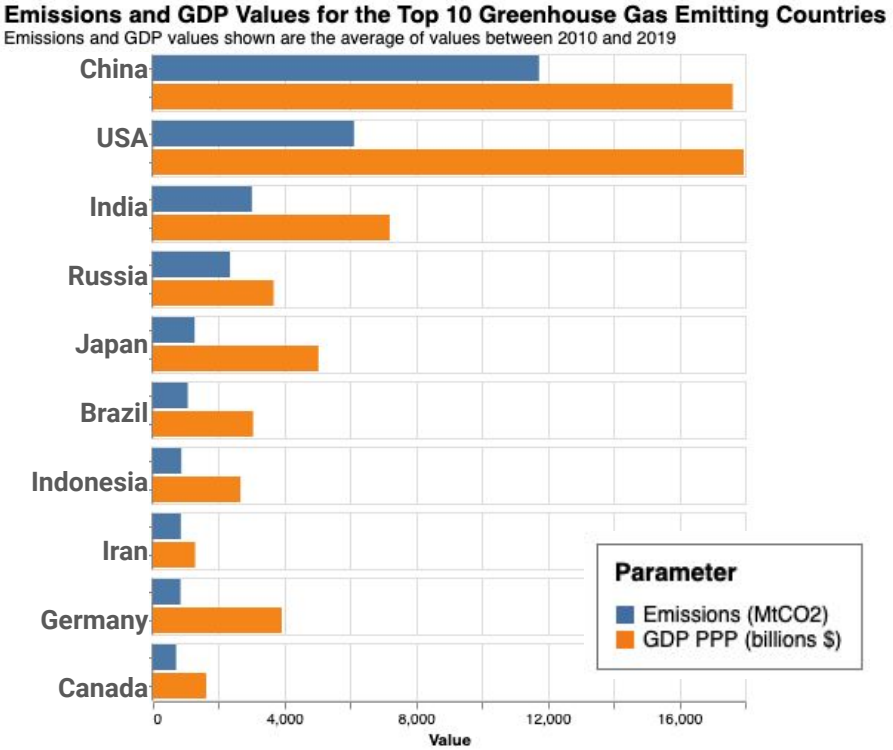
We chose to log scale both axes to show just how strong this relationship is and inset the original plot to show the true scale of the outlying countries. This data is heavily skewed with the top 25 countries emitting 79% of the world's greenhouse gas, while the bottom 168 countries make up the remaining 21%*.



*Based on a mean aggregation of total GHG emissions for 2015-2019

Top 10 Emitting Countries

Analysis



Highest Emissions in Top GDP Countries

Total greenhouse gas emissions (including Land Use Change and Forestry) were averaged for all countries between 2010 and 2019. These averaged emissions values were sorted to identify the top ten emitting countries and plotted in the figure on the left. The Purchasing Power Parity measure of GDP was also averaged and included to compare economic output between top emitting countries. **A notable trend is that the highest emitting countries are also high GDP countries.** While these countries are high emitters, several have reduced their emissions substantially since their all-time high. As shown in table 1, the United States, Russia, Germany, and Japan are top GDP and GHG emitting countries that have lowered their total emissions the most since their all-time high.

Table 1. Most GHG reductions since peak emissions, by country.

Country	Amount of GHG Reductions Since Peak Emissions (MtCO2)*
United States	**786**
Ukraine	592
Russia	**538**
Germany	**378**
United Kingdom	315
Japan	**182**

* = GHG values exclude Land Use Change and Forestry

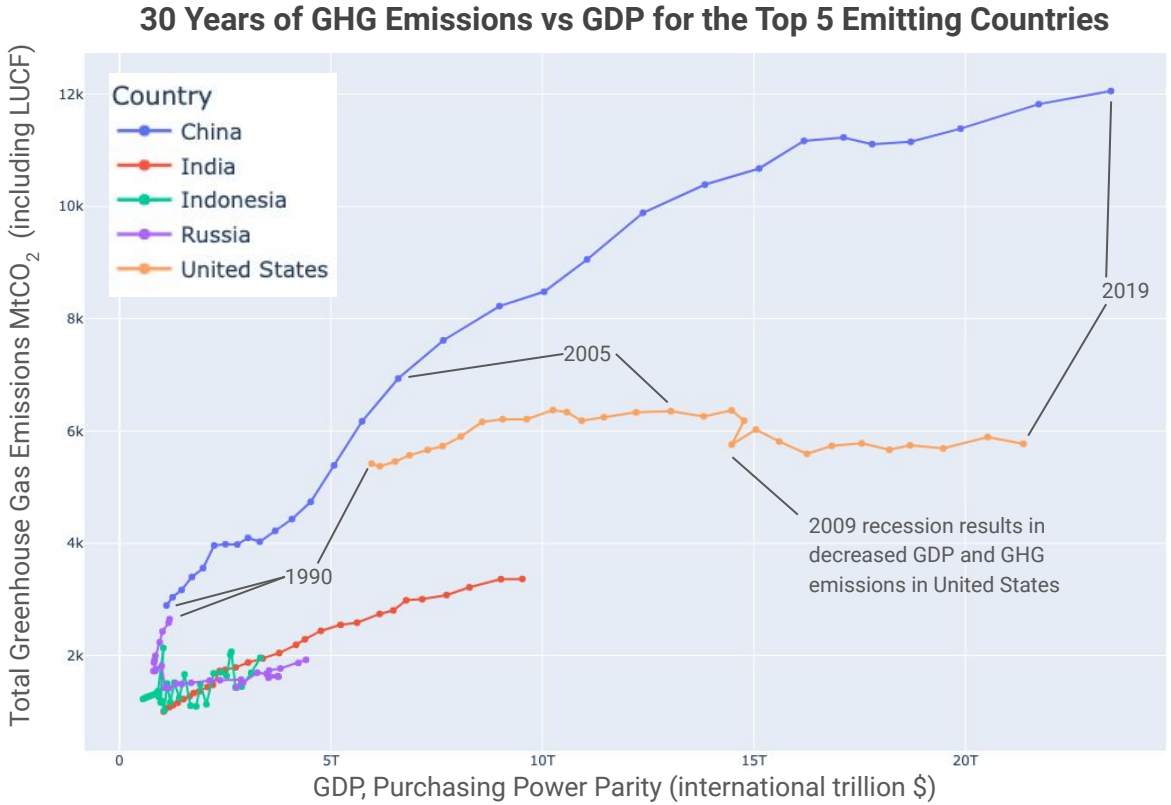
Elephants in the Room

Analysis

GDP Growth, Stable Emissions?

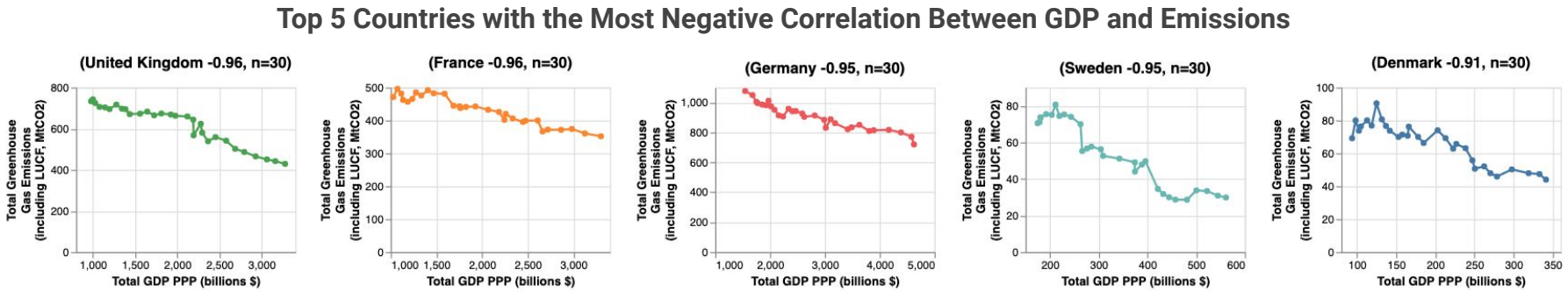
The US and China are far and away the biggest contributors of Greenhouse Gas emissions. They are also the two countries with the highest GDP outputs. Each point on these lines represents a GDP/GHG measurement for a particular year.

By the end of 2005 China's emissions output passed the US and has strongly increased since. The distance between China's GDP points shows that the country has experienced explosive growth during this timespan. The US has maintained steady GDP growth, but the most interesting takeaway here is that the sustained GDP growth has not meant that GHG emissions increased as well. This is rare as GDP shows a strong positive correlation with GHG emissions in the complete dataset.



Going Against the Grain (Negative Correlations)

Analysis



Reducing Emissions as GDP Increases

For each country, a pearson correlation test was conducted for the country-specific GDP and emissions data. Contrary to the world-wide trend that emissions increase as GDP increases, some countries were observed doing the opposite. The small multiple plots above show the 5 countries that have the most negative correlation between greenhouse gas emissions and GDP.

- The UK, France, and Germany are the highest emitters in this group, but have also lowered their total emissions the most as their GDP increased and far exceeds the others that are highlighted here.
- Sweden and Denmark have less of a decrease in overall emissions compared to the others but the rate at which they are dropping emissions proportional to GDP remains among the strongest of any country in the world.

Going Against the Grain (Changes by Sector)

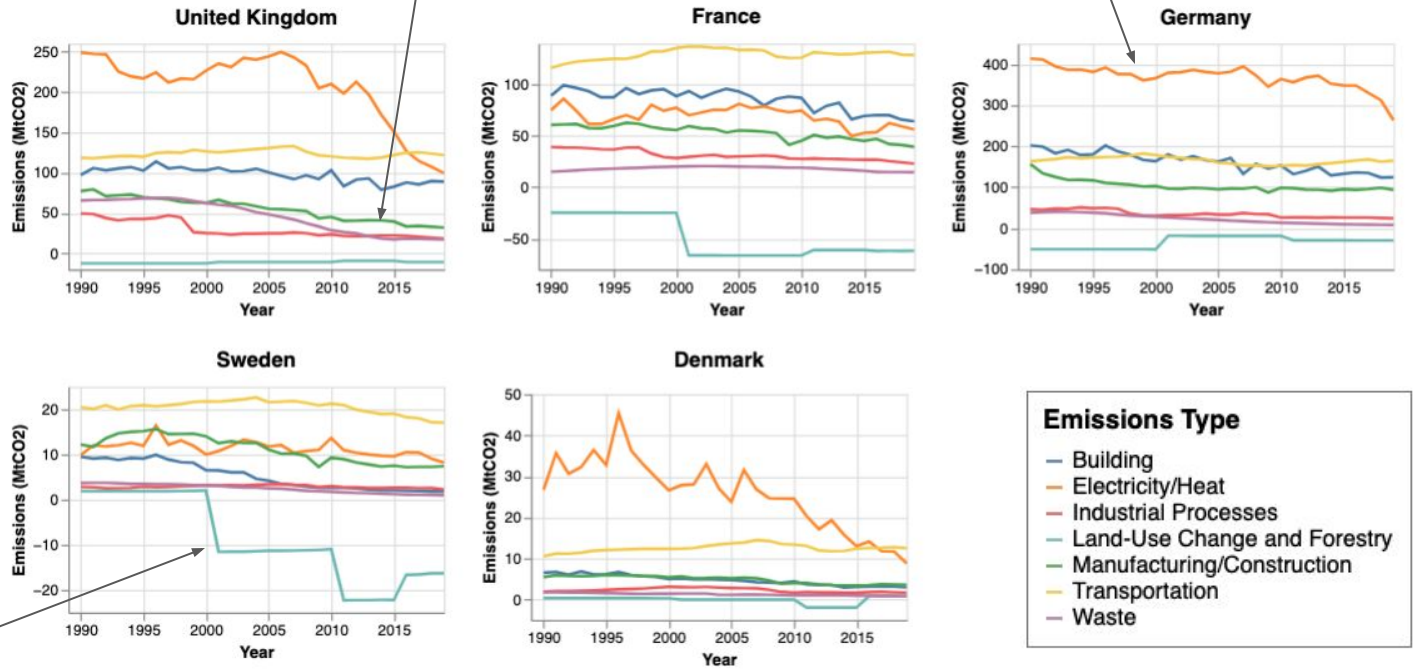
Analysis

How Are Countries Reducing GHG Emissions?

These time series plots show the trend in sector-specific emissions for each country identified in the previous slide. We can identify that these countries are decreasing emissions primarily through electricity and heat, building-related emissions, and manufacturing and construction.

Emissions from **manufacturing and construction** are decreasing for all countries shown, especially in the UK.

Countries are reducing the most emissions associated with **electricity and heat.**

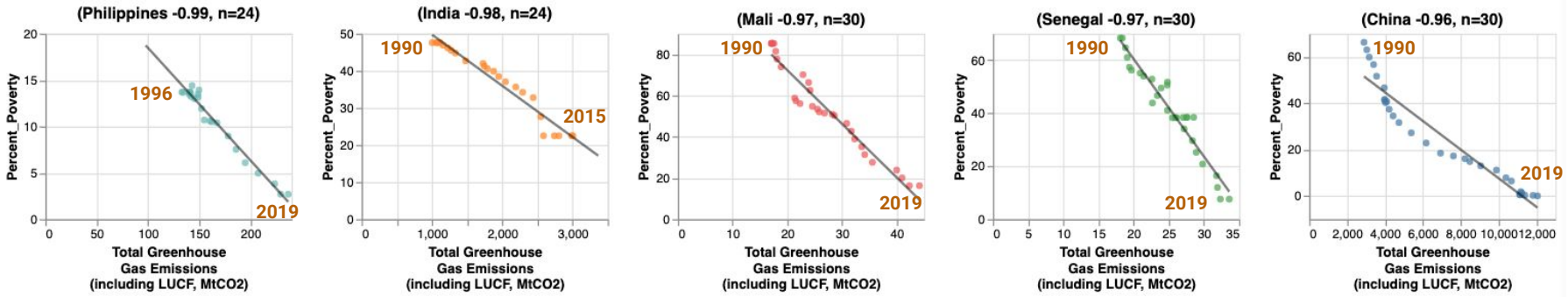


Land use change and forestry has become more negative over time in Sweden and France.

Winning the Battle Against Poverty

Analysis

Selected Countries with Negative Correlation with Poverty Rate and Emissions



The Largest Negative Correlations Between GHG and Poverty

The pearson correlation between the international poverty rate and greenhouse gas emissions was examined within each country. Despite the global correlation between emissions and poverty rate being very weak and insignificant, some countries showed a strong negative correlation between these variables.

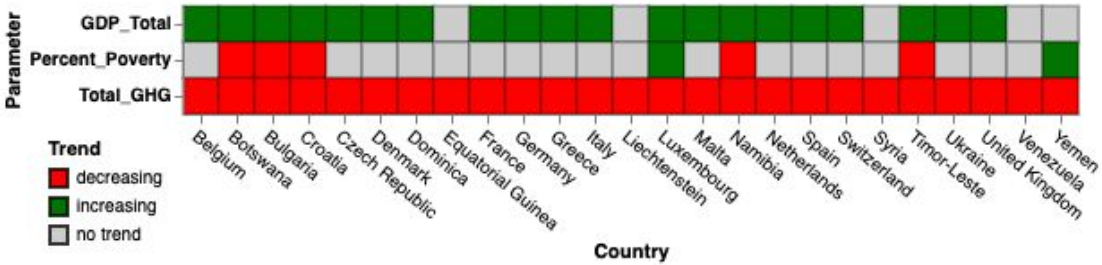
The five countries chosen for these small multiple plots because of their dramatic difference in poverty values. These are within the top 11 most negatively correlated countries for this indicator and the Pearson r value ranges only 0.0284 between Philippines and China. All show very strong trends. One hypothesis that can be drawn from this observation is that developing countries increase their emissions in order to lower poverty and develop their economies.

Mann-Kendall Trends

Analysis

The nonparametric Mann-Kendall trend test was applied to each country-specific group to analyze the monotonic trend of poverty, GDP and emissions data over time for each country. Groups with less than 4 data points were not analyzed and flagged as having 'no trend.' Countries with significant decreasing trends in emissions were identified and plotted in this tilebar chart. The analysis showed that most countries decreasing emissions are European countries that are also increasing GDP.

Mann-Kendall Trends for Selected Countries between 2010 and 2019



Conclusion

We found strong positive correlation between GHG emissions and GDP growth. However, we have also shown several highly developed European countries which have decreased emissions while promoting strong GDP growth. The US also falls into this category, reflecting the findings of Yamaka et al., 2021.

The global trend remains that countries increase emissions at the same time that they increase their GDP output. We can speculate that high output, *decreasing* emission countries are mature enough to transitioned into service based economies. This is reflected in our emission by sector analysis, which shows Manufacturing/Construction as one of the greatest sources of reductions.

We saw several developing countries reduce their poverty rates as GHG emissions increased, suggesting that this rise in development was helping to improve the quality of life in those nations. In contrast, several countries identified in Mann-Kendall are decreasing both emissions and poverty while GDP increases. These such countries are what we hoped to identify in this analysis.

Statement of Work

Combined Effort

- Report writing + construction
- Data manipulation for analysis

Patrick Sollars

- Workspace setup + team coordination
- Pulling datasets
- Initial data manipulation
- Similar study research
- General correlation analysis + visualizations

Jacob Rankin

- In-depth analysis of emission reductions
- In-depth analysis of correlations in specific countries and sectors
- Advanced visualizations, small multiples
- Mann Kendall analysis

References + Datasets

Britz, W., Jafari, Y., Nekhay, O., & Roson, R. (2022). Assessing inequality and poverty in long-term projections of economic growth: A general equilibrium analysis for six developing countries. Economic Modelling, 106066. https://doi.org/10.1016/j.econmod.2022.106066

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Yamaka, W., Phadkantha, R., & Rakpho, P. (2021). Economic and energy impacts on greenhouse gas emissions: A case study of China and the USA. Energy Reports, 7, 240–247. https://doi.org/10.1016/j.egyr.2021.06.040