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A Comparative Analysis of Carbon Emissions from Countries of Varying Fossil Fuel Dependence

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Research-in-Progress

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Abstract

The objective of this research is to compare the true drivers of carbon emissions in different types of countries and compare these to the policies currently in place to abate emissions. The Carbon Dioxide Information Analysis Center (CDIAC) data will be used to collect data on total emissions, liquid emissions, solid emissions, and gas emissions. These will be compared to socioeconomic factors for 10 countries in a canonical correlation analysis to determine which factors are most predictive of different types of fossil fuel usage. These factors will then be deconstructed by the Kaya Identity for each country, and compared to that country's climate policy to determine if the policy is considering the most critical factors. Previous research covered in this research- in-progress paper considers the reasoning between choosing the selected 10 countries, previous emissions modeling, and projected current trend models into 2100. This will serve as a guide to what exactly countries like the types of countries explored here need to focus on to limit emissions.

Keywords

Emissions, Carbon, Climate, Sustainability, Trend Analysis, Greenhouse Effect

Extended Abstract

Without the natural greenhouse effect, Earth would radiate heat back to space through longwave radiation, making the surface temperature -19 ^{o}C (Le Treut et al. 2007). This is negated by the greenhouse gases (GHGs), such as carbon dioxide (CO_2), water vapor, and methane, which are located in Earth's atmosphere. These gases trap infrared radiation, creating the greenhouse effect that warms the entire planet and does not allow heat to escape the atmosphere (Le Treut et al. 2007). Although the greenhouse effect allows Earth to have a habitable temperature, this warming effect has accelerated in the post-industrial era. Global atmospheric CO_2 levels have risen by 40% since pre-industrial levels (Birdsey et al. 2018). One of the largest drivers of this increase is the burning of fossil fuels, which emit CO_2 and increase the atmospheric concentration of GHG's (Jackson et al. 2018). The burning of fossil fuels and cement production are responsible for 90% of CO_2 emissions from humans (Jackson et al. 2018). Increased CO_2 in the atmosphere is stimulating changes in the climate due to increased global surface temperature, potentially leading to increased frequency and duration of extreme weather events, species extinction and migration, and increased human competition for water and other natural resources (Le Treut et al. 2007, Birdsey et al. 2018, Allen et al. 2018).

Limiting carbon emissions will decrease atmospheric GHG's. Currently, there is a global push to address climate change and rising carbon emissions. This global awareness is embodied by the International Panel on Climate Change, a task force created by the United Nations to collect and examine the scientific information relative to understanding the uncertain future regarding climate change (Le Treut et al. 2007). The latest Intergovernmental Panel on Climate Change (IPCC) report concludes that the global surface temperature should remain at the 1.5 ^{o}C deviation from the mean temperature and should not rise to 2 ^{o}C

(Allen et al. 2018). The cap at 1.5 to 2 ^{o}C shift in temperatures has become a benchmark for the global attention to warming and climate trends. However, this cap is a universal number. It is a goal for the entire planet, which is made up of countries with different levels of ability to reach that cap. It is a much different challenge for a country like China to meet that global cap than it is for a country like The Marshall Islands. Research is lacking concerning effects of policy on small countries, island nations, developing countries, countries with fossil fuel-based economies, and others that do not draw international attention. An aggregate solution such as the IPCC temperature change cap might not be effective enough to solve the global climate change problem, which is woven together by many countries with vastly different locations, populations, resources, and economies. Beyond the heavy emitters, there are many countries that need to address this global problem. This Research in Progress will attempt to look for individualized solutions for different types of countries, rather than one global goal.

Presently, this research-in-progress has consisted of collecting Carbon Dioxide Information Analysis Center (CDIAC) data for 10 different countries (Gilfillan et al. 2019). These countries are China, India, The United States, Germany, Thailand, Argentina, The Marshall Islands, Saudi Arabia, Ethiopia, and Iceland. These countries were selected because they represent different types of countries with different economies, cultures, and locations. The countries above have all submitted policies to the Paris Agreement that outline their future goals for lowering climate emissions. Trendlines were developed for each of these countries current emissions, and predicting their future emissions given policy initiatives. The analysis of these curves has demonstrated that not all countries total emissions look similar. The bulk of countries studied create the majority of emissions from liquid fuel consumption. These countries are Ethiopia, Iceland, Marshall Islands, Saudi Arabia, Thailand, and United States. China, Germany, and India derive the majority of emissions from solid fuel usage. This group contains 2 of the 3 heavy emitters, India and China. Only Argentina's total emissions are mostly made up of gas fuel consumption. Saudi Arabia does not release any emissions from solid fuels at all. The Marshall Islands only emit from liquid fuel. The US emitted more from liquid fuel consumption in 2015 than both of the other two heavy emitters combined. These differences in total emissions constitution reinforces the need for mitigation solutions that are tailored to how specific countries emit. Trend lines produced by this analysis were then used to create current emissions scenarios which could be projected into the future. The best fit trend for each country was extended out to the year 2100 by creating a time series of the previous data and using it to forecast. Current emissions projections imply that no actions are taken to affect the current trend of climate emissions into the year 2100. In these models, only the United States and Germany will achieve net zero carbon emissions without policy change. Even the developing nations in this study are predicted to trend upward if policy is not enacted or followed. If the current emissions pattern proceeds, the 3 heavy emitters alone will emit near 11,230,729,000 metric tons of carbon combined in 2050. For most types of nations in this study, even those that have green technology in place currently, policy will be needed to transition to decreasing emissions, achieve zero emissions, and eventually express negative emissions.

Past research has outlined the need for a more individualized approach to climate policy and action. The next steps of this research will try to examine what policy needs to cover for each individual type of country. To achieve this, data will be collected on socioeconomic factors that influence a country's fossil fuel usage. These will include but are not limited to: gross domestic product, size, location, and population. These values will be compared to fossil fuel usage levels and fuel usage types through a canonical correlation analysis. This is a type of factor analysis that will show which of these factors is most closely related to the usage of different types of fossil fuels for each country. These will then be further broken down in a decomposition analysis for each country using the KAYA identity, which is an equation that determines a countries fossil fuel dependence. It is described below:

$$CO_2 = population \times \frac{GDP}{capita} \times \frac{energy}{GDP} \times \frac{CO_2}{energy}$$

These results from the factor analysis and the KAYA decomposition analysis will then be compared between individual countries and a conclusion will be drawn about what factors are playing the largest role in fossil fuel usage for countries explored in this analysis. This will serve as a guide to what exactly countries like the types of countries explored here need to focus on to limit emissions. This individualized analysis will ultimately show what drives emissions for certain types of countries, and how specific countries will need

to reduce emissions to reach the IPCC 2 degrees of warming cap. Finally, each country's driving emission factors will be compared to their Paris Agreement policy submission, and it will be determined if each country's policy is acting on the true factors that are driving emissions overall.

Although there are heavily researched global solutions (Allen et al. 2018) for the pathway to zero emissions, there is less research regarding individual countries pathways to get there. This research compares different countries' current trends in emissions, and eventually will focus on the challenges each of these faces to reduce emissions. We stress that there is not a universal approach to reducing emissions; a country with high emissions and a large economy will need to approach achieving net zero emissions differently than a developing country, a country with currently declining emissions, or even an island nation. By studying the different approaches countries can take to reach this goal, multiple policies can be developed that are tailored to specific types of countries, informing local decision-making to reduce global emissions. As countries are impacted by climate change, providing unique approaches to combating emissions for individual countries will be essential to achieve global carbon neutrality.

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