Exploration of the Economic Repercussions of Climate Change

Submitted by

Natalie Marie Adams

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Mentor: Dr Zeina AlSalman, Assistant Professor of Economics

Department of Economics

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Abstract

Global climate change has been largely amplified by human influences and can now be linked to more than just the changing weather conditions and worsening natural disasters. Research gathered and analyzed over the past several decades is now able to connect shifts in climate to changes in global economies through various economic factors. This paper will look at recent studies and model data spanning those economic factors to determine if there is a visible link showing responses of global economies to climate change. Through this data analysis there is evidence to support the claim that the climate change effects span farther than increased severity of weather conditions and often dip into varying sectors of economies. This information will help policy makers determine the best course of action in fighting the effects of climate change. In addition, it will also allow policy makers to curate proper prevention methods to suppress further damage from occurring. Helping the countries most affected by climate change will benefit all economies by protecting trade and supply chains on a global scale.

Introduction

Shifts in climate have been largely amplified by human influences and can now be connected to changes in global economies. The connections between climate change and economic factors is a complex and critical area of study that requires careful examination by many different perspectives. This paper contributes to the current literature by combining knowledge from current studies as well as conducting original data analysis to examine how certain economic factors are affected by climate change. The two main research questions raised in this analysis are ‘How do specific economic indicators respond to shifts in climate?’ and ‘How can the findings inform policy decisions to mitigate climate change effects on economies?’ Using the prior literature as well as the information gathered from the data modeling, we will be able to answer these questions and guide officials in making policies to help slow current climate change effects while also preventing further damage. The structure of the paper will be as follows:

1. Review of the Current Literature.
2. Data Context, Methodology, and the Original Modeling Analysis.
3. Discussion of Results.
4. Current Policy and Future Implications.

Current Research

From the beginning of the twentieth century, rises in temperatures have been unwavering and since the 1980s, they continue to accelerate at a significant rate. These Global temperature increases have been at the forefront of potential causes to various natural disasters and worrisome events such as increasing intensity of hurricanes, continuing sea level rise, and changing weather patterns. The International Panel on Climate Change (IPCC) suggests that human influences have been the unequivocal driving force of this global temperature increase (Holland et al., 2021). More specifically, activities such as agricultural operations, the burning of fossil fuels, and the growing urbanization of areas can be linked to elevated levels of the primary greenhouse gas emissions elements such as carbon dioxide, ozone, methane, and water vapor (Ullah et al., 2022). With this expansion of human activities and emissions, the geographical effects of climate change have been seen globally from poorer emerging markets to leading economies. Due to its large scale, macroeconomists have also begun exploring how climate change is now influencing economic factors such as the per capita real output growth, production, income, and investment.

Using a stochastic growth model of data from 174 countries over the years of 1960 to 2014, economists Kahn et al. (2021), analyze the effects of deviations in long term historical averages of temperature and precipitation on productivity. The results of the study were not found to be significant in relation to precipitation but show that temporary temperature shocks or deviations from historical temperature values will only have short-term growth repercussions. However, the long term increase in temperature driven by climate change could have an adverse impact on an economies future ability to grow, and hence, leading to less economic growth in the long run. In connection, the research of Kohn et al. (2021) looks specifically at income groups based on climate regions highlighting that rich countries do not need to take as drastic of responses to weather shocks and climate variability on their economic activity as opposed to their poorer counterparts. However, it is important to note that these richer economies are still not immune to the effects of changing temperatures. It is hypothesized that the lesser effects of temperature increases are due to the richer areas being urbanized, with much of their economic activity taking place indoors. This concept is illustrated by Singapore's effort to shelter its economy from rising temperatures by increasing their economic engagement with places that specifically have air conditioning. This in turn allows workers who are aware of and are affected by the rising temperatures the opportunity to live in a temperature-controlled space that will protect them from the heat affecting their productivity. The conclusion of the research done by Kahn et al. (2021) illustrates that the deviation from the historical norm of temperatures adversely affects long run per capita GDP growth regardless of hot or cold climates as well as rich or poor areas (Kahn et al., 2021).

In connection, other economists have explored the link between changes in climates and shifts in agricultural yields which in turn would affect GDP, food prices, and the overall volume of agricultural production. A study conducted by researchers Fujimori et al. (2018) illustrated the macroeconomic impact of climate change by utilizing an integrated assessment modeling framework. This model is often used to link aspects of the economy and human processes with environmental changes. For this specific paper, the group took into consideration numerous factors such as mitigation policy, socio-economic assumptions, the use of different climate models, and more. Their findings show that the global impact of these factors were small when compared to other factors in different sectors of the economy. However, it is also important to note that regardless of the small macroeconomic changes, it does not indicate climate change in relation to the agricultural sector is any less important. In fact, the authors stated that the changes are directly related to humans' basic needs therefore leaving the potential for a human health effect. Another conclusion drawn from the study was that no definitive trend could be seen based on the regional information used. There is however the suggestion that the impacts of GDP could be larger in developing countries and regions since the value of added agriculture to GDP is higher than developed countries (Fujimori et al., 2018). These findings almost rival the conclusions of the previous paper referenced (Kahn et al., 2021), where it was said that countries that are more developed do not see as severe effects of climate change. This is because both studies have limitations such as the data pool used in either, the abilities of the researchers to cover all aspects of the topic, and missing elements due to uncertainties and model capabilities. This leads to the question of how to identify the areas most at risk from climate changes and to measure their macroeconomic responses?

Data Modeling

Data Context

In order to explore the links between climate change and shifts in economic activities, I chose to utilize two data sets. The first data set was collected from the US economic time series using data available from the Federal Reserve Bank of St. Louis through their database (Federal Reserve Economic Data also known as FRED). This data set includes six variables listed below with their respective definitions.

- **Date:** date of collection (taken monthly spanning July 1, 1967 to April 1, 2015)
- **Pce:** personal consumption expenditures (in billions of US dollars), refers to the measure of consumer spending
- **Pop:** total population (in thousands)
- **Psavert:** personal savings rate (%), refers to the calculated ratio of personal savings to disposable personal income
- **Uempmed:** median duration of unemployment (in weeks), refers to the length of time a person classified as unemployed has been continuously looking for work

- **unemploy:** total number of unemployed (in thousands), refers to the measurement of people currently unemployed in the US (includes those who were not employed at the time of the survey reference week, were available for work, and made an active effort to acquire a job within the time period of that the survey was conducted)

Below is a table showing the first six rows of this economic data frame:

date	pce	pop	psavert	uempmed	unemploy
1967-07-01	506.7	198712	12.6	4.5	2944
1967-08-01	509.8	198911	12.6	4.7	2945
1967-09-01	515.6	199113	11.9	4.6	2958
1967-10-01	512.2	199311	12.9	4.9	3143
1967-11-01	517.4	199498	12.8	4.7	3066
1967-12-01	525.1	199657	11.8	4.8	3018

The second data set used in this analysis has eleven variables all relating to various climate conditions. It is sourced from the Massachusetts Institute of Technology under the file name "climate_change.csv." Listed below are an explanation of each of the variables included:

- **Year:** year of data collection (spanning May 1983 to December 2008)
- **Month:** the observation month (categorized 1-12, beginning with January being classified as 1 and ending with December being classified as 12)
- **MEI:** multivariate El Nino Southern Oscillation index (MEI) which helps to capture an encompassing representation of atmospheric and oceanic abnormalities that take place during El Nino or La Nina-Southern Oscillation (weather effects in the Pacific Ocean that affect global temperatures- El Nino warms the oceans surface while La Nina refers to the cooling off of the ocean's surface)

- **CO_2, N_2O, CH_4:** atmospheric concentrations of the greenhouse gasses, carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), respectively, expressed in ppmv (parts per million by volume)
- **CFC.11, CFC.12:** atmospheric concentrations of powerful greenhouse gasses, trichlorofluoromethane (CFC-11) and dichlorodifluoromethane (CFC-12), respectively, expressed in ppbv (parts per billion by volume)
- **TSI:** the total solar irradiance (TSI- the rate at which the sun's solar power is deposited per unit area)
- **Aerosols:** the mean stratospheric aerosol optical depth at 550 nm (affects how much of the sun's energy is reflected back into space and is linked with events such as volcanic eruptions which result in new particles being added to the atmosphere)
- **Temp:** the difference in degrees Celsius between the average global temperature in that period and a reference value

The table below shows the first six rows of the climate data frame:

Year	Month	MEI	CO2	CH4	N2O	CFC 11	CFC 12	TSI	Aerosols	Temp
1983	5	2.556	345.96	1638.59	303.677	191.324	350.113	1366.102	0.0863	0.109
1983	6	2.167	345.52	1633.71	303.746	192.057	351.848	1366.121	0.0794	0.118
1983	7	1.741	344.15	1633.22	303.795	192.818	353.725	1366.285	0.0731	0.137
1983	8	1.130	342.25	1631.35	303.839	193.602	355.633	1366.420	0.0673	0.176
1983	9	0.428	340.17	1648.40	303.901	194.392	357.465	1366.234	0.0619	0.149
1983	10	0.002	340.30	1663.79	303.970	195.171	359.174	1366.059	0.0569	0.093

Methodology

To begin, in order to properly understand the relationship between climate change and its potential effects on economies, research must be done on various aspects of economies. In order to analyze this data I chose to utilize Rstudio which is an integrated development environment used for importing, exploring, modeling, and plotting data. My first step was to merge the two data frames into a single master data frame connected by the date of data collection. This ensured that each set of climate variables data points were matched up with the correct set of economic variables data points recorded on the same date. Below is an image of the first few rows of this combined master data frame:

Year	Month	Day	pce	pop	psavert	uempmed	unemploy	MEI	CO2	CH4	N2O	CFC 11	CFC 12	TSI	Aerosols	Temp
1983	10	01	2357.6	234907	9.7	9.4	9887	0.002	340.30	1663.79	303.970	195.171	359.174	1366.059	0.0569	0.093
1983	11	01	2366.3	235078	10.3	9.3	9499	-0.176	341.53	1658.23	304.032	195.921	360.758	1366.107	0.0524	0.232
1983	12	01	2393.6	235235	10.1	8.7	9331	-0.176	343.07	1654.31	304.082	196.609	362.174	1366.061	0.0486	0.078
1983	5	01	2245.9	233922	9.9	12.3	11154	2.556	345.96	1638.59	303.677	191.324	350.113	1366.102	0.0863	0.109
1983	6	01	2276.0	234118	9.1	11.3	11246	2.167	345.52	1633.71	303.746	192.057	351.848	1366.121	0.0794	0.118
1983	7	01	2304.4	234307	9.6	10.1	10548	1.741	344.15	1633.22	303.795	192.818	353.725	1366.285	0.0731	0.137

From there, using an open-source data visualization package called ggplot2 within R, I was able to create various easily readable graphs and charts representing both the economic data and climate data separately, as well as the relationship between the two through their variables. In the “Data Visualization” section of this paper the code and resulting graphs are presented. It was important to gain a holistic understanding of the data through these visualizations in order to best make conclusions about the connections between economic data and climate data.

Economic Context

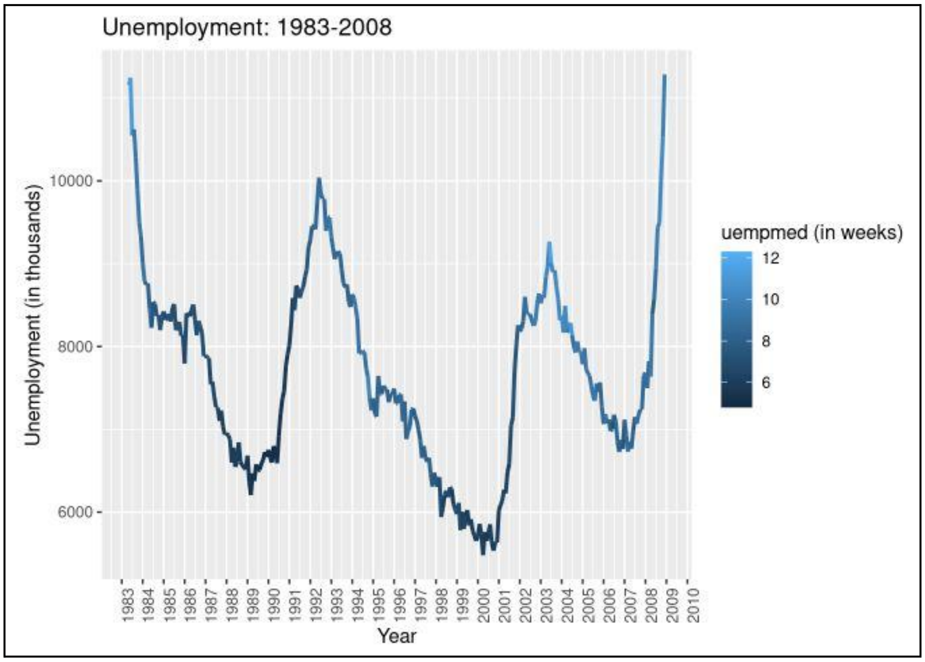

Figure 1: Unemployment

Figure 1 is a time series plot that illustrates the number of unemployed people (in thousands) from 1983-2008. Additionally, the color of the data points correspond to the duration of unemployment (measured in weeks). As shown in the key to the right of the graph, the darker the point, the shorter median unemployment duration and the lighter the point the longer the unemployment duration. The shape of the graph illustrates variation in levels of unemployment consistent with the standard flow of economic cycles. There are troughs (low number of unemployed persons) in the years 1989, 2000, and 2006. In these same years, we can see a correlation between low levels of unemployment and shorter durations of unemployment denoted by the dark color of the points. Conversely, the peaks of the graph have the lighter points illustrating the longest unemployment duration commonly seen in recessionary periods like 1983, 1992, and 2008. While there is no individual factor that can capture all angles relating to the overall health of the labor market, the rate of unemployment is considered by many economists to be one of the most important economic indicators.

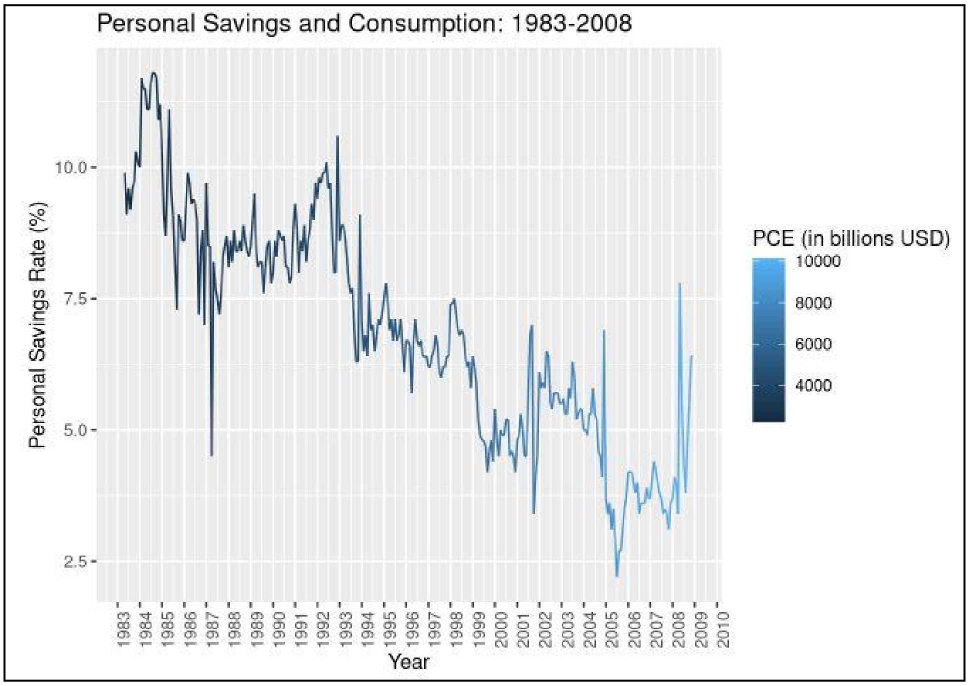

Figure 2: Savings and PCE

Figure 2 illustrates the yearly personal savings rate between 1983 and 2008. Similar to the previous graph, the data points are differentiated by color relating to the personal consumption expenditure (in billions of USD). The lower the spending, the darker the point is and the lighter the point, the more people are spending on goods and services among households. The figure illustrates that over time, the fall in the personal saving rates corresponds to a rise in PCE. This means that as the savings rates decrease, the amount of spending on goods and services will increase. As an economic indicator, personal savings is tracked to learn how the country's financial health is fairing and to assist in predicting consumer behaviors as well as looking at trends for economic growth. Additionally, PCE is used to gauge the health of the economy as well as seeing how consumers will respond and adjust their buying habits to price changes.

Basic Climate Indicators

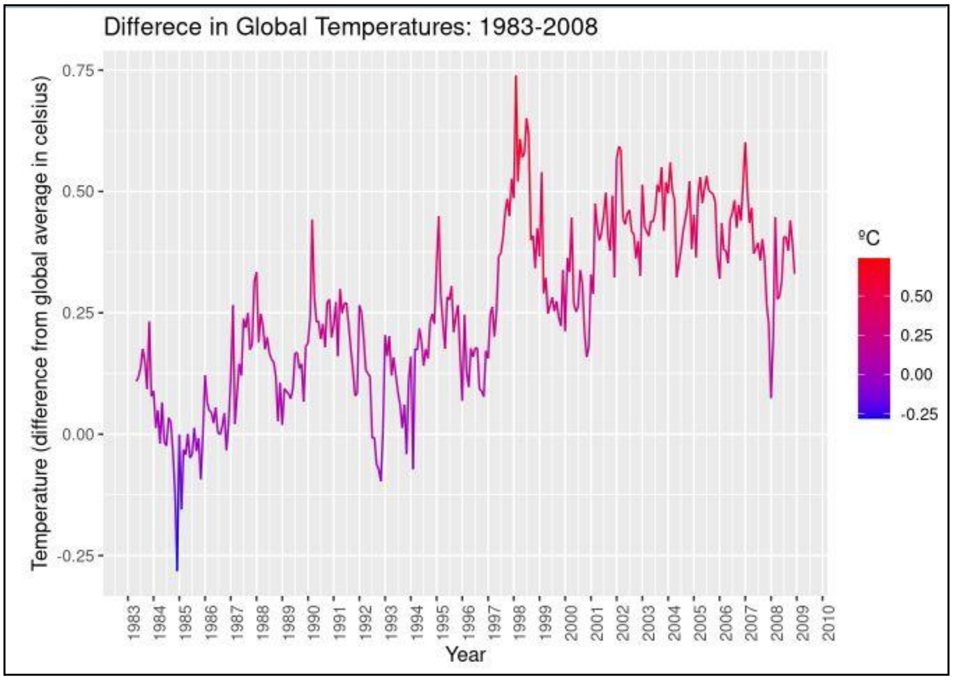

Figure 3: Temperature

Figure 3 depicts the difference in degrees Celsius between the average global temperature and the recorded temperature over the years 1983 to 2008. In order to see this relationship better the plot has been colored with a gradient based on the magnitude of the difference in degrees celsius. We can see that as the years increase, the difference in recorded temperature from the reference value (the average global temperature) also has an upwards trend. This is illustrated by the data points moving further away in the later years from that reference value denoted by 0.00. In other words, through the data presented we can observe the recorded temperatures straying further away from the historical norm of the global average temperature and becoming warmer. This is worrisome because water and air temperatures are responsible for helping to shape weather patterns, guide life cycles, and maintain sea levels.

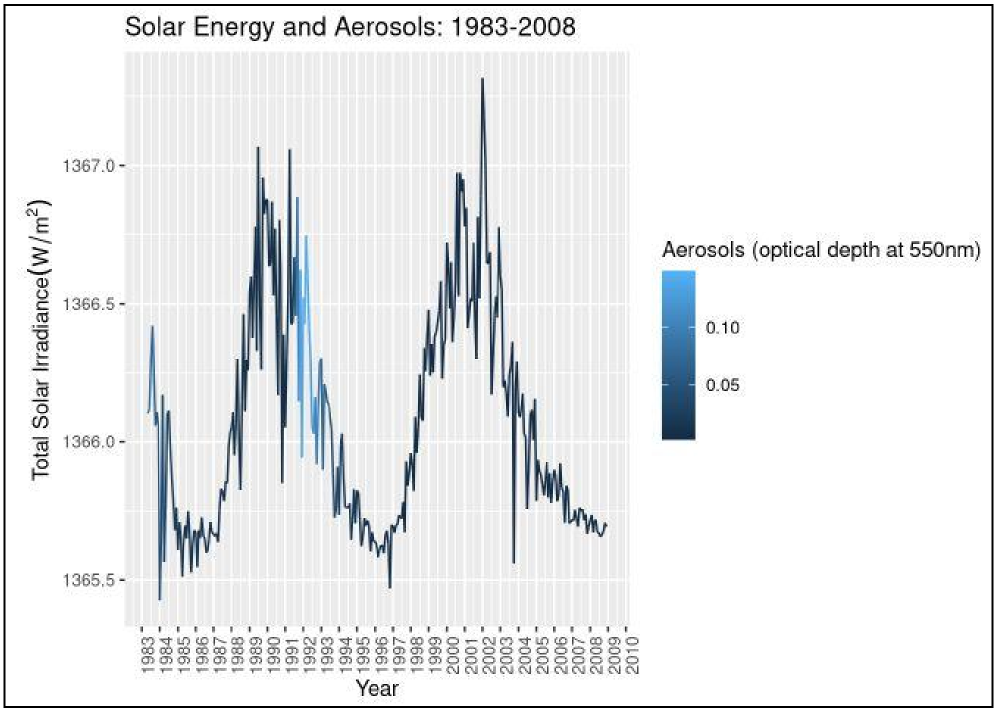

Figure 4: Solar Energy and Aerosols

Formerly known as the "solar constant," the climate parameter graphed above is now known as the total solar irradiance (TSI). TSI is often referred to as one of the fundamental climate parameters due to it measuring the totality of the energy propelling the climate system. In this graph, the lighter the data point is the higher the mean stratospheric aerosol optical depth (how much of the sun's light is prevented from reaching the ground due to aerosol particles). Overall, the aerosol levels appear to stay at a relatively constant level. However, we do see a spike in levels for the years 1991 through 1992. After additional research, it is known that this increase in aerosol levels could be attributed to the eruption of Mount Pinatubo in the Philippines (the second largest volcanic eruption of the century). The eruption caused an estimated 17 megatons of SO_2 to be released into the middle and lower stratosphere (Zhao et al., 1993).

Major Greenhouse Gasses

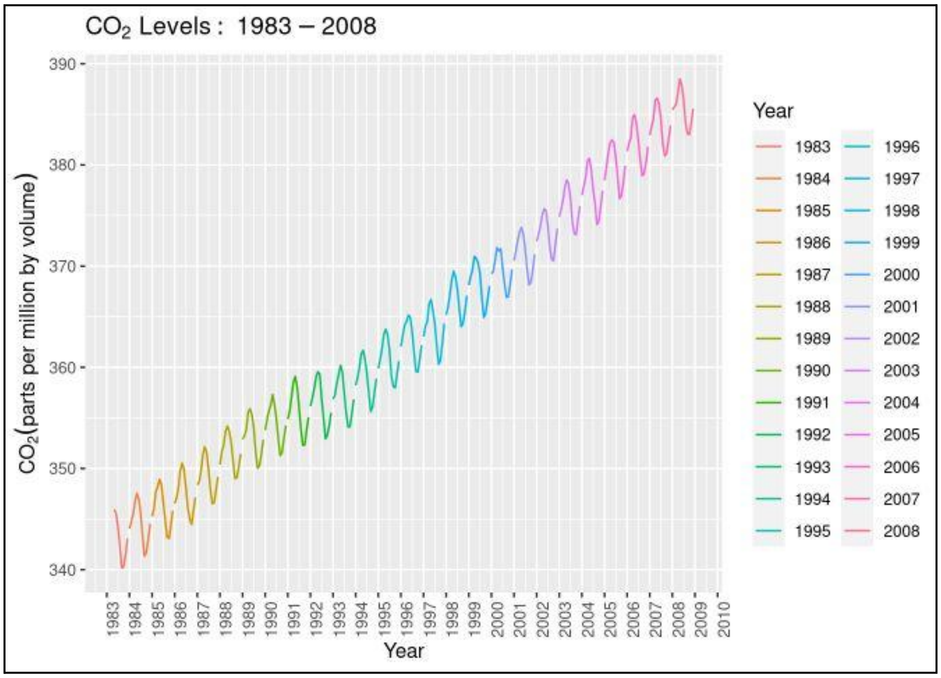

Figure 5: CO_2

The graph above represents the carbon dioxide (CO_2) levels in ppmv from the years 1983 to 2008. The yearly cycles of the data come from seasonal fluctuation, fossil fuel combustion connected to human activities, and the overall destruction of vegetation. In the spring, there is an increase of plants which absorb more CO_2 and use sunlight to synthesize foods from carbon dioxide and water. All of which lead to lower levels of CO_2. Conversely, the fall is when plants begin to lose their leaves and bodies of water cool meaning there is less absorption of CO_2. Additionally, it is important to note that even with the yearly fluctuations of CO_2 levels, there is an observable consistent increase in the overall levels overtime. CO_2 is an important climate factor to study and analyze due to its connection to the greenhouse effect. By adding more CO_2 to the atmosphere, it speeds up the natural greenhouse effect, causing global temperature to rise which was seen in the previous graph "Difference in Global Temperatures: 1983-2008".

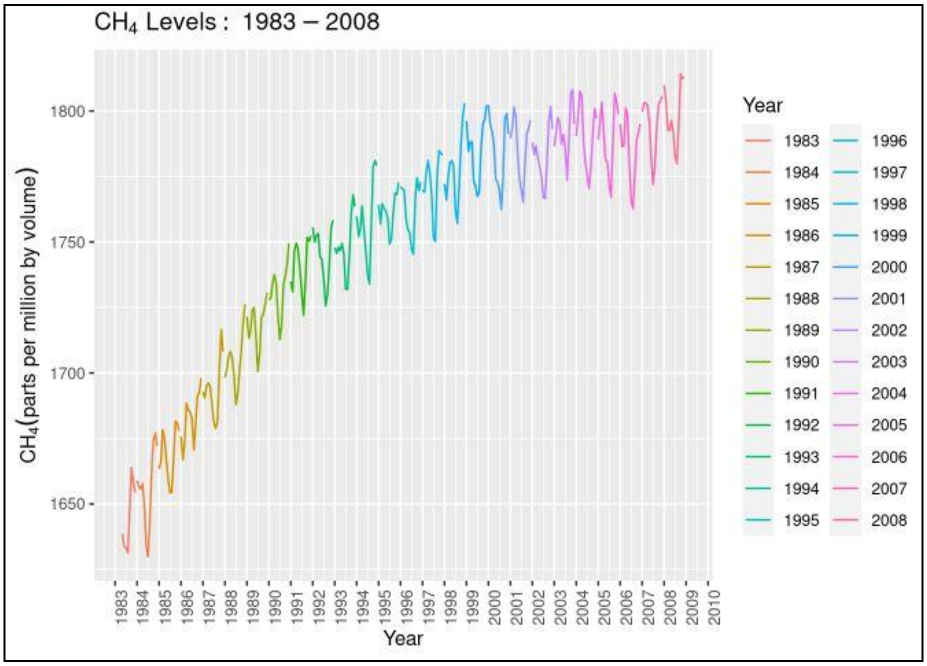

Figure 6: CH_4

Following the CO_2 graph we have the graph above illustrating historic data for CH_4 levels. CH_4, better known as methane, is emitted during the production, extraction, and transport of coal, natural gasses, and oil. It is often referred to as the second most important contributor to greenhouse gas after CO_2. This is due to the fact that methane's ability to trap heat within the atmosphere is even stronger than carbon dioxide. Acting as an insulator of the Earth, CH_4 absorbs the energy therefore slowing the rate heat leaves the Earth. In the years we have illustrated on the graph, there is a visibly steady increase which then tapers out to a smaller increase. Knowing the context of the effects of increasing CH_4 levels, we can connect the increase in this graph back to the increases we saw in the “Difference in Global Temperatures: 1983-2008” model.

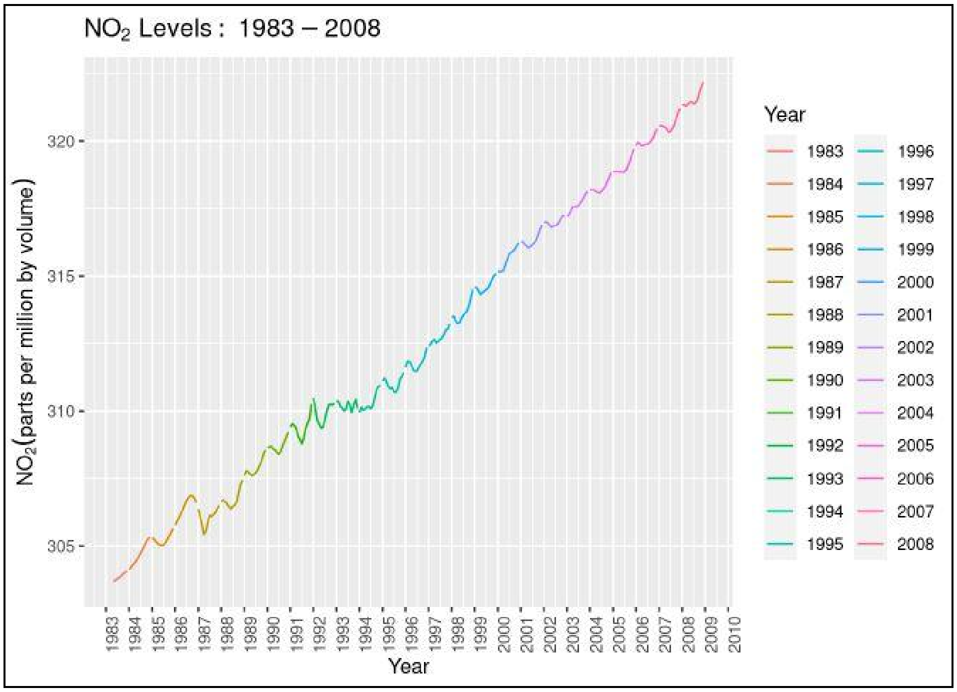

Figure 7: NO_2

Nitrogen Dioxide otherwise known as NO_2 is emitted during various human activities including but not limited to agricultural, industrial, and other land uses, combustion of fossil fuels, and the treatment of wastewaters. It is a part of the group of highly reactive gasses known as nitrogen oxides (NOx). Increased levels of NO_2 can have health and environmental issues varying in severity. When NO_2 reacts with oxygen, water, and other common chemicals in the atmosphere, it forms acid rain harming sensitive ecosystems and creates smog (also called smoke fog, it is a combination of fog, smoke, and atmospheric pollutants). Breathing in high levels of NO_2 can inflame airways, and increase the likelihood of irreversible damage to the respiratory system. Health issues such as these can affect economic activity though their impact on labor productivity as well as the overall labor supply.

Special Emphasis on CFCs

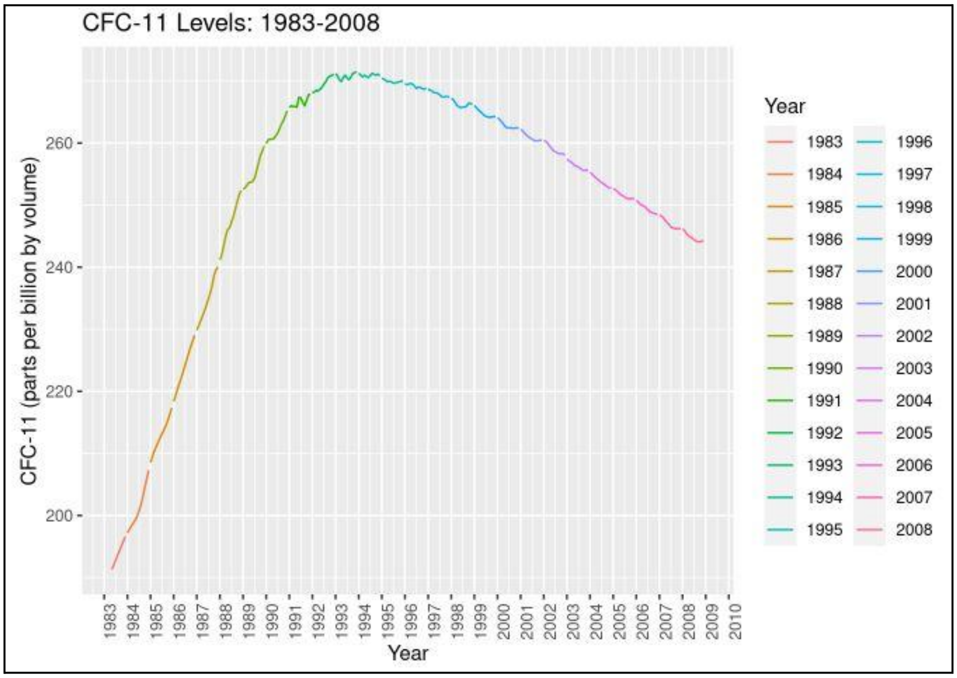

Figure 8: CFC-11

The above plot depicts how the levels of chlorofluorocarbon-11, more commonly referred to as CFC-11, have behaved over the years 1983 to 2008. CFC-11 is a part of a group of ozone-depleting chemicals known for destroying the earth's protective ozone layer and is also classified as a prominent greenhouse gas. Its main uses included being used as refrigerant in building chillers, insulation foams, and as solvents. However, with the wide use of CFCs also came harmful impacts on the ozone which caused a chain reaction of other health, and environmental issues from the thinning of the ozone layer. In order to combat these risks, the United Nations Environment Programme (UNEP) developed a program known as the Montreal Protocol. In an article from the Office of Environmental Quality within the US department of state outlines the treaty as follows, “the Montreal Protocol, finalized in 1987, is a global agreement to protect the stratospheric ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS)” (*The Montreal Protocol on substances that* *deplete the ozone layer - united states department of state* 2023). Having the title of being the only U.N. treaty ratified by every country on Earth, the substantial positive effects of the Montreal Protocol can be seen in the above data with decreasing levels of harmful CFCs after its passing.

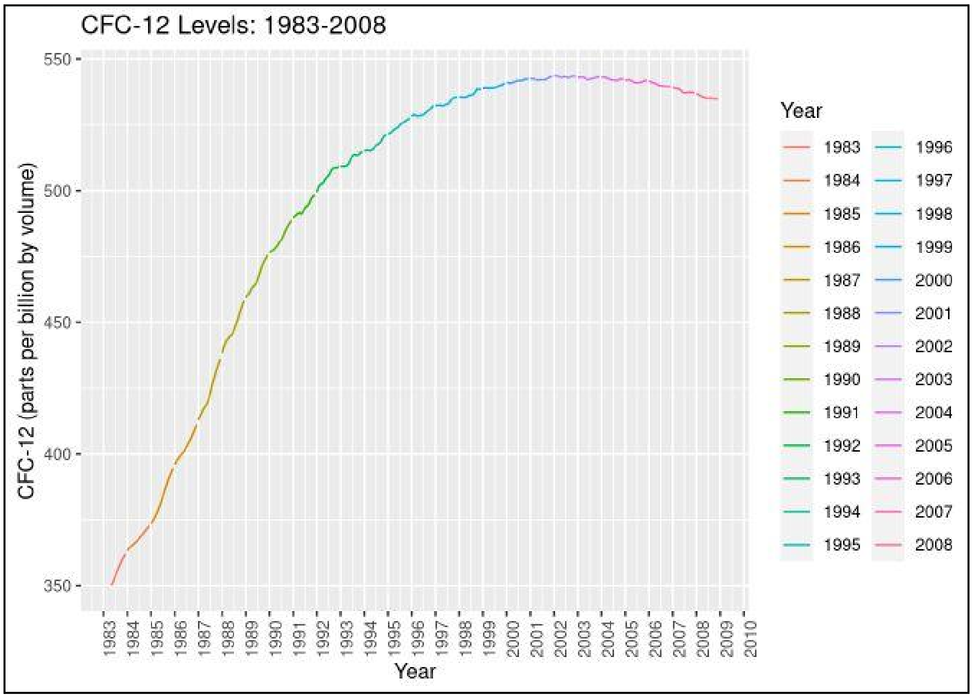

Figure 9: CFC-12

The graph above showcases the trend of chlorofluorocarbon-12 (also called CFC-12) from 1983 to 2008. Much like its counterpart CFC-11 in the previous graph, CFC-12 was widely utilized in aerosol sprays, refrigeration, and air conditioning systems more specifically in automobiles and trucks. Due to its ozone-depleting properties, CFC-12 was also targeted by the Montreal Protocol. The graph illustrates the levels of CFC-12 in response to global phasing out efforts. This is seen by the stabilization and then decrease of those levels.

Correlation Plots

After a comprehensive look at individual economic and climate indicators, it's pertinent to also explore potential interactions between them. Correlation plots help to provide a visual representation of the strength and direction of relationships between two chosen variables. They also help to identify patterns and highlight variables that might be influencing one another.

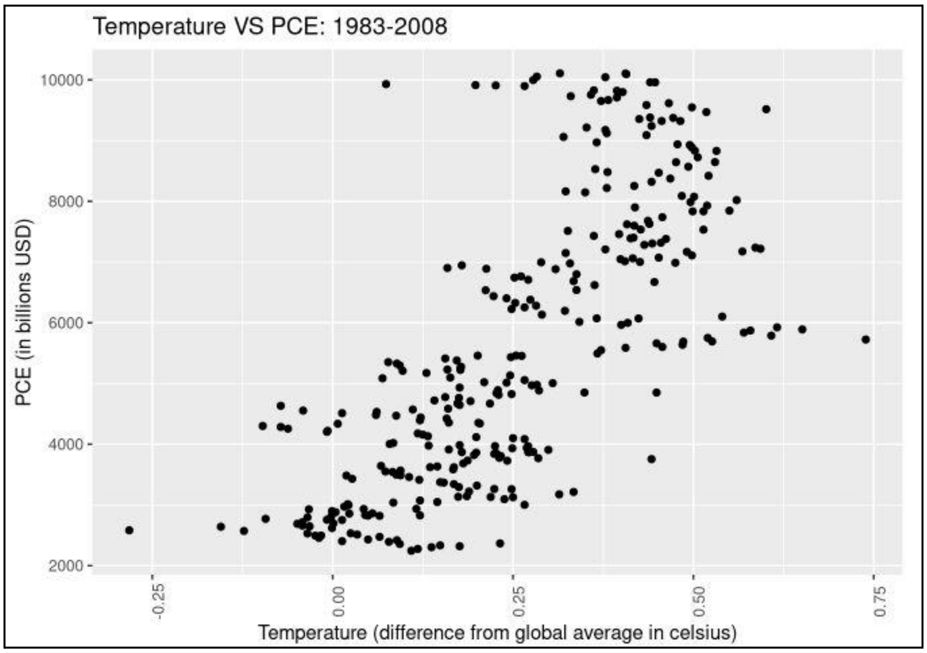

Figure 9: Temperature vs PCE

The correlation plot presented above depicts the relationship between the difference in temperature and personal consumption expenditure. Visually there is a positive correlation. In other words, as the temperature difference increases, there's a general (but not strong) tendency for personal consumption expenditures (PCE) to also rise. However, it is important to note that given the dispersion of data points, and taking into account outliers and room for collection error, other factors might also be influencing PCE. This observed relationship should be interpreted with caution. In context, this relationship might present itself as increased spending on air conditioning or other cooling solutions during warmer time periods. Expenditures related to adaptation to changing climate patterns, such as renovations, infrastructure changes and creation, or purchasing of new goods better suited for the changed environment.

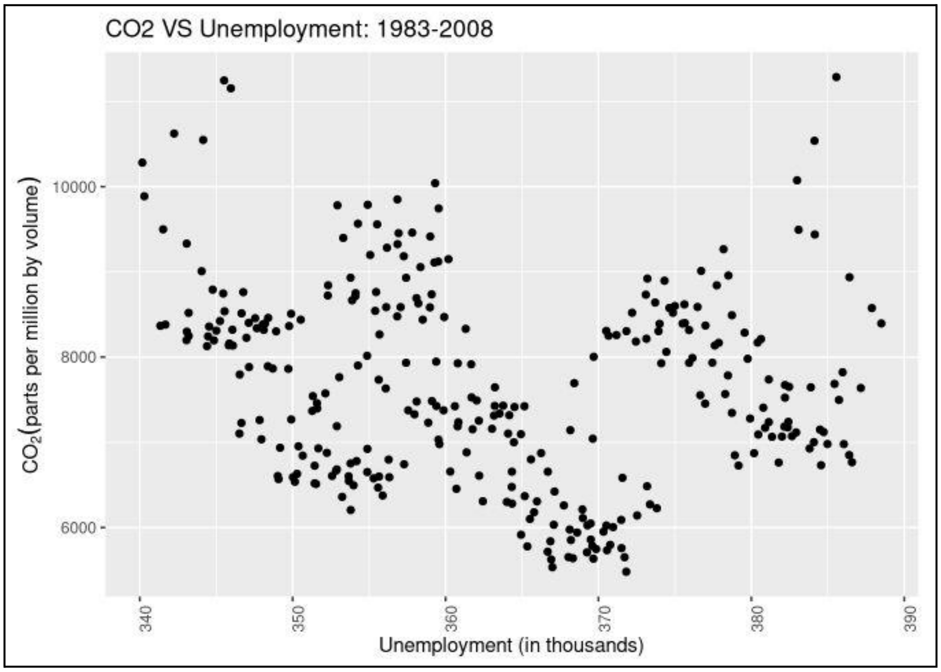

Figure 10: CO_2 vs Unemployment

The scatter plot above illustrating the relationship between CO_2 levels and unemployment follows a cosine-like oscillation. This brings up the conversation of whether there are specific economic occurrences, policies put in place, or global incidents that could give an explanation as to why this relationship between CO_2 and unemployment fluctuated in such a manner. As the graph oscillates, it's evident that there's some type of periodic nature to the relationship between the two variables. While the exact cause of this cyclicality is cause for deeper exploration, it is pivotal to consider how broader economic cycles, and even global events may influence both unemployment rates and CO_2 emissions. However, as stated in the above explanation, caution should be taken when determining relationships. Any number of external factors could be concurrently influencing both variables.

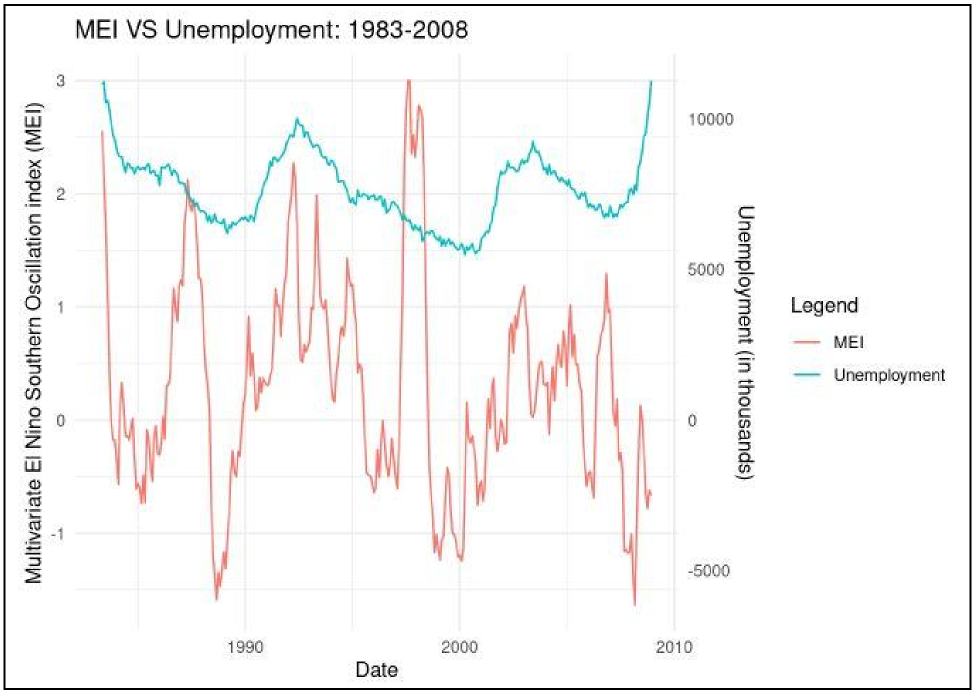

Figure 11: MEI vs Unemployment

The graphical representation of the relationship between the MEI index and unemployment shown above offers intriguing information. Generally, there appears to be a similar movement between weather events (denoted by the MEI index) and fluctuations in the level of unemployment. These trends suggest that distinct climatic shifts (the warming effects of El Niño or the cooling impact of La Niña) might have influence on various economic activities. These climatic events could affect sectors such as agriculture, leading to employment shifts corresponding to the weather patterns. However, the period right before the year 2000 offers an example of an anomaly. Despite the MEI index showing a strong climatic event, unemployment trends downwards. Several potential explanations can be inferred, such as a relation to the dot-com boom. That boom period might have countered any potential negative impacts arising from climatic events. Additionally, around the same time there was an acceleration in technological advancements. It is also important to note that the effects of these climate events on the economy might not be seen immediately. There could be a lag where the effects of a high MEI value will manifest in economic indicators a few months or even years in the future.

Discussion

Before diving deeper into the implications and interpretations of the data, it's important to highlight the main findings that emerge from our analysis. To begin we observe a relationship between temperature differences and Personal Consumption Expenditure (PCE). As the observed temperature differences increase, there is a general trend for PCE to also rise. Furthermore, the relationship between CO_2 levels and unemployment shows a cyclical pattern. This suggests potential periodic influences affecting both unemployment and CO_2 emissions simultaneously. Additionally, the data for the MEI index (which reflects significant weather events like El Niño and La Niña), tends to move in unison with unemployment rates. This synchronous relationship suggests potential impacts of these climatic events on employment. Also, there is the analysis showing a clear upward trend in levels of greenhouse gasses such as CO_2, CH_4, and N_2O over the study period years 1983 to 2008, which corroborates the wider understanding of increasing anthropogenic influences on the environment. Finally, there are the declining levels of CFC-11 and CFC-12 after the late 1980s. This aligns with global efforts to reduce ozone-depleting substances, through an international agreement called the Montreal Protocol.

Examining in more detail, the relationship between temperature differences and personal consumption expenditure (PCE) shows a positive correlation suggesting an increase in spending as global temperatures increase as well. It is important to look into the potential reasons for this type of correlation. For example, it could be hypothesized that as temperatures become more extreme (in either direction, namely hotter summers or colder winters), consumers might be spending more on energy related expenses for cooling or heating, buying specialized items, or even relocating to areas with more bearable temperate conditions. These adaptations could lead to an increased PCE. Investigating this from a different perspective, a study done by Lai et al. on the short term effects of temperature shocks on consumption showed that climate shocks in either direction have a direct and immediate negative effect on consumption. Additionally, in the long run, the authors' projections indicated that without taking into account adaptation, climate change would work to reduce aggregate consumption. However, when adaptation was accounted for there was no evidence of consumption reducing (Lai et al., 2022). This understanding complements the findings of Kohn et al., who proposed that the lesser effects of temperature increases are due to the richer areas adapting and urbanizing where the bulk of their economic activity takes place. Knowing these findings can help in creating future studies to look at further PCE data categorized by expenses to pinpoint where these shifts in spending are seen most and why. Having those detailed insights could then guide policy-making, ensuring economies are more prepared to respond to the multitude of challenges posed by climate change.

Moving to the relationship of CO_2 levels and unemployment, the cyclical nature might suggest that as industries expand and contract in response to economic conditions and generalized economic cycles, so do their emission levels. Economic upswings or booms often come with increased production, higher energy usage, and higher emissions. Conversely, during recessions or downturns, industries might scale back their operations, which leads to reduced employment and emissions. Connecting the insights provided by the International Panel on Climate Change (IPCC), it is clear that human-driven activities (such as agricultural operations and urbanization) are significant contributors to greenhouse gas emissions (Holland et al., 2021). Fluctuations in the occurrence of these activities, driven by varying economic conditions, could directly impact both CO_2 levels and employment opportunities within the sectors. Furthermore, Kahn et al. (2021) have explored the repercussions of climate changes on long-term economic growth. It is possible that regions heavily impacted by climate shifts may see a simultaneous increase in CO_2 emissions levels (due to increased energy consumption for adaptive measures) and a decrease in employment status as sectors struggle to keep up and adapt to new environmental conditions. However, it is always pertinent to consider that not all sectors of the economy will emit CO_2 on equal levels. Future research could dive deeper into identifying industries contributing most to these fluctuations and exploring the influence of technological advancements or "green initiatives" on this relationship.

Looking at the relationship between the MEI index and unemployment suggests that significant climatic events like El Niño or La Niña might have impacts on different sectors of the economy. For example, industries such as agriculture, fisheries, and even tourism could be particularly vulnerable to these types of climatic shifts. Similarly, Fujimori et al. (2018), in their analysis of the macroeconomic impact of climate change, highlighted the susceptibility of the agricultural sector to climatic shifts. Taking these ideas into account, events like El Niño could drastically affect agricultural yields, in turn subsequently influencing GDP, food prices, and overall production volumes. Conversely, the climate event noted just before the year 2000 presents an interesting divergence from this concept. It could be speculated whether significant advancements in technology or policy changes at the time acted as buffers against the adverse impacts of these climatic shifts on employment. This speculation somewhat mirrors the findings of Kahn et al. (2021), who hypothesized that more developed regions might have the ability to better navigate the challenges posed by rising temperatures, possibly due to adaptive measures or technological innovations. However, to fully grasp the complexity of these relationship dynamics, it is important for future research to not only explore the direct impacts of these climatic events, but also explore potential mitigating factors that could influence unemployment trends during such periods.

Analyzing the consistent upward trend in greenhouse gas levels (particularly CO_2, CH_4, and N_2O) over the sample period from 1983-2008, not only aligns with the narrative of human-induced climate change but also highlights the urgency of addressing these alarming trends. The data modeled in this paper highlights a consistent increase in these emissions, reflecting global patterns of urbanization, deforestation, and increased combustion of fossil fuels. When compared with recent research on the EU by authors Murawska and Goryńska-Goldmann (2023), similarities and variances become apparent. While the data presented in this paper depicts a trend of rising emissions over the years, studies focused on the EU region reveal a more nuanced picture. For instance, the agricultural sector is often considered less impactful than industry in many discussions, but accounted for a more substantial portion of total GHG emissions in the EU. With the authors' more specialized research, they were able to identify potential regional variations in emission sources. Additionally, the observed cyclical nature of CO_2 levels and its oscillating relationship with unemployment resonate with the findings from the EU. Emissions from specific sectors seemed to be inherently tied to their economic prominence. The more economically developed an EU country, the higher its emissions. However, this relationship gets complicated when dissecting emissions by sector, highlighting the intricacy of the relationship between economic health and emissions. Drawing from these comparisons, it is clear that while overarching global trends exist, regional specificities play a crucial role in shaping greenhouse gas emissions. This understanding helps to outline the importance of tailoring interventions and policies to address both global and local contexts (Murawska & Goryńska-Goldmann, 2023).

Finally, the decline in CFC-11 and CFC-12 after the late 1980s is evidence of the impact that international cooperation and policy can have on environmental trends. Prior to the Montreal Protocol's inception, the world faced rapidly depleting ozone layers, with potential catastrophic implications for ecosystems and human health. Through the Protocol, not only were ozone-depleting substances curbed, but it also sparked innovative solutions in industries relying on these substances, ultimately driving technological advancements in refrigeration and air conditioning systems while providing a hopeful narrative for the future of climate change policy writing and implication. However, as we progress into the 21st century, challenges surrounding GHG emissions present a much larger, more complex problem. The idea of globalizing policy in relation to climate related crises is supported by the findings of Ullah et al. (2022) specifically in their GHG emissions research. They say that, “Ultimately, the government should develop a clear globalization strategy in which it reduces GHG emissions. This can be successfully accomplished by incentivizing the positive impacts of globalization…” (Ullah et al., 2022). Their suggested course of action calls for a memorandum of understanding for a multinational treaty to be signed outlining guidelines for GHG emissions reductions in diverse sectors of production, manufacturing, and transportation of goods. Such an agreement, inspired by the successes of the past, may help to pave the way for a more sustainable future.

Moreover, as these relationships between climate change and economic factors are studied and investigated, it becomes crucial to constantly question, validate, and further examine the data, always being aware of external influences, potential extraneous determinants, and the ever-evolving global context. Understanding these intricacies is the key to shaping policies and strategies that can balance economic growth with environmental sustainability. As we continue to face the escalating challenges of climate change, research, multidisciplinary collaboration, and an unwavering commitment to deepening our comprehension is crucial. Such tasks are imperative to creating a future where economies thrive harmoniously within the carrying capacity of the planet.

Action

As mentioned previously, the further exploration of climate research and its implications in relation to various aspects of life is pertinent in formulating effective and impactful solutions to the challenges of climate change. But understanding alone is not enough. It must be coupled with quick, concrete actions.

One of these actions is embracing multidisciplinary collaboration. Climate change is a multifaceted issue as demonstrated by its effects branching throughout different sectors of life. Therefore its solutions require the collective expertise of economists, environmentalists, urban planners, and many more. A united front is essential. One example of effective collaboration is the European Green Deal by the European Union, which involves coordinated efforts across its member countries to address climate challenges. The main goals of the deal is to create no net emissions of greenhouse gasses by the year 2050, have economic growth decoupled from resource use, and to leave no person and no place behind. This initiative integrates economic, environmental, and urban planning strategies to create a comprehensive approach to the sustainability of reducing climate change effects.

Additionally, there is the strategy of prioritizing education and outreach. Informing the public about the intricate relationship between the economy and climate change will help in spurring grassroots movements and upping the demand for sustainable solutions at the local, national, and global levels. Countries like Canada have implemented carbon pricing mechanisms, emphasizing the role of public awareness in influencing individual and corporate behavior towards reducing greenhouse gas emissions. Public understanding is key to the success of such policies.

Countries can also invest in sustainable innovations. Both the public and private sectors should work to divert resources to develop and implement green technologies and create and grow sustainable practices, ensuring long-term economic and environmental health. Germany's Renewable Energy Act (EEG) serves as an example of this idea in practice. The act calls for changes in energy law, creating a legal basis for continuing the growth of renewable energy in the long term in order to meet clean energy source goals. This demonstrates the impact of sustained investment in sustainable innovations. This policy has facilitated the growth of renewable energy sources, contributing to both economic development and environmental sustainability.

Likewise, lobbying for progressive policies can also have significant positive impacts. Governments worldwide must be urged to enact regulations and incentives promoting sustainability, making it integral to both domestic and international agendas to address these issues. The Paris Agreement otherwise known as the Paris Accords or the Paris Climate Accords, serves as a landmark example of this international cooperation. Countries globally have committed to a legally binding climate change treaty outlining specific actions against limiting the factors of climate change and their repercussions. It was endorsed and put into place by 196 Parties at the UN Climate Change Conference (COP21). This showcases the power of collective lobbying for progressive policies on a global scale.

Finally, there is cultivating personal responsibility. Every individual has their own important role to play. From making sustainable consumer choices, to advocating for climate action in one's community, the collective impact of individual actions should not and cannot be underestimated in this discussion. The Net Zero by 2050 commitment in the United Kingdom emphasizes the importance of individual and community-level actions in achieving broader national goals. This showcases how personal responsibility can contribute to a collective movement towards sustainability.

This research highlights the relationship between climate change and economic patterns. The challenges are often viewed as monumental, but so are the opportunities for innovation, growth, and collaboration with one another. As we navigate this crucial turning point, it is our collective duty to create a future where growth and sustainability thrive in tandem with one another.

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