Research on Global Evolution of Green House Gas (GHG) Emissions Over the Past 30 Years

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1 Abstract

This report investigates the evolution of greenhouse gas (GHG) emissions over the past 30 years in selected countries from Asia, Africa, Europe, Oceania, South America, and North America using historical GHG Emissions Data from Climate Watch, analyzed with RStudio. We examine global GHG emission patterns and compare emissions between the northern and southern hemispheres. Our findings indicate that, most countries have maintained relatively stable emission levels with some fluctuations, while China exhibits a clear increasing trend. Additionally, China and the United States have significantly higher emissions than other countries. In conclusion, there is an overall increasing trend in global emissions. It is crucial to develop strategies and policies for achieving net-zero GHG emissions globally.

2 Introduction

Climate change has become an increasingly severe issue nowadays. Greenhouse gases (GHGs), such as carbon dioxide, methane, and nitrous oxide, absorb infrared radiation and trap heat, contributing to global warming and climate change. With the urgent need to reduce greenhouse gas emissions and achieve net-zero greenhouse gas emissions, our group has posed several questions: How have greenhouse gas emissions evolved over the past 30 years in selected representative countries from Asia, Africa, North America, Oceania, South America, and Europe? What are the emission levels of each representative country in their respective Northern and Southern Hemispheres? Additionally, what is the trend of global GHG emissions?

2.1 Data Descrition

Source: The historical greenhouse gas (GHG) emissions data from 1990 to 2019 was collected from Climate Watch.

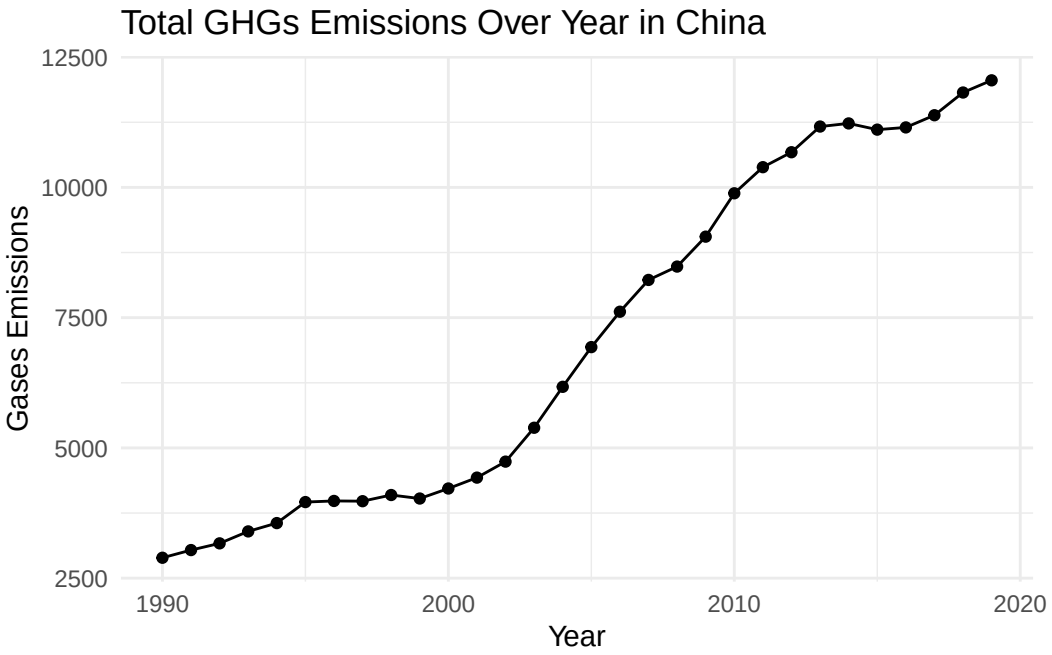
Variable	Description
Country	The name of the country from which the emission data is collected
Gas	Various types of GHGs (We refer only to total GHGs in our report)
Unit	The unit of GHG emissions (MtCO2e)
Year	The year in which the emissions were recorded
Emissions	The amount of greenhouse gases emitted

3 Part I: Gas Emissions Change within Countries Over Year

We've chosen six countries—Australia, Brazil, China, the United States, the United Kingdom, and South Africa—to represent six continents: Oceania, South America, Asia, North America, Europe, and Africa, respectively. Our goal is to analyze the trends in greenhouse gas emissions over a 30-year period for each country.

We'll begin by creating line graph for every country and matching up the year with the emissions data to start with our research. We will be able to identify any obvious trends or correlations in the emissions data throughout the 30-year period due to this visual illustration. We can figure out whether each country's emissions data has a linear trend by closely reviewing these line graphs.

3.1 China

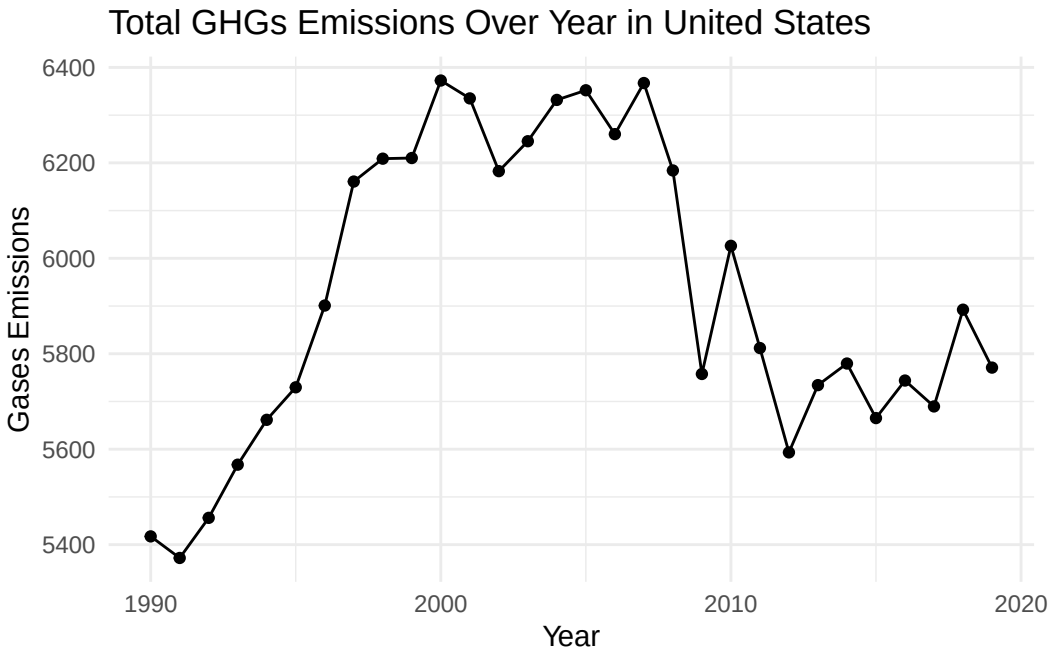


China's greenhouse gas emissions have increased constantly since 1990, and only dropped a little bit around the year 2015.

```
            Df    Sum Sq   Mean Sq F value Pr(>F)
Year         1 302443630 302443630   530.1 <2e-16 ***
Residuals   28  15976101    570575
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value of China's greenhouse gas emissions ANOVA test is less than 2e-16, indicating that there is a statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions have changed over 30 years.

3.2 United States

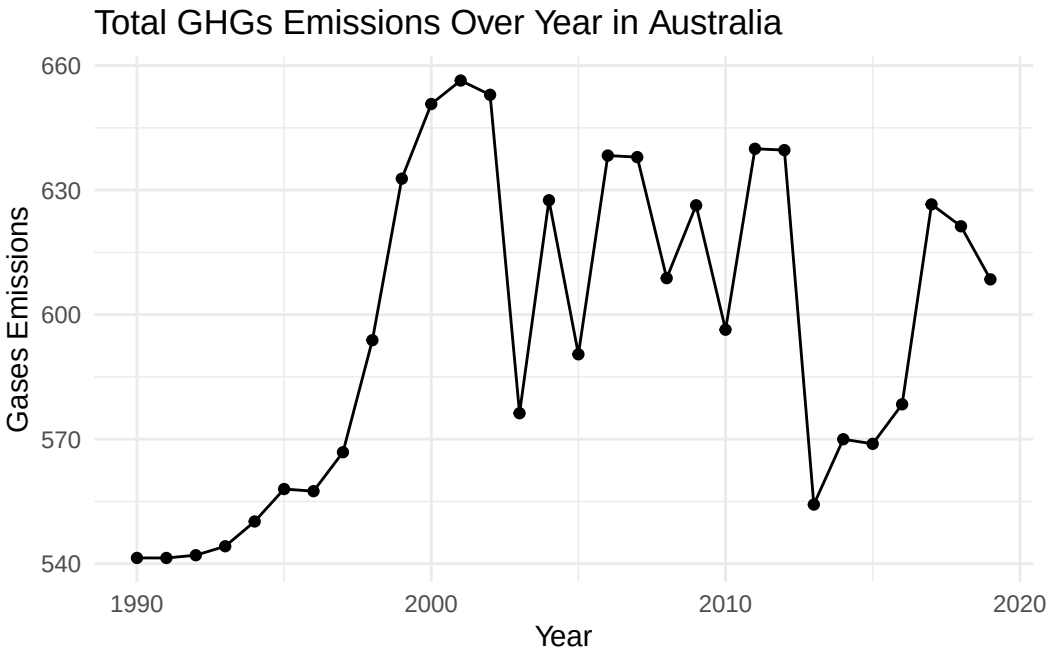


The United States greenhouse gas emissions were quite high from 1997 to 2008. However, it dropped suddenly in 2009 and then stayed constant at that level.

```
            Df  Sum Sq Mean Sq F value Pr(>F)
Year         1   13669   13669   0.133  0.718
Residuals   28 2882681  102953
```

The p-value of the United States' greenhouse gas emissions ANOVA test is 0.718, indicating that there is no statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions of the United States have not significantly changed over the past 30 years.

3.3 Australia

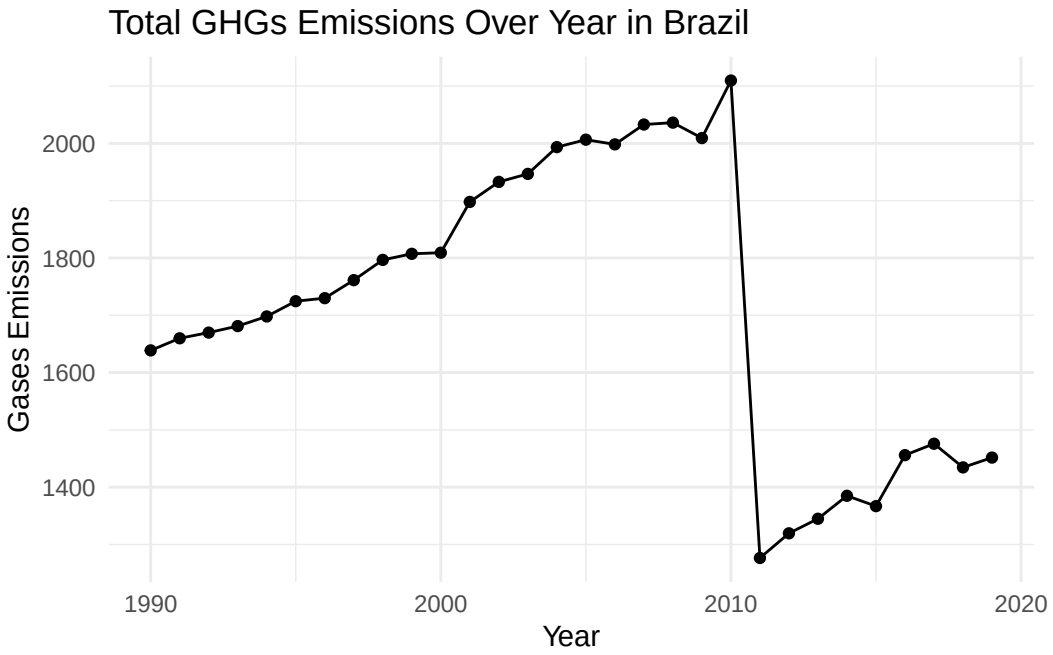


Since 1995, greenhouse gas emissions in Australia have surged suddenly, reaching its highest point around 2000, then fluctuating in the following years.

```
            Df Sum Sq Mean Sq F value Pr(>F)
Year         1   7812    7812   6.087   0.02 *
Residuals   28  35940    1284
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value of Australia's greenhouse gas emissions ANOVA test is 0.02, indicating that there is a statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions have changed over 30 years.

3.4 Brazil

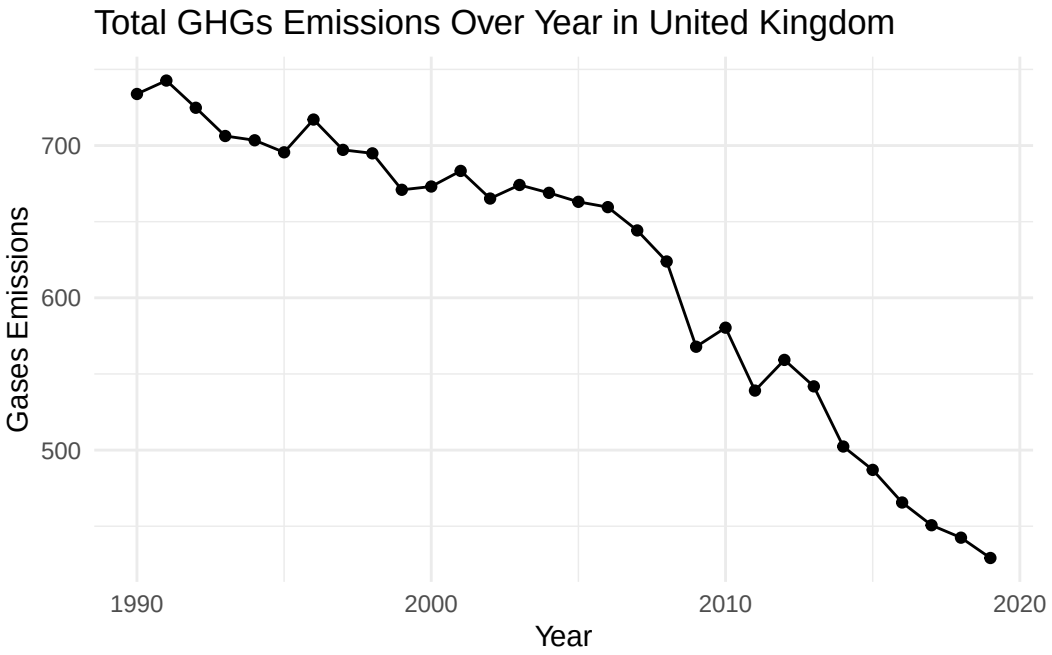


Brazil's greenhouse gas emissions increased constantly from 1990 to 2010, then dropped suddenly in 2010, and increased again, but never reached the same levels as before.

```
            Df  Sum Sq Mean Sq F value Pr(>F)
Year         1  257484  257484   4.525 0.0424 *
Residuals   28 1593304   56904
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value of Brazil's greenhouse gas emissions ANOVA test is 0.0424, indicating there is a statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions have changed over 30 years.

3.5 United Kingdom

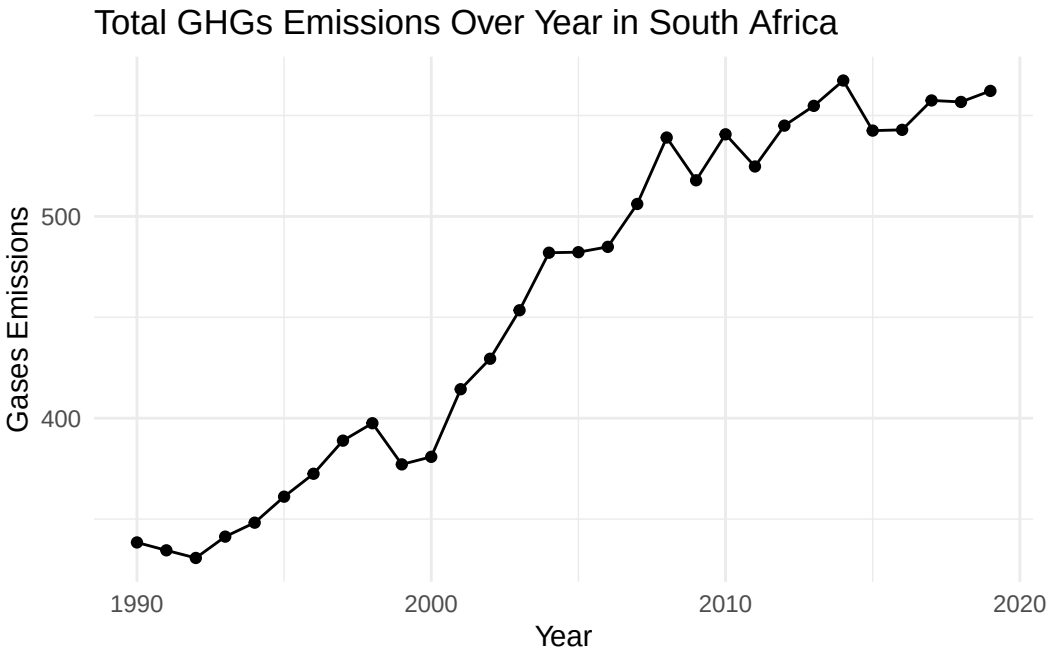


It is very surprising that the United Kingdom's greenhouse gas emissions are constantly decreasing each year.

```
            Df Sum Sq Mean Sq F value   Pr(>F)
Year         1 247152  247152   262.1 9.55e-16 ***
Residuals   28  26406     943
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value of United Kingdom's greenhouse gas emissions ANOVA test is 9.55e-16, indicating there is a statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions have changed over 30 years.

3.6 South Africa



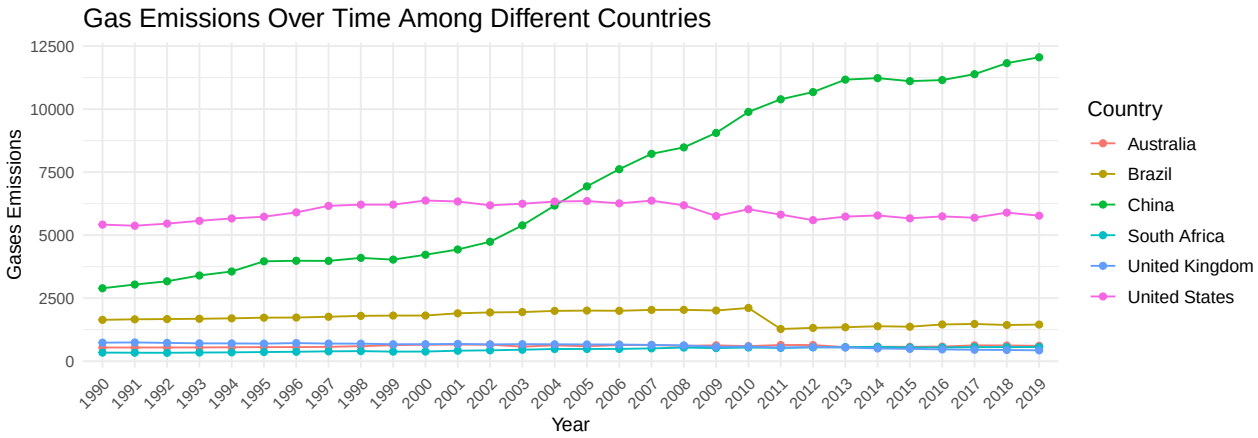
South Africa's greenhouse gas emissions are constantly increasing with some fluctuations between years.

```
            Df Sum Sq Mean Sq F value Pr(>F)
Year         1 198739  198739   449.5 <2e-16 ***
Residuals   28  12380     442
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value of South Africa's greenhouse gas emissions ANOVA test is less than 2e-16, indicating there is a statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions have changed over 30 years.

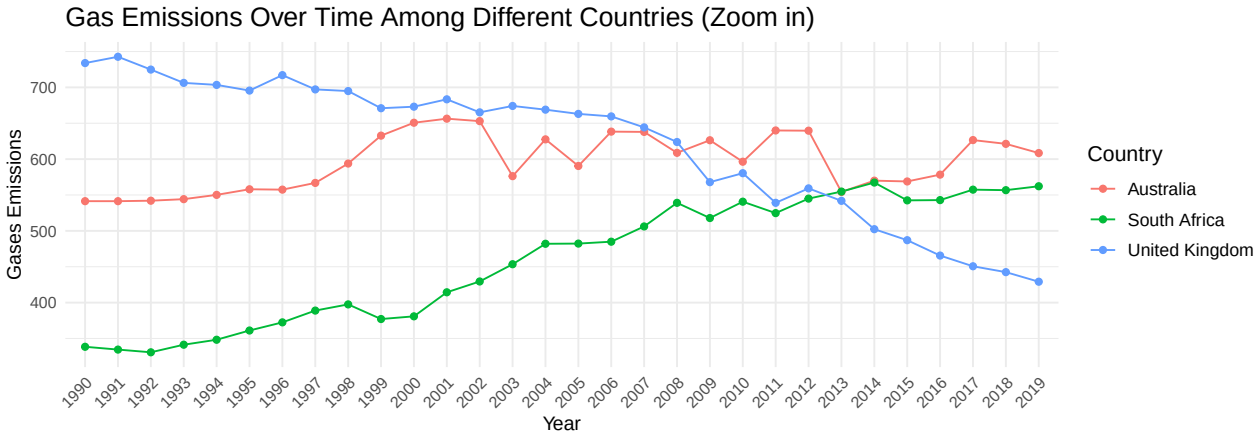
3.7 All Countries

We want to compare the trend of GHGs emissions across all representative countries, so we created a line graph that includes all six representative countries.



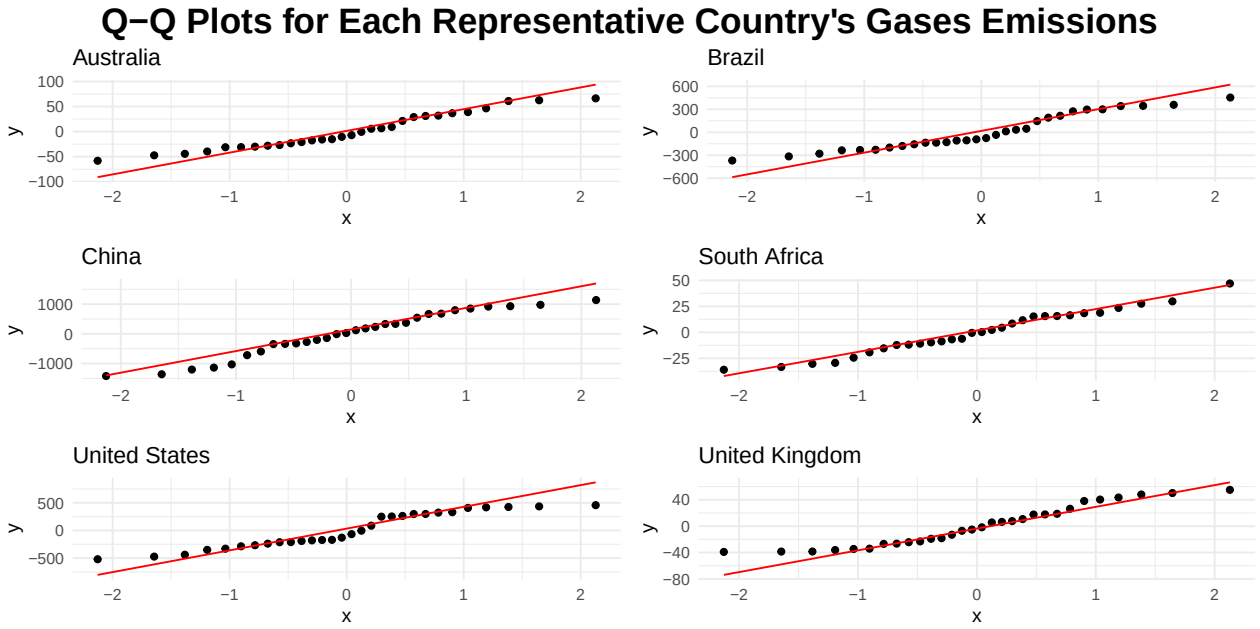
In the line graph we created, China presents a clear and consistent linearly increasing trend, suggesting the need for China to implement policies to decrease GHG emissions. Conversely, other countries have GHG emissions that are more stable with some fluctuations. However, China, the United States, and Brazil still have higher emissions than the rest of the countries. Interestingly, Brazil's emissions data reveals a linear trend from 1990 to 2010, then followed by a sudden decrease in emissions from 2010 to 2011, plummeting from 2109.66 MtCO e to 1276.46 MtCO e. This unusual anomaly in Brazil's emissions trend suggests that there may be policy changes focused on environmental conservation that could lead to a significant reduction in gas emissions.

Since it is quite hard to tell the difference in trend between South Africa, the United Kingdom, and Brazil, we have produced another graph with specific emphasis on these three countries.



It is clearer now that the United Kingdom began with the highest GHG emissions among the three but later decreased its emissions and became the country with the least emissions among the three. Although Australia's overall emissions did not change much, it experienced many fluctuations. Lastly, South Africa's emissions have increased over the years, and in the year 2013, GHG emissions of South Africa and Australia were almost the same.

3.8 Q-Q Plot

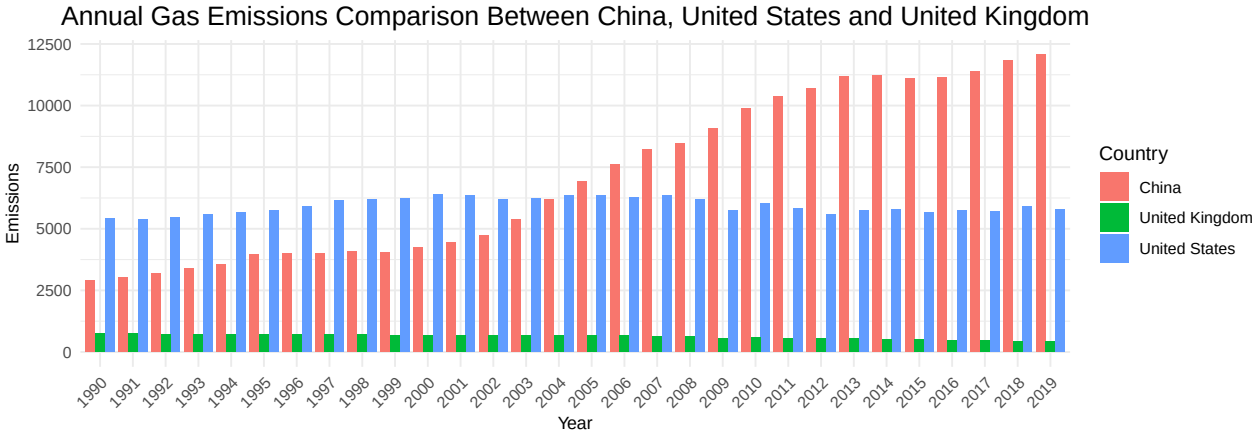


The Q-Q plots for each representative country's gases emissions of residuals aligning well with the line suggests that the residuals are approximately normally distributed.

4 Part II: Comapring Gas Emissions Between Countries

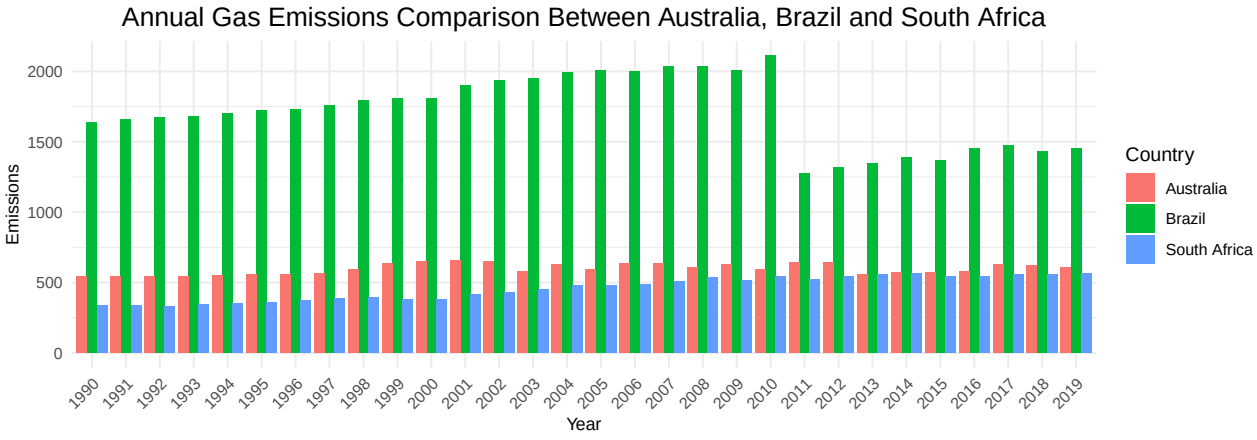
This part we aim to compare the representative countries collectively using a line graph and then reviewing them geographically, distinguishing between the Northern Hemisphere and the Southern Hemisphere. The Northern Hemisphere includes China, the United States and the United Kingdom, while the Southern Hemisphere comprises Australia, Brazil and South Africa.

4.1 North Hemisphere

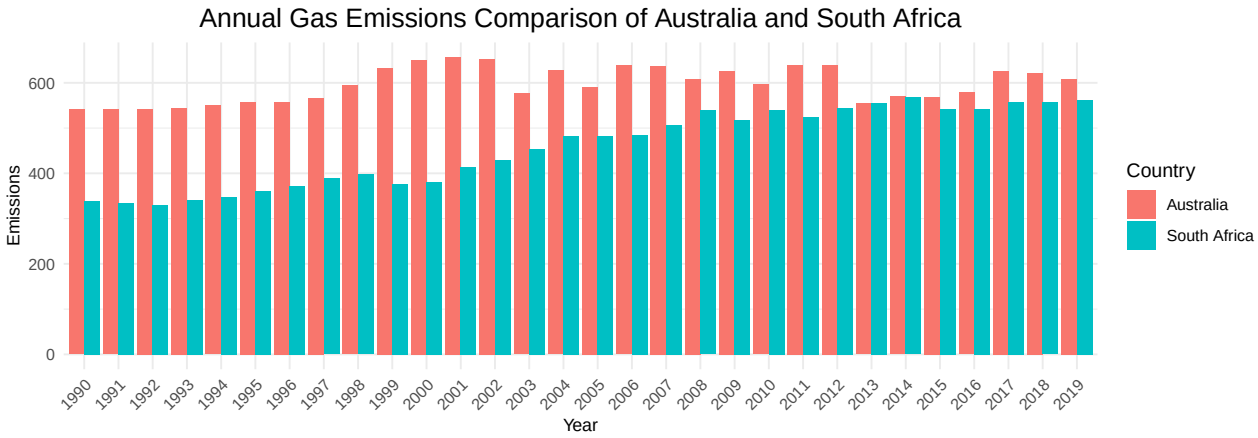


In the Northern Hemisphere, China and the United States have very high greenhouse gas emissions. China had the largest gas emissions after the year 2005 among the four countries. The United States had more stable GHG emissions with some fluctuation. However, the United Kingdom has much lower gas emissions than them. Additionally, the greenhouse gas emissions of the United Kingdom decreased slightly each year.

4.2 South Hemisphere

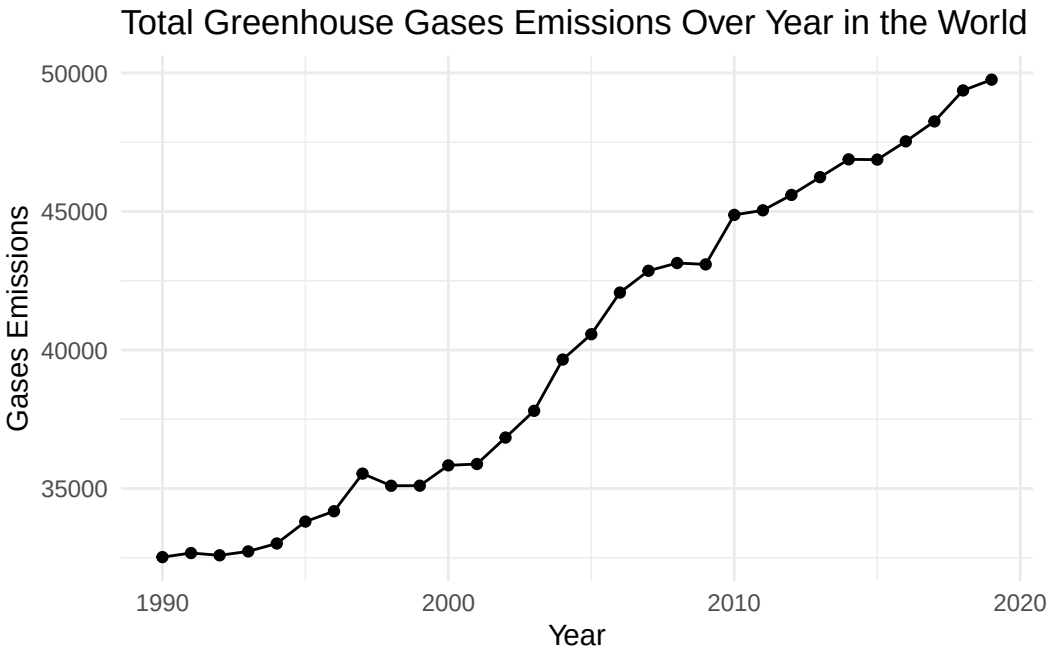


This plot above represents the greenhouse gas emissions from three countries in the Southern Hemisphere over the years from 1990 to 2019. Australia's gas emissions appear relatively consistent over the years, with a slight decline after 2012. Brazil's gas emissions are significantly higher than Australia's throughout the entire time period, peaking around 2010, and tend to decrease afterward. Although South Africa's emissions slightly increase over the years, the total greenhouse gas emissions are the lowest among the three countries. However, we want to take a closer look at Australia and South Africa to compare the GHG emissions differences more clearly. Therefore, we have created a second plot.



After zooming in on the plot, from 1990 to 2011, Australia had higher GHG emissions than South Africa. However, after 2011, the difference in GHG emissions between Australia and South Africa became smaller. Overall, Australia had slightly higher GHG emissions than South Africa throughout the period. This could be due to various factors including industrialization and economic activity.

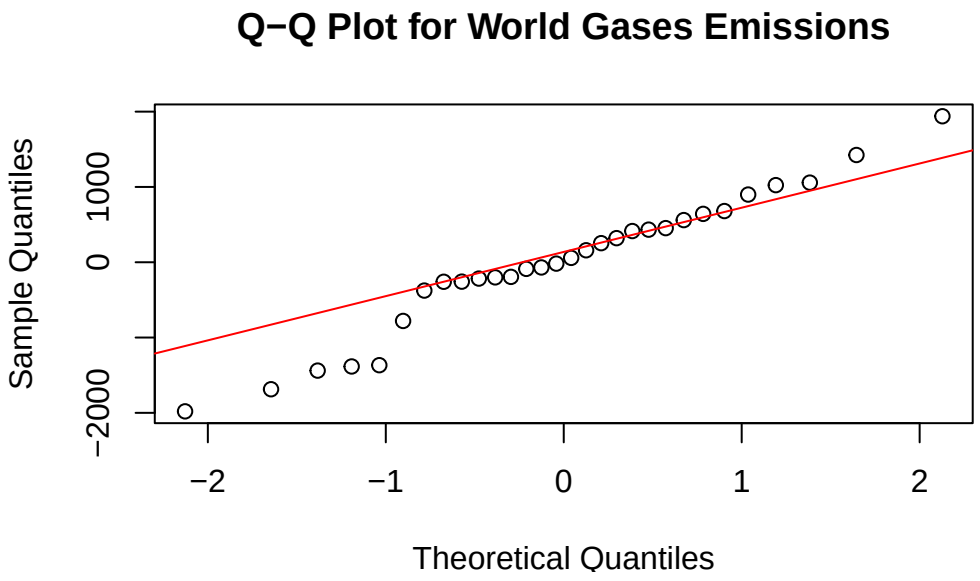
5 Part III: Global Emissions Change



The plot above illustrates the trend of global greenhouse gas emissions from 1990 to approximately 2019. Between 1990 and 2000, the gas emissions increase steadily but with relatively slow change. In the subsequent decade, the emissions began to rise at a more pronounced rate, particularly between 2000 and 2005, when the curve became markedly steeper, indicating a rapid acceleration in gas emissions. From 2010 to 2019, there was a continued and significant increase in greenhouse gas emissions. This indicates that the global emissions are accelerating.

```
            Df    Sum Sq   Mean Sq F value Pr(>F)
Year         1 984305081 984305081    1132 <2e-16 ***
Residuals   28  24349793    869635
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The p-value of World's greenhouse gas emissions ANOVA test is less than 2e-16, indicating that we have sufficient evidence to suggest a statistically significant relationship between emissions and the year. This implies that greenhouse gas emissions have changed over 30 years.



The Q-Q plots for the World's gases emissions of residuals align well with the line, indicating that the residuals are approximately normally distributed.

6 Conclusion

In conclusion, the analysis of GHG emissions over the past 30 years reveals that most representative countries have maintained relatively stable emissions, except for China that shows a clear increasing trend. Additionally, China and the United States exhibit significantly higher emissions compared to other countries. Overall, global emissions are increasing. These findings underscore the urgent need for effective strategies and policies to achieve net-zero GHG emissions globally.

However, the result of this report is not perfect, for example, we did not specify different types of greenhouse gases. It provides a solid foundation for future iterations and improvements. Future studies could specify different types of greenhouse gases and use the data to build a prediction model to forecast future GHG emissions.