Relation Between the Greenhouse Gases and World Temperature

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Abstract

Environmental issues are one of the prominent debates today. The climate crisis has begun to manifest itself in recent years. One of the leading causes of the climate crisis is the increase in the temperature of the world over the years. It is argued that greenhouse gas emission leads to an increase in world temperature. This article will show the relationship between gas emissions and global temperature rise by using the Bayesian model.

Keywords: world temperature; greenhouse gas emission; environment; Bayesian Analysis

1.Introduction

Global warming has been a hot topic recently. The temperature measurement of the world gives us an idea about the extent of global warming. World temperature has increased approximately 1°C in the last 100 years.

One of the main reasons for the increase in world temperature is greenhouse gas emissions. Greenhouse gas emissions act like a blanket in the air, trapping heat in the atmosphere and warming the earth.

2. Methods and Data

The aim is to show the causal relation; therefore, DAG (Directed Acyclic Graphs) is used.

The probabilistic model is created to analyze the causal relationship between world temperature and greenhouse gas emissions. The model consists of two parts. The first model was established by simple regression. The second model was created using splines. Spline analysis is divided into three parts.
In splines, I get the parameter weights for each basis function.

I used data between the years of 1990 and 2018 for greenhouse gas emissions and world temperature. I took the data from Nasa and Our World in Data.

3. Model

First, classical linear regression is used to look at the causal relation between world temperature and greenhouse gases. The DAG is in Figure 1.

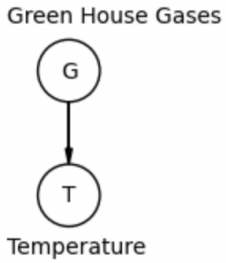

Figure 1: DAG for Greenhouse Gases and Temperature

In this DAG, it is assumed that green house gases are the cause of world temperature. The constructed linear model is below.

$$T_i \sim \text{Normal}(\mu_i, \sigma)$$
$$\mu_i = \beta G_i$$
$$\beta \sim \text{Normal}(0, 0.5)$$
$$\sigma \sim \text{Exponential}(1)$$

Figure 2: Linear Model

In this model, temperature and greenhouse gases are standardized. Standardization means that each data point is subtracted from its mean and then divided by its standard deviation. Since data is standardized, I choose the value zero for the mean of beta and zero point five for the variance for the beta. I assumed that beta and temperature are normally distributed. Also, I assumed that the variance of temperature is distributed as exponential. Prior predictive analysis for this model is below.

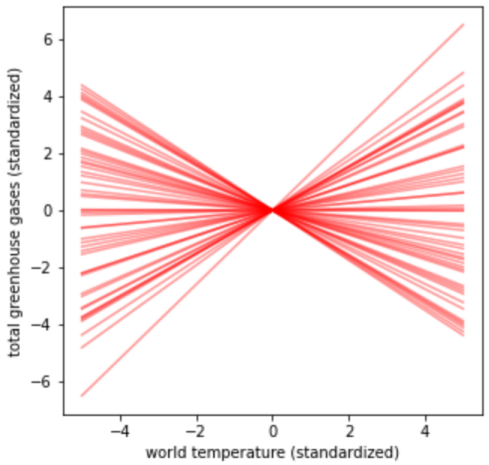

Figure 3: Prior predictive analysis for beta

Prior predictive analysis showed that this prior is suitable; therefore, I constructed the posterior predictive analysis. The results are in Figure 4.

	mean	sd	hdi_3%	hdi_97%
beta	0.945	0.056	0.842	1.048
sigma	0.303	0.044	0.224	0.384

Figure 4: Results of Posterior Predictive Analysis

As seen above, the beta has a value of 0.946, and it is positive. Therefore, it can be said that an increase in total greenhouse gases and world temperature has a positive relation.

Secondly, B-Splines are used to analyze the causal relation. In this analysis, years are also added to the model. The DAG for the model is below.

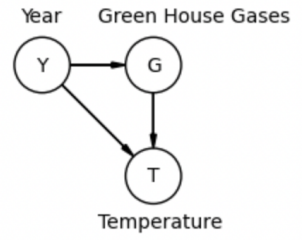

Figure 5: DAG for B-Spline Model

While using B-Splines, I did three models. All these models used standardized data. First, I built the model to look at the effect of years on world temperature. Second, I built the model for the effects of years of greenhouse gases. The final model is the effect of greenhouse gases on world temperature.

While analyzing the relationship between year and world temperature, I used the model below.

$$
\begin{aligned}
T_i &\sim \text{Normal}(\mu_i, \sigma) \\
\mu_i &= \alpha + \sum_{k=1}^{K} w_k B_{k,i} \\
\alpha &\sim \text{Normal}(0, 1) \\
w_j &\sim \text{Normal}(0, 1) \\
\sigma &\sim \text{Exponential}(1)
\end{aligned}
$$

Figure 6: B-Spline Model for years and temperature

I used 8 knots for this model and basis function can be seen in the Figure 7.

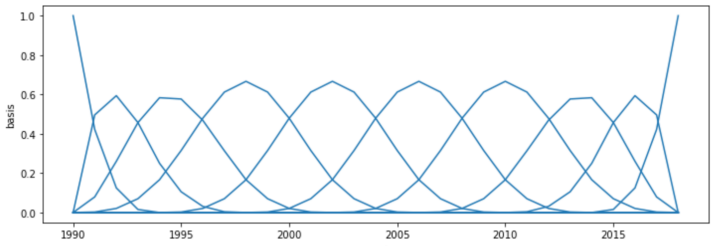

Figure 7: Basis function

I constructed posterior predictive analysis for this model and results are in the Figure 8.

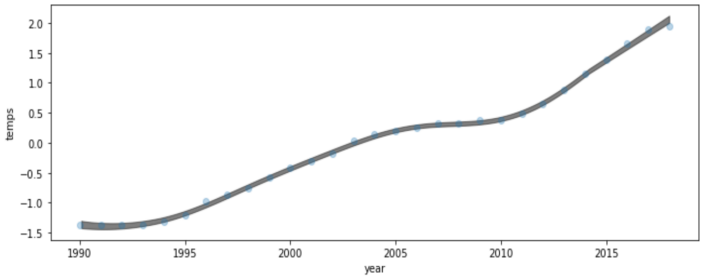

Figure 8: The relation between years and world temperature.

In the graph, it is seen that there is a rapid increase in world temperature between the years 1990 and 2018.

While analyzing the relation between year and greenhouse gas emission, I constructed a similar model.

$$
\begin{aligned}
G_i &\sim \text{Normal}(\mu_i, \sigma) \\
\mu_i &= \alpha + \sum_{k=1}^{K} w_k B_{k,i} \\
\alpha &\sim \text{Normal}(0, 1) \\
w_j &\sim \text{Normal}(0, 1) \\
\sigma &\sim \text{Exponential}(1)
\end{aligned}
$$

Figure 9: B-Spline Model for years and greenhouse gases

I again used 8 knots in this model, therefore basis function is the same as Figure 7.

The results of posterior predictive analysis are shown in Figure 10.

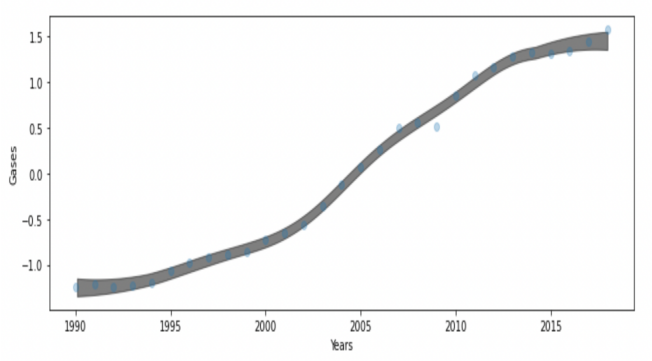

Figure 10: The relation between years and greenhouse gases

As seen in the graph, there is an increase in the greenhouse gases between years 1990 and 2018.

Finally, I constructed a B-spline model for relation between world temperature and greenhouse gases.

$$G_i \sim \text{Normal}(\mu_i, \sigma)$$
$$\mu_i = \alpha + \sum_{k=1}^{K} w_k B_{k,i}$$
$$\alpha \sim \text{Normal}(0, 1)$$
$$w_j \sim \text{Normal}(0, 1)$$
$$\sigma \sim \text{Exponential}(1)$$

Figure 11: B-Spline Model for world temperature and greenhouse gases

In this model, I used 4 knots and basis function can be seen in the Figure 12.

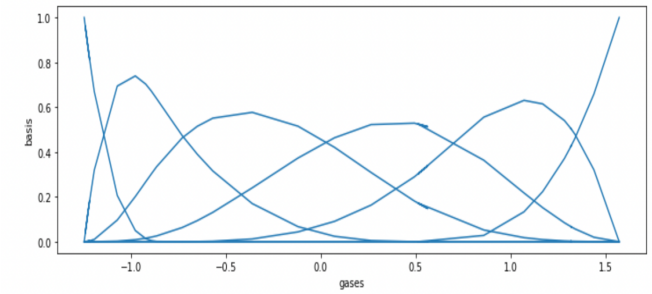

Figure 12: Basis function

I constructed the posterior predictive samples for model between world temperature and greenhouse gas emissions. Results are in the Figure 13.

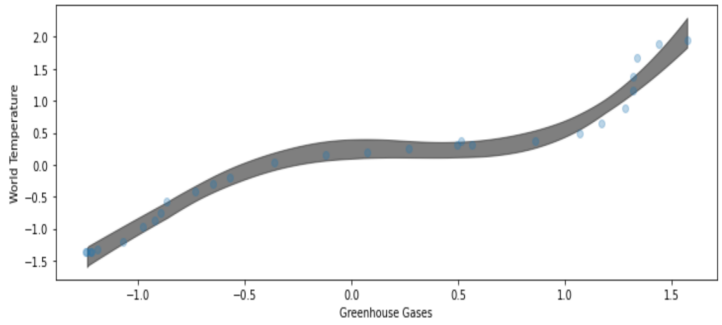

Figure 13: The relation between world temperature and greenhouse gases

In the graph above, it is obvious that when the greenhouse gases increase, world temperature is also increasing. There is a positive relation between them.

4. Model Comparison

Since the aim is to understand the causal relation between greenhouse gases emission and an increase in world temperature, I compared the models constructed for this relation. First, I constructed simple linear regression. Second, I constructed B-Spline models. I created three B-spline models, but I used the last one, which shows the relation between temperature and greenhouse gases. WAIC is used for this comparison. B-Spline model is better according to comparison. The results are in Figure 14.

	rank	waic	p_waic	d_waic	weight	se	dse	warning	waic_scale
SPLINE	0	-20.620722	6.634682	0.000000	1.000000e+00	9.658008	0.000000	True	deviance
SIMPLE	1	13.609608	1.664119	34.230329	3.783640e-13	5.522443	7.956424	False	deviance

Figure 14: Waic Comparison

5. Discussion

In the model constructed, it is shown that greenhouse gas emission is a cause of the increase in world temperature. I also aimed to predict the carbon level where the temperature will be 2°C because 2°C is the critic for the world. This temperature will lead to the extinction of many species. If I would predict the greenhouse gas level where the temperature is 2°C, I can also predict the year at 2°C by using this greenhouse gas level. That's why I analyze the relation between year and gas level. However, I could not make this prediction, I just showed the relation.

References

Raftrey A., Zimmer A., Frierson D. (2017). Less than 2°C Warming by 2100 Unlikely. *Natural Climate Change*

Mansfield L., Nowack P., Kosoar M. (2020). Predicting global patterns of long-term climate change from short-term simulations using machine learning. *Climate and Atmospheric Science*