

My title*

My subtitle if needed

First author

Another author

April 7, 2024

First sentence. Second sentence. Third sentence. Fourth sentence.

1 Introduction

You can and should cross-reference sections and sub-sections. We use R Core Team (2023) and Wickham et al. (2019).

The remainder of this paper is structured as follows. Section [2](#)...

2 Data

Some of our data is of penguins ([?@fig-bills](#)), from Horst, Hill, and Gorman (2020).

Warning: Continuous x aesthetic
i did you forget ``aes(group = ...)``?

Talk more about it.

And also planes ([?@fig-planes](#)). (You can change the height and width, but don't worry about doing that until you have finished every other aspect of the paper - Quarto will try to make it look nice and the defaults usually work well once you have enough text.)

Talk way more about it.

*Code and data are available at: [LINK](#).

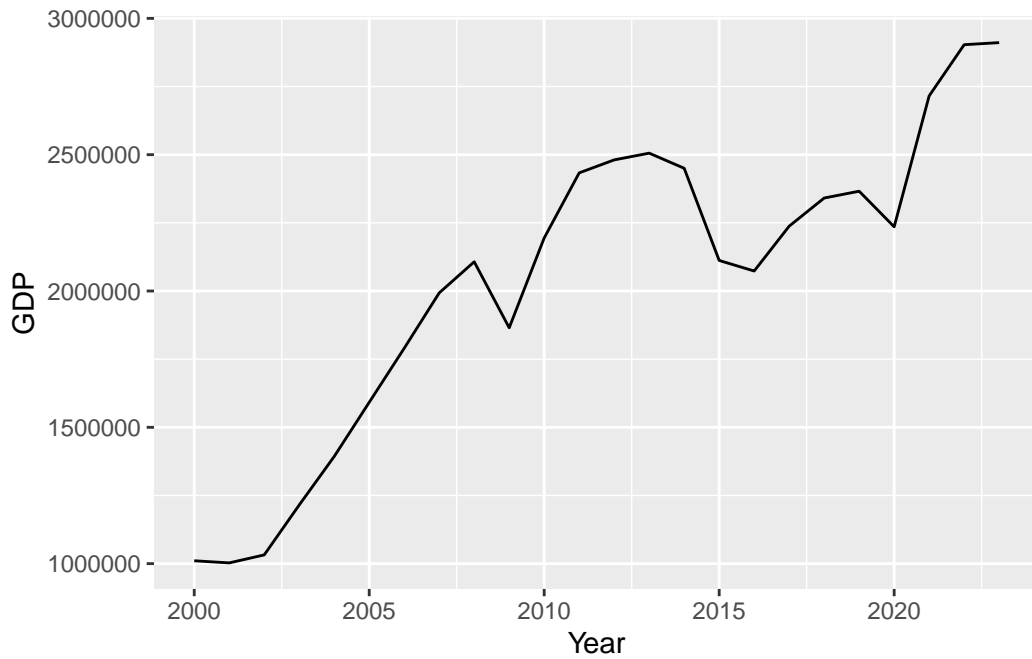


Figure 1: Time Series Plot of GDP

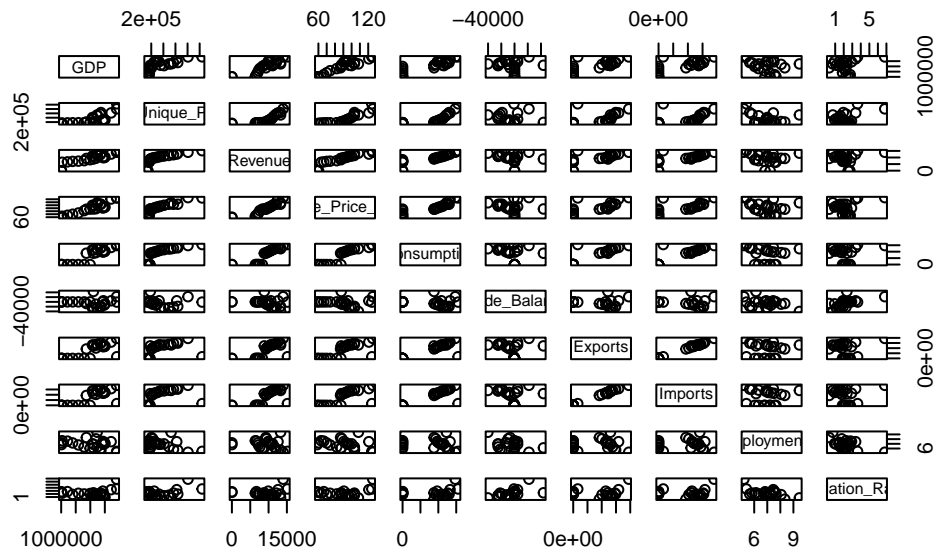


Figure 2: Bills of penguins

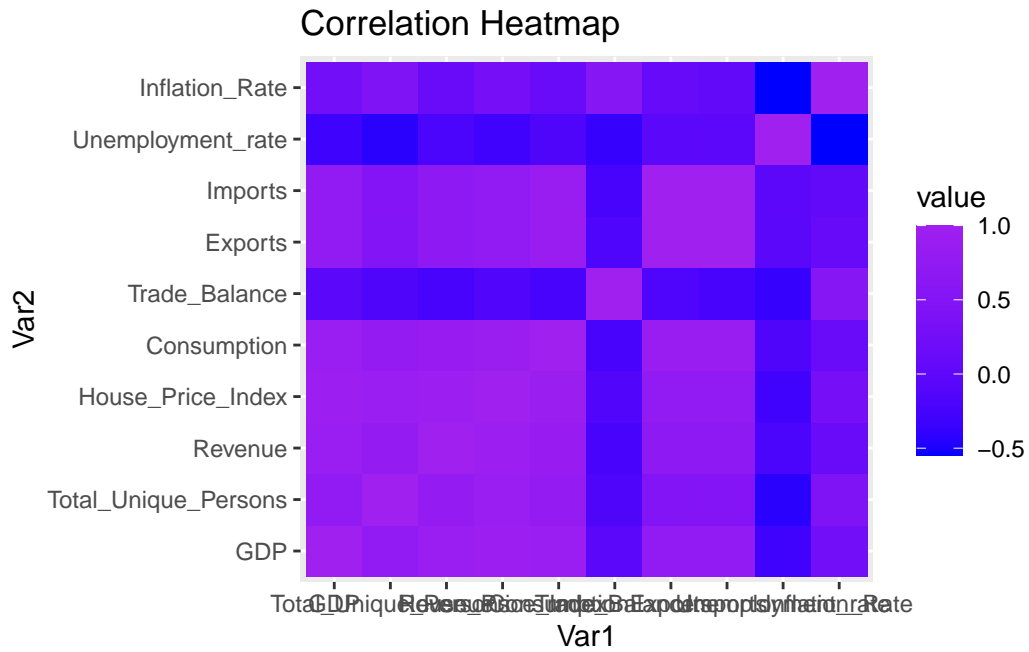


Figure 3: Bills of penguins

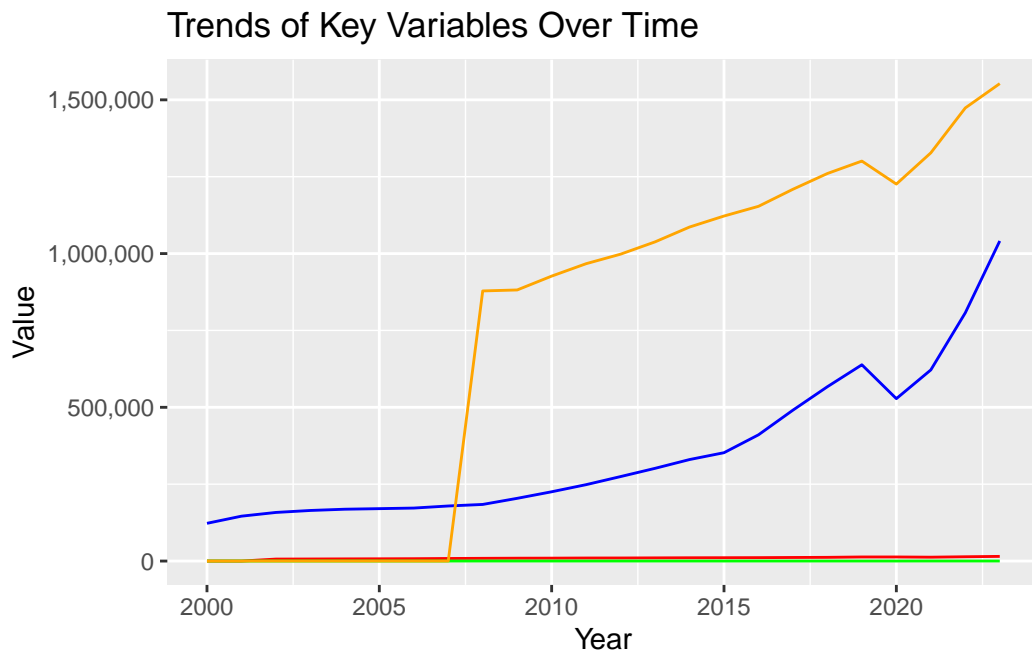


Figure 4: Bills of penguins

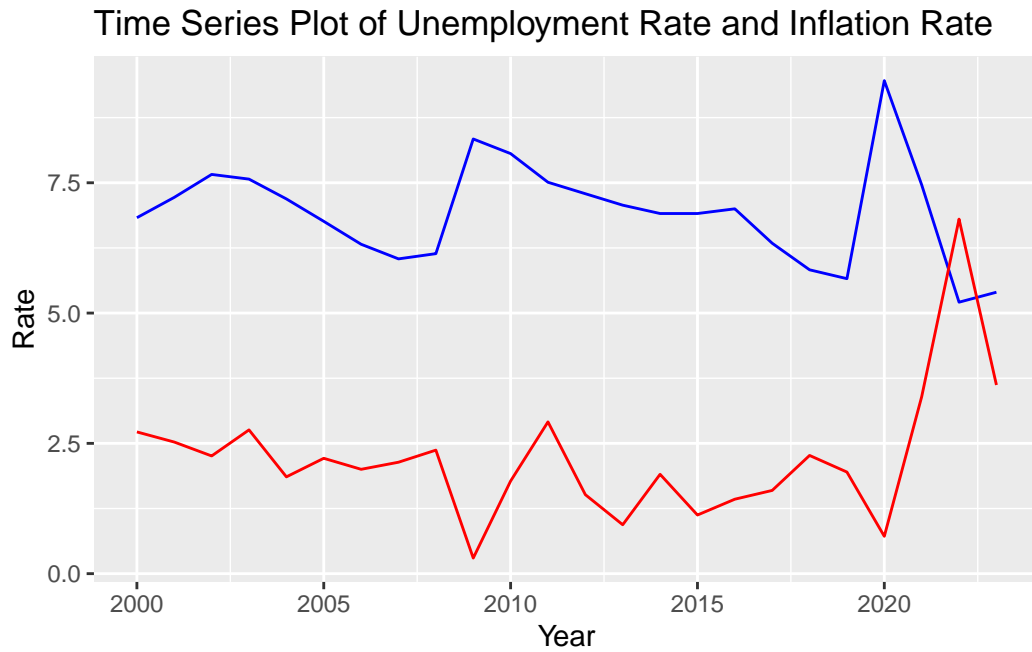


Figure 5: Bills of penguins

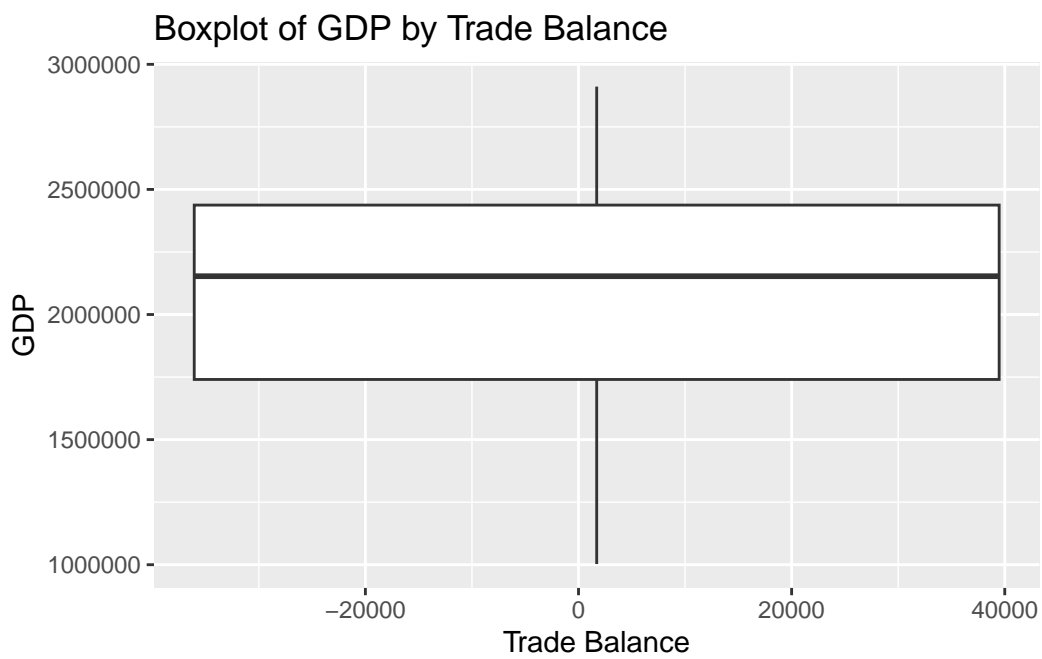


Figure 6: Bills of penguins

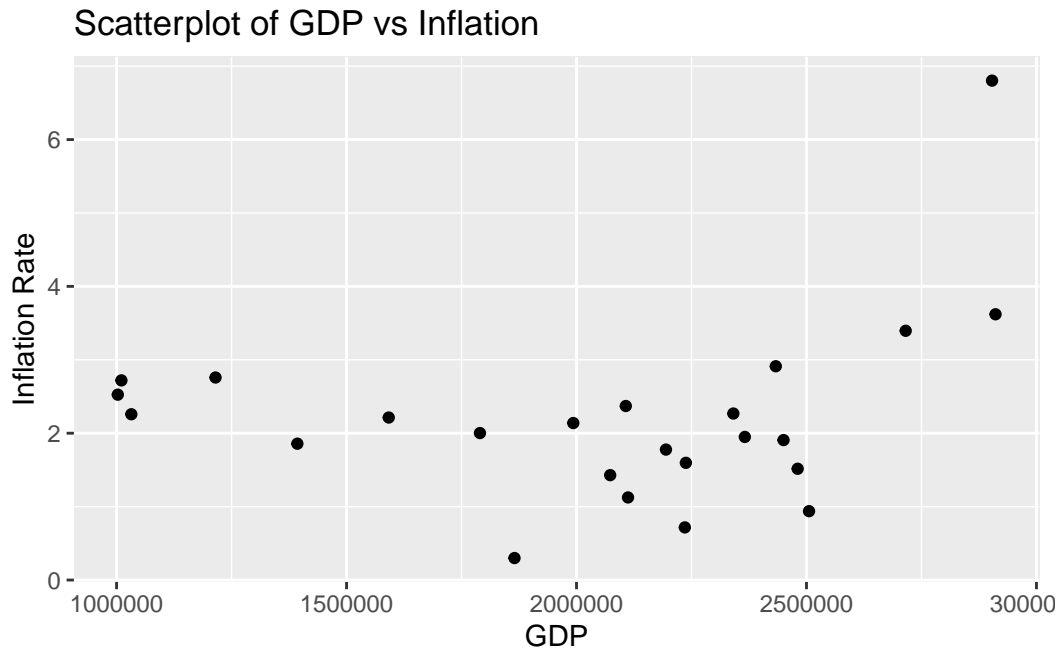


Figure 7: Bills of penguins

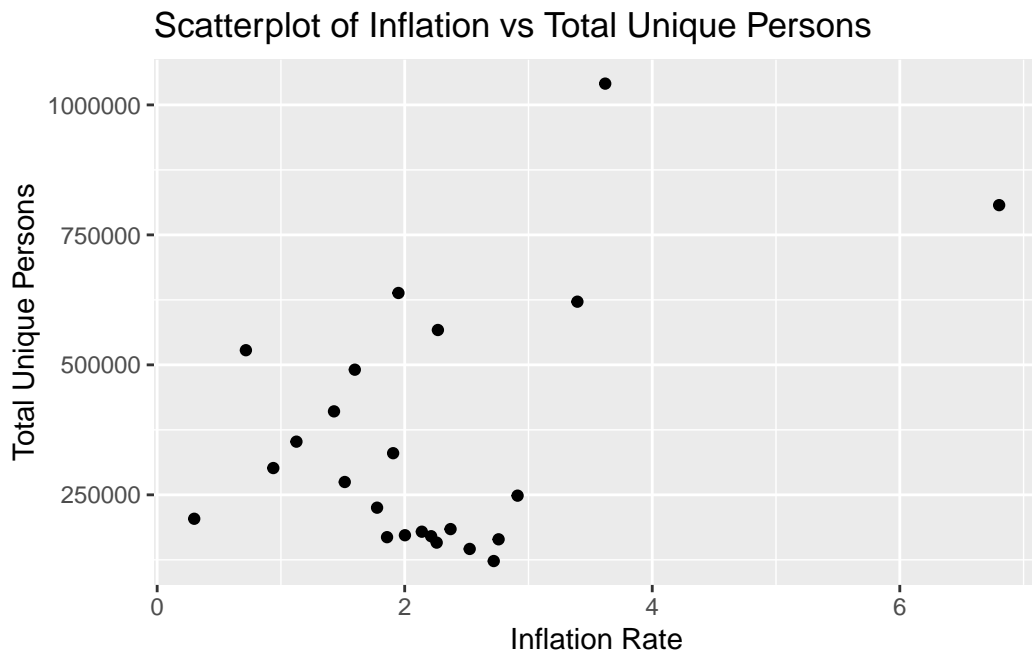


Figure 8: Bills of penguins

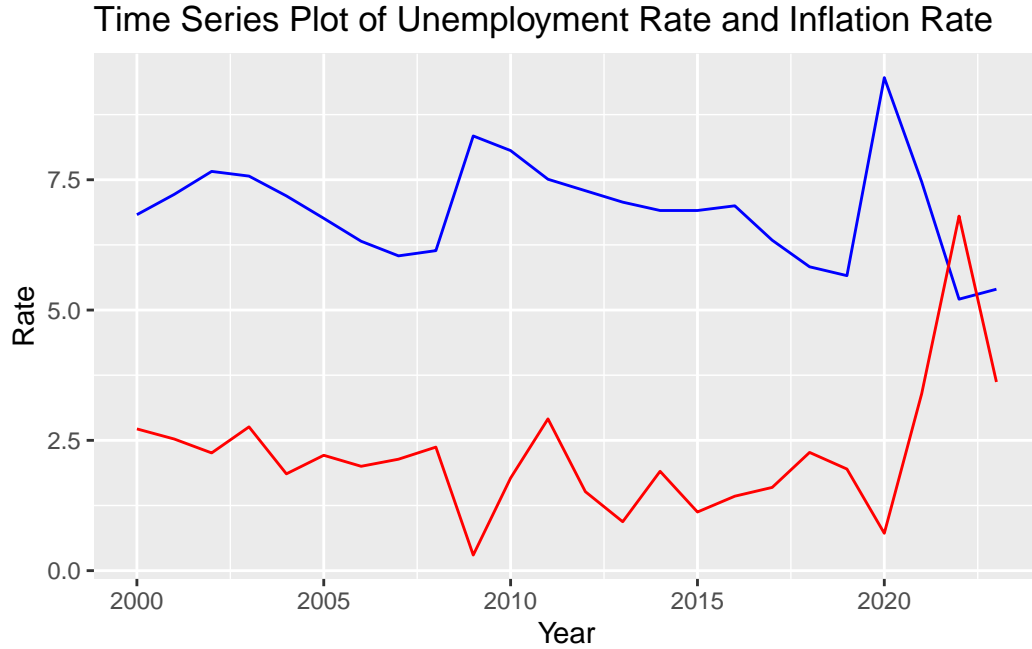


Figure 9: Bills of penguins

3 Model

4 Model 1

The goal of our modeling strategy is to analyze the relationship between various economic indicators and the Gross Domestic Product (GDP) of Canada.

4.1 Model set-up

Let's define the following variables:

- (y_i) : GDP for the (i) -th year
- (x_{1i}) : Total_Unique_Persons for the (i) -th year
- (x_{2i}) : Revenue for the (i) -th year
- (x_{3i}) : House_Price_Index for the (i) -th year
- (x_{4i}) : Consumption for the (i) -th year
- (x_{5i}) : Exports for the (i) -th year
- (x_{6i}) : Unemployment_rate for the (i) -th year
- (x_{7i}) : Inflation_Rate for the (i) -th year

We assume that the GDP (y_i) for each year (i) follows a normal distribution with mean (μ_i) and standard deviation (σ), where:

[

$$\begin{aligned} y_i | \mu_i, \sigma &\sim \text{Normal}(\mu_i, \sigma^2) \\ \mu_i &= \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} \\ \alpha &\sim \text{Normal}(0, 2.5^2) \\ \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7 &\sim \text{Normal}(0, 2.5^2) \\ \sigma &\sim \text{Exponential}(1) \end{aligned}$$

]

We use the `rstanarm` package in R to fit the Bayesian generalized linear model.

4.2 Model justification

We expect that changes in Total_Unique_Persons, Revenue, House_Price_Index, Consumption, Exports, Unemployment_rate, and Inflation_Rate will have an impact on the Gross Domestic Product (GDP) of Canada. Specifically, we anticipate a positive relationship between GDP and Total_Unique_Persons, Revenue, House_Price_Index, Consumption, and Exports, and a negative relationship between GDP and Unemployment_rate and Inflation_Rate. These relationships are hypothesized based on economic theory and empirical evidence.

5 Model 2

The goal of this modeling strategy is to analyze the relationship between various economic indicators and the inflation rate in Canada.

5.1 Model set-up

Let's define the following variables:

- (y_i): Inflation_Rate for the (i)-th year
- ($x_{\{1i\}}$): Total_Unique_Persons for the (i)-th year
- ($x_{\{2i\}}$): GDP for the (i)-th year
- ($x_{\{3i\}}$): Annual_Change_GDP for the (i)-th year
- ($x_{\{4i\}}$): Revenue for the (i)-th year
- ($x_{\{5i\}}$): House_Price_Index for the (i)-th year
- ($x_{\{6i\}}$): Consumption for the (i)-th year
- ($x_{\{7i\}}$): Exports for the (i)-th year

- (x_{8i}): Unemployment_rate for the (i)-th year

We assume that the Inflation_Rate (y_i) for each year (i) follows a normal distribution with mean (μ_i) and standard deviation (σ), where:

$$\begin{aligned}
 & y_i | \mu_i, \sigma \sim \text{Normal}(\mu_i, \sigma^2) \\
 & \mu_i = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} + \beta_8 x_{8i} \\
 & \alpha \sim \text{Normal}(0, 2.5^2) \\
 & \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8 \sim \text{Normal}(0, 2.5^2) \\
 & \sigma \sim \text{Exponential}(1)
 \end{aligned}$$

We use the `stan_glm` function in R to fit the Bayesian generalized linear model.

5.2 Model justification

We expect that changes in Total_Unique_Persons, GDP, Annual_Change_GDP, Revenue, House_Price_Index, Consumption, Exports, and Unemployment_rate will have an impact on the inflation rate in Canada. Specifically, we anticipate a positive relationship between inflation rate and Total_Unique_Persons, GDP, Revenue, House_Price_Index, Consumption, and Exports, and a negative relationship between inflation rate and Unemployment_rate. These relationships are hypothesized based on economic theory and empirical evidence.

6 Results

In this study, we sought to identify the factors that significantly contribute to the Gross Domestic Product (GDP) and Inflation Rate. We applied a Bayesian generalized linear model to a dataset encompassing a range of economic indicators over a period of years.

6.1 Model Summary

Our GDP model results are summarized in Table 1. The Bayesian regression model revealed several key economic indicators that were significantly associated with GDP. The estimated coefficients from the model indicate the direction and magnitude of each variable's effect. Notable factors with positive influence include Total_Unique_Persons, suggesting that population growth positively correlates with GDP. Similarly, Annual_Change_GDP, Revenue, House_Price_Index, and Consumption all positively impact GDP. On the contrary, Exports

Table 1: Explanatory models of flight time based on wing width and wing length

	GDP model
(Intercept)	−389 026.97 (539 307.25)
Total_Unique_Persons	−1.88 (0.46)
Annual_Change_GDP	24 893.32 (20 117.41)
Revenue	30.03 (24.46)
House_Price_Index	29 472.09 (6993.46)
Consumption	0.80 (0.25)
Exports	−0.88 (0.36)
Unemployment_rate	−52 476.64 (45 025.57)
Inflation_Rate	53 901.17 (43 512.86)
Num.Obs.	24
R2	0.929
R2 Adj.	0.918
Log.Lik.	−318.388
ELPD	−325.9
ELPD s.e.	2.1
LOOIC	651.7
LOOIC s.e.	4.2
WAIC	649.5
RMSE	117 581.47

Table 2: Explanatory models of flight time based on wing width and wing length

	Inflation model
(Intercept)	0.79 (3.18)
Total_Unique_Persons	0.00 (0.00)
GDP	0.00 (0.00)
Annual_Change_GDP	0.13 (0.12)
Revenue	0.00 (0.00)
House_Price_Index	−0.01 (0.05)
Consumption	0.00 (0.00)
Exports	0.00 (0.00)
Unemployment_rate	−0.03 (0.27)
Num.Obs.	24
R2	0.610
R2 Adj.	0.160
Log.Lik.	−28.873
ELPD	−38.5
ELPD s.e.	4.9
LOOIC	77.1
LOOIC s.e.	9.8
WAIC	73.3
RMSE	0.70

showed a slightly negative association, which needs further investigation into the nature of exports and their economic value.

The model demonstrates an excellent fit with an R-squared value of 0.929, indicating that approximately 92.9% of the variance in GDP is explained by the included predictors (See Table 1). The adjusted R-squared, which accounts for the number of predictors in the model, is slightly lower at 0.918, affirming the robustness of the model. The Root Mean Square Error (RMSE) of 117581.47 provides an estimate of the model's prediction error.

Our Inflation model results are summarized in Table 2. The coefficient for `Annual_Change_GDP` is 0.13 with a standard error of 0.12, suggesting a possible positive relationship with inflation, though this effect is not statistically significant since the coefficient is less than twice its standard error. `House_Price_Index` has a coefficient of -0.01 with a standard error of 0.05, indicating a minor and statistically non-significant negative relationship with inflation. `Unemployment_rate` has a coefficient of -0.03 with a standard error of 0.27, indicating a slight negative relationship with inflation, but again this is not statistically significant. All other variables, including `Total_Unique_Persons`, `GDP`, `Revenue`, `Consumption`, and `Exports`, have coefficients of 0.00, which means they have no identified relationship with inflation based on this model.

The Root Mean Square Error (RMSE) of 0.70 is relatively low, suggesting that the model's predictions are, on average, close to the observed values. However, the RMSE must be contextualized within the scale of the inflation rate to assess its practical significance.

6.2 GDP Coefficient Plot Summary:

The plot Figure 10 indicates that none of the predictors show a statistically significant impact on the dependent variable, as the confidence intervals for all coefficients include zero. Notably, `Annual_Change_GDP`, `Unemployment_rate`, and `Inflation_Rate` have the most substantial effects among the predictors, with `Annual_Change_GDP` showing a potentially positive effect and the latter two showing negative effects. The sigma parameter is significantly different from zero, confirming the presence of variability in the model's residuals.

6.3 Inflation Coefficient Plot Summary:

Similar to the first, Figure 11 plot also suggests that none of the variables provide a statistically significant prediction of the dependent variable, given that all confidence intervals encompass zero. The predictors' coefficients are centered even closer to zero compared to the first plot, indicating an even less pronounced effect. `Annual_Change_GDP` has a coefficient that is slightly above zero but still not statistically significant. There is no `Inflation_Rate` variable present in this model, which may suggest a different model focus or specification.

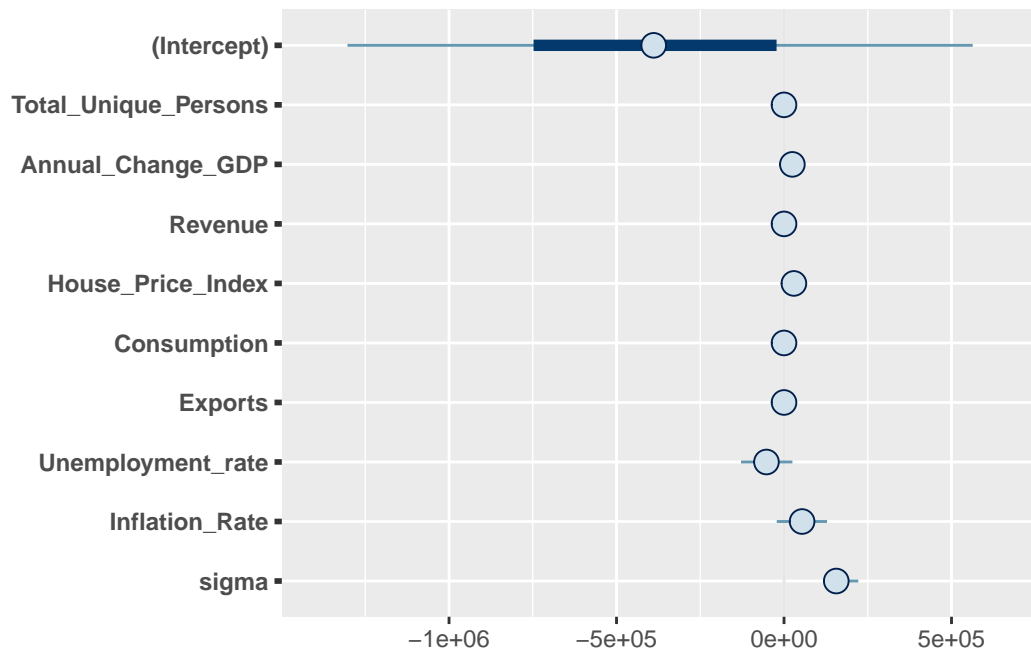


Figure 10: Explanatory models of flight time based on wing width and wing length

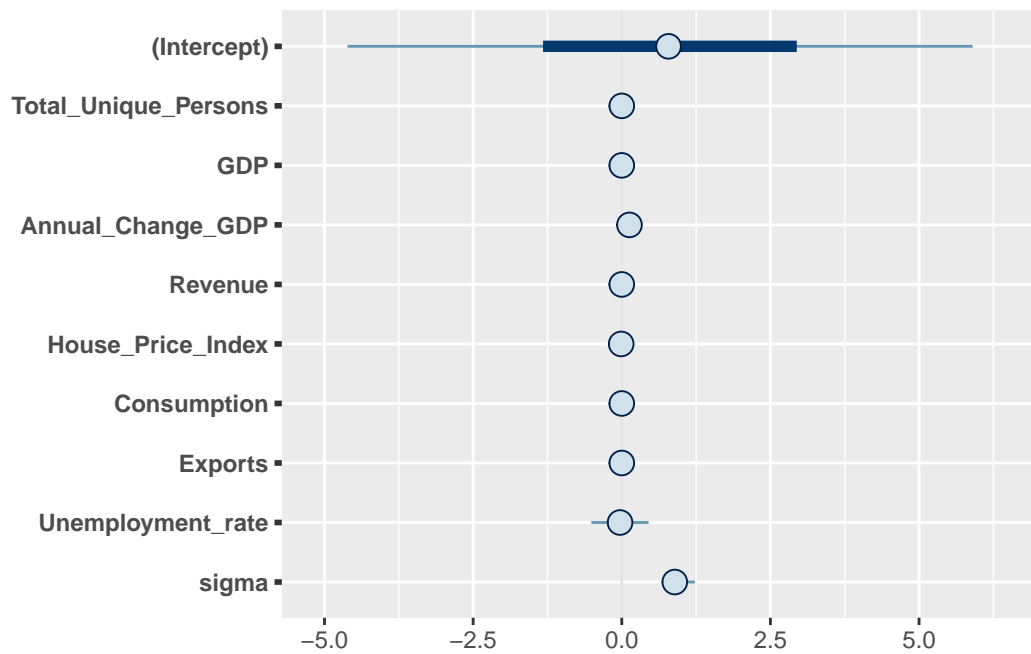


Figure 11: Explanatory models of flight time based on wing width and wing length

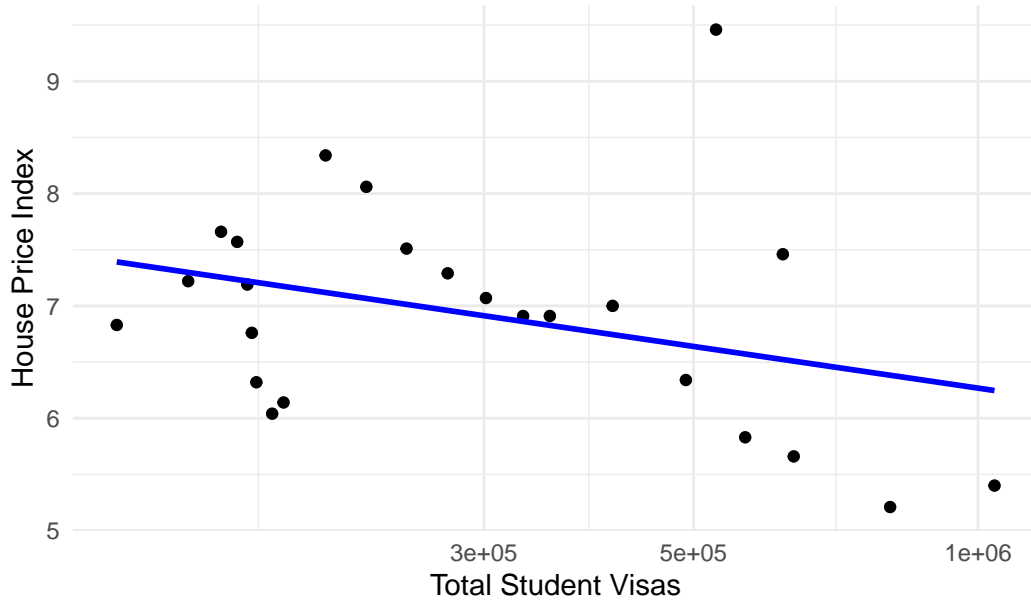


Figure 12: Regression Relation Between House Price Index and Student Population

6.4 Predictions

Using the model we created and trained, we predicted the GDP of Canada for 2024 given the economical constraints of 2024 as seen in Figure 13. The predicted GDP for the given data is: 2.3433652×10^6

As seen, the GDP decreases quite drastically given the number of fewer students entering the country.

It is anticipated that the economy's supply and demand sides will be impacted by population loss. Generally speaking, a decline in population indicates a decrease in the labour supply (since the population is the source of labour) and a decrease in the labour input used in production; on the demand side, it indicates a decrease in the demand for housing, consumption goods and services, and investment because these items are demanded by people. It is anticipated that these adjustments will eventually cause the gross domestic product to decline. (<https://www.nature.com/articles/s41599-023-02223-7>)

The Figure 14 shows the relationship between increasing GDP and house price index of Canada. This shows that as the GDP grows, the house price index of the country also increases as the linear relationship between these variables is very direct. This relationship means that any change in the GDP of the country would have an effect on the housing market as well. As the government places a cap on the student population entering the country and the

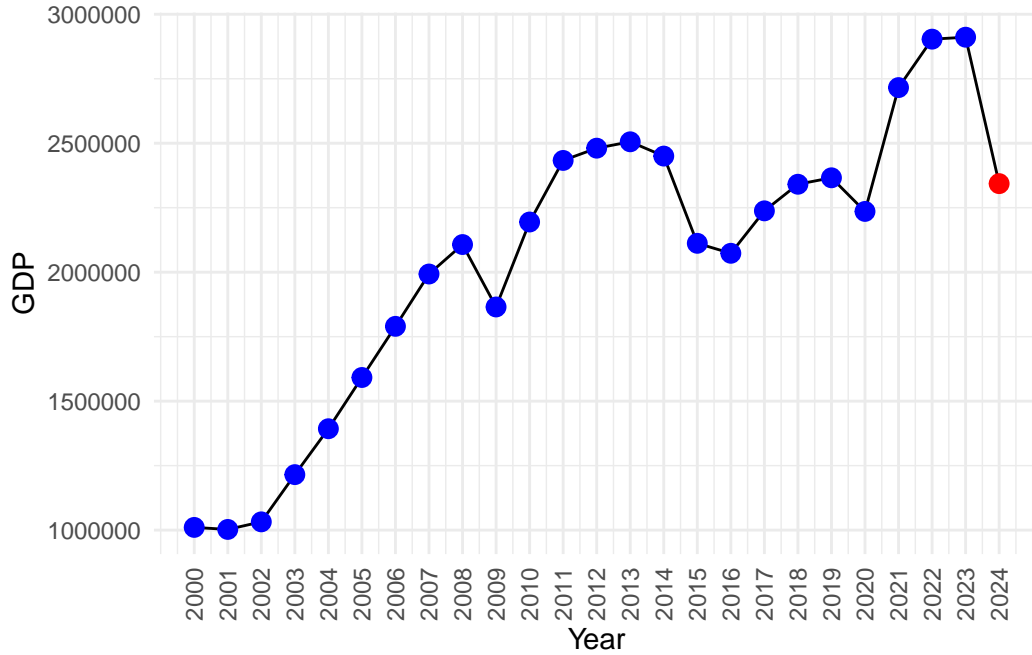


Figure 13: Predicted GDP for the Next Year along with Previous Years' Values

GDP decreases, this entails the house price index to decrease as well. As quoted by ___, “Rising house prices have a positive impact on real GDP through the consumption effect and the construction of new houses (housing investment). Basically, the strength of this positive effect relies on a large share of homeowners (especially regarding the consumption effect).” (<https://typeset.io/papers/search-frictions-housing-prices-and-growth-2w5hf4izya>)

This brings us to the second point about the effect that lower number of homeowners have on the housing market of the country. With the cap induced, there are smaller number of people entering the country and contributing to the GDP of the country. The decline in the GDP contributes to the decline in the housing market prices which makes the house price index decrease as well and this can be seen in Figure 15. As Gerrard Flitti added that population decline would “absolutely” have negative economic impacts in the long term, with labor shortages leading to a decrease in GDP, inflation, and recession. “It just basically sinks the economy for years to come unless there’s a massive increase in productivity,” Filitti said. (<https://www.foxbusiness.com/media/impending-us-population-decline-could-lead-another-depression-more-inflation-experts>)

The other aspect of the economic analysis for this study was the effect on inflation caused by the change in student visa numbers. The Figure 16 shows the predicted inflation rate for 2024 to be 6.1860473. A decreasing population can lead to a shortage of labor, which in turn can drive up wages as employers compete for a smaller pool of workers. Higher wages can lead to higher production costs for goods and services, potentially causing cost-push

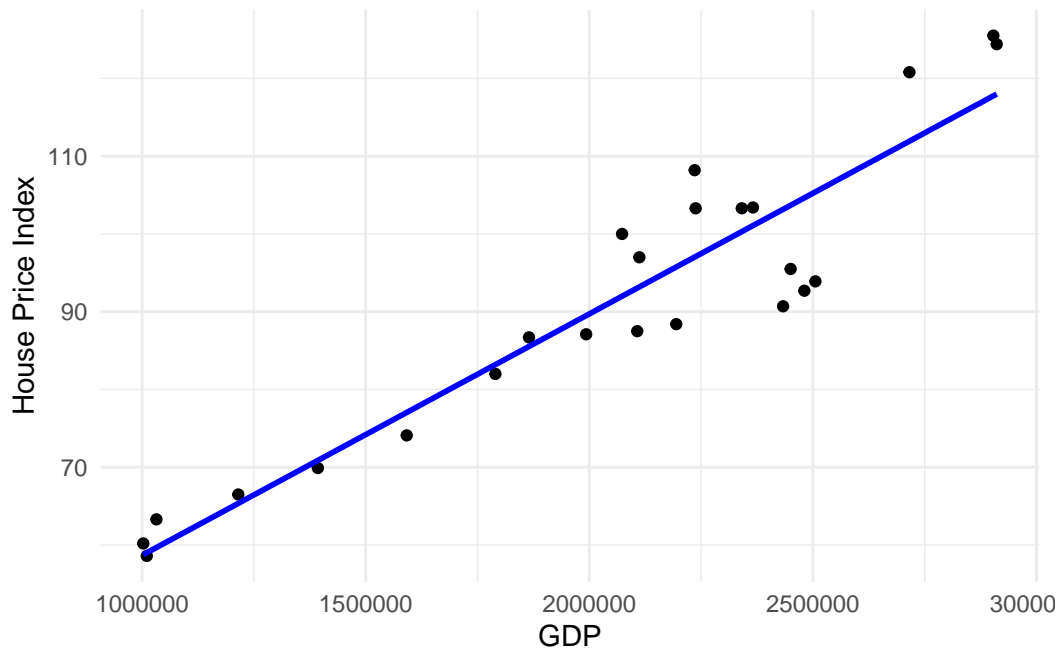


Figure 14: Regression Plot: GDP vs. House Price Index

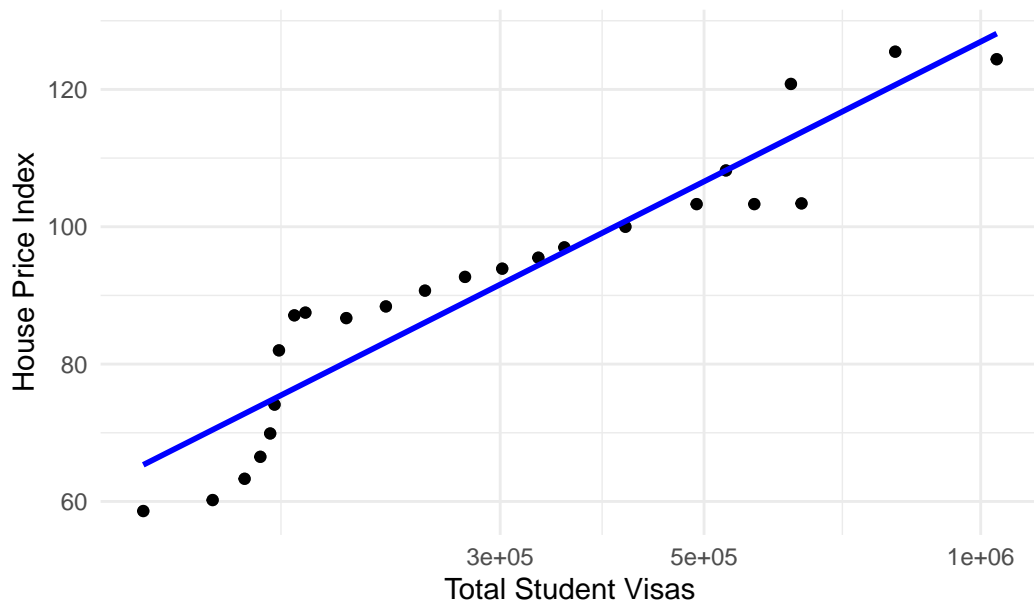


Figure 15: Regression Relation Between House Price Index and Student Population

inflation. This can be used to explain the extremely high inflation for 2024 being predicted. This notation can be seen in other countries like the US. For instance, the Federal Reserve Bank of Atlanta points out that population aging is a significant factor contributing to labor shortages in the United States, which, in turn, has been fueling inflation. Since 2019, there's been a notable increase in the population of those aged 65 and older, while the population of prime-age workers (ages 25 to 54) has barely changed. This demographic shift towards an older population has led to a tighter labor market, as there are fewer younger people entering the workforce to replace retiring workers. Such a scenario can lead to wage inflation as employers compete for a smaller pool of workers, ultimately driving up production costs and contributing to cost-push inflation(<https://www.atlantafed.org/economy-matters/economic-research/2023/01/12/we-re-getting-older-and-the-labor-market-shows-it>). With a decrease of young population entering the labour force of Canada, the country can expect to experience a cost-push inflation.

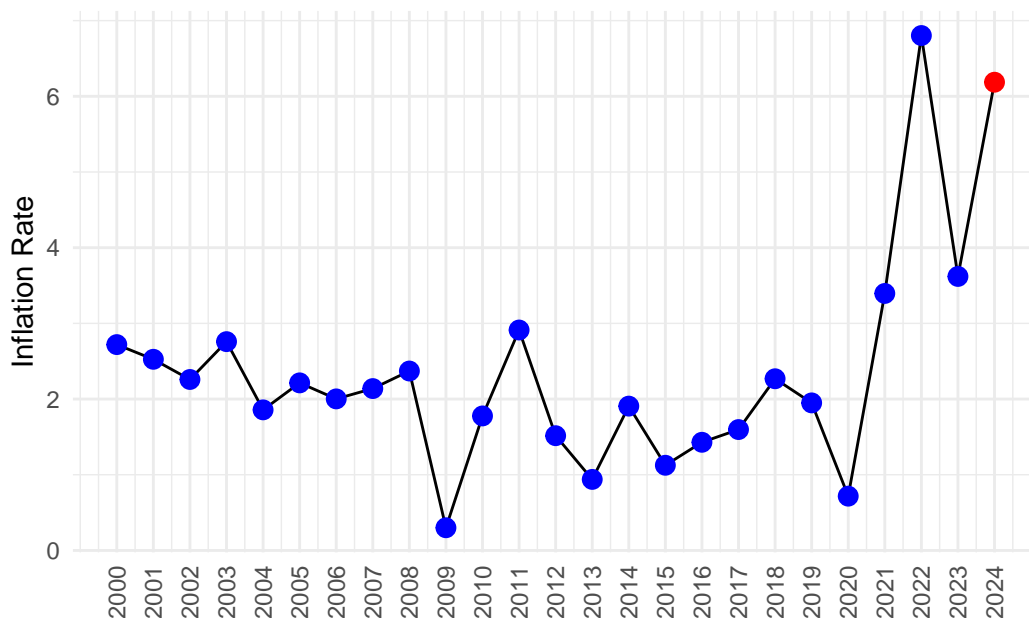


Figure 16: Predicted Inflation Rate for the Next Year along with Previous Years' Values

7 Discussion

7.1 Weaknesses and next steps

The dataset used in this analysis may be subject to various biases, which could affect the validity and generalizability of the findings. There is measurement bias in the dataset from

inaccuracies or inconsistencies in data collection methods, such as self-reporting or sampling errors. The dataset also a collection of different datasets with different units of measurements and converting them into one unit dataset arises measurement bias. Also alot of values of different years were missing for different variables of the dataset that were sourced from other datasets and websites, which creates biases. Furthermore, the analysis process itself is susceptible to weaknesses such as model assumptions, variable selection bias, and overfitting. Model assumptions may not be met by the data, leading to biased estimates or incorrect conclusions. Variable selection bias could influence results depending on which variables are included or excluded from the analysis. Overfitting may occur if complex models fit the training data too closely but generalize poorly to new data. These weaknesses highlight the importance of careful consideration and transparency throughout the research process to mitigate biases and ensure the reliability of the findings.

In future research, it would be beneficial to address several avenues for further exploration and refinement. Firstly, expanding the dataset to include additional relevant variables could enhance the depth of the analysis and provide a better understanding of the factors influencing economic indicators. Additionally, conducting longitudinal studies to track changes over time and incorporating dynamic modeling techniques could offer insights into the evolving nature of economic relationships. Furthermore, considering the impact of external factors such as policy interventions, socio-economic trends, and global events on the studied phenomena could enrich the analysis and provide valuable insights for policymakers and practitioners. Overall, this cap of 360,000 on international students for two years is a big step taken by the governnment and its economic effects need to studied furthur to help decrease possible losses in different sector of the economy.

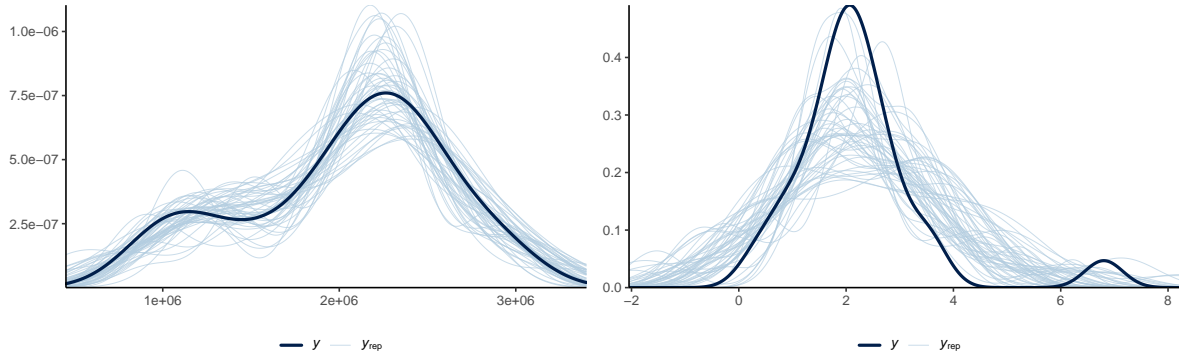
Appendix

A Additional data details

A.1 Posterior predictive check

In Figure 17a we implement a posterior predictive check. This shows the fit between the observed GDP data and the data simulated from the model's posterior distribution. The x-axis likely represents the GDP values, while the y-axis indicates the density of these values within the data. It appears that the model has varying success in capturing the distribution of the observed GDP. The central mass of the predictive simulations (represented by the numerous blue lines) seems to align well with the peak of the observed data (the solid black line), suggesting that the model accurately captures the median of the GDP data.

In Figure 17b we compare the posterior with the prior. This shows the model's predictions are consistent with the observed data. The tail behavior and the central peak of the observed data distribution are captured within the range of the simulations, although there might be some discrepancies at the peak.



(a) Posterior prediction check

(b) Comparing the posterior with the prior

Figure 17: Examining how the model fits, and is affected by, the data

References

- Horst, Allison Marie, Alison Presmanes Hill, and Kristen B Gorman. 2020. *Palmerpenguins: Palmer Archipelago (Antarctica) Penguin Data*. <https://doi.org/10.5281/zenodo.3960218>.
- R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>.
- Wickham, Hadley, Mara Averick, Jennifer Bryan, Winston Chang, Lucy D'Agostino McGowan, Romain François, Garrett Golemund, et al. 2019. “Welcome to the tidyverse.” *Journal of Open Source Software* 4 (43): 1686. <https://doi.org/10.21105/joss.01686>.