

Analyzing the Relationship Between Interest Rates and Economic Growth Across Varying Financial Crises

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GitHub Repository: https://github.com/snazzy77/STAT107_Team-17_Financial-Crisis

Abstract

We will be analyzing the relationship between interest rates and economic growth/indicators across financial crises that occurred in 2001, 2008, and 2020 (the dot-com crisis, the great recession and the COVID-induced recession). We will specifically analyze GDP growth and unemployment during the three major U.S. financial crises and we will determine whether changes in interest rates reveal relationships with GDP growth and unemployment across economic disasters. According to our preliminary analysis, interest rates and GDP growth seem to move in the same direction; however, the strength and significance of this relationship varies across crises. In this project, we analyze the relationship between U.S. interest rates and unemployment during both crisis and non-crisis periods. We aim to determine whether monetary policy reacts more strongly to labor market conditions during recessions.

Introduction

The ultimate goal of this project is to explore how interest rates interact with key economic indicators such as GDP growth and unemployment during varying financial crises. Understanding this relationship will lead to a better comprehension of how monetary policy affects the country's economy, which will benefit economists or politicians who are interested in how the Federal Reserve's actions affect the economy. We will fit separate linear regression models for each recession to test whether interest rates are significant predictors of GDP growth, and then evaluate whether a unified model across all periods can describe the data effectively and accurately.

Data

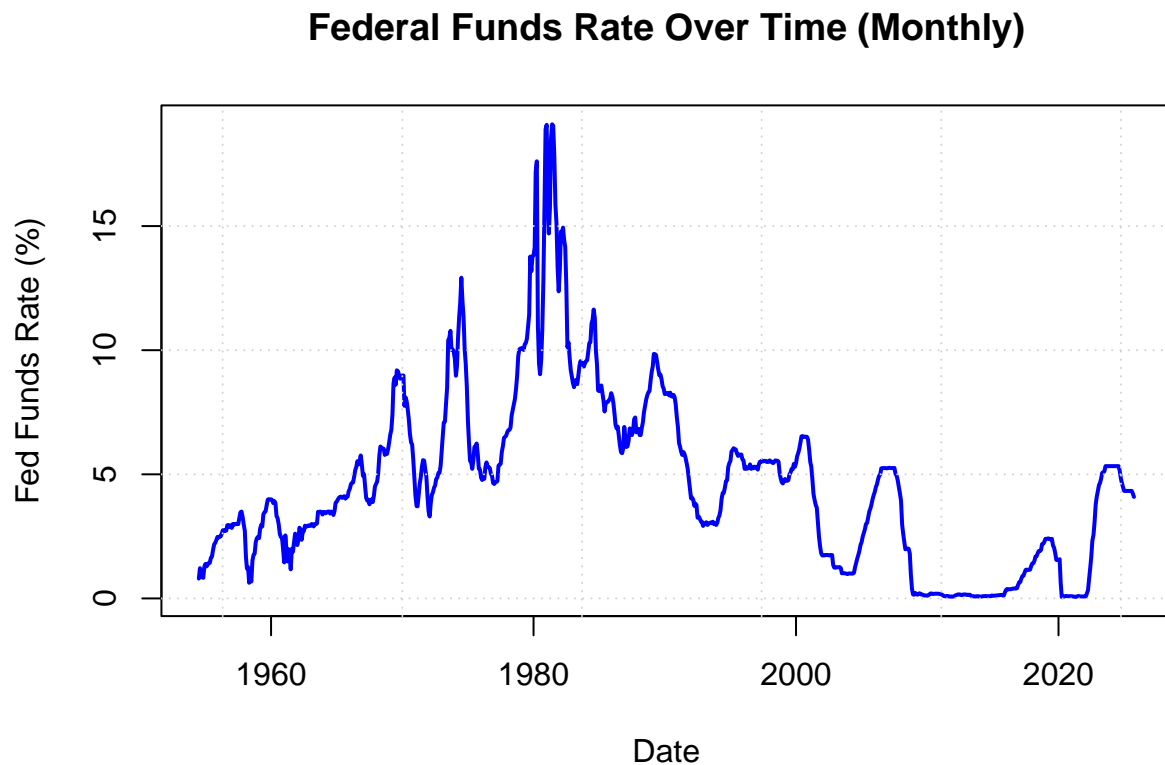
We filtered the dataset to include only complete observations, removed missing values, and ensured both variables were aligned by month and time period. Data was split into crisis vs non-crisis subsets for modeling. Our dataset will be a combination of public economic data from the Federal Reserve Economic Data (FRED) database. Key variables we will utilize include:

- Date
 - Quarter (YYYY-Q)
- Interest_Rate

- – Federal Funds Effective Rate (%)
- GDP_Growth
- – Quarterly GDP growth rate (%)
- Unemployment_Rate
- – Civilian Unemployment Rate (%)

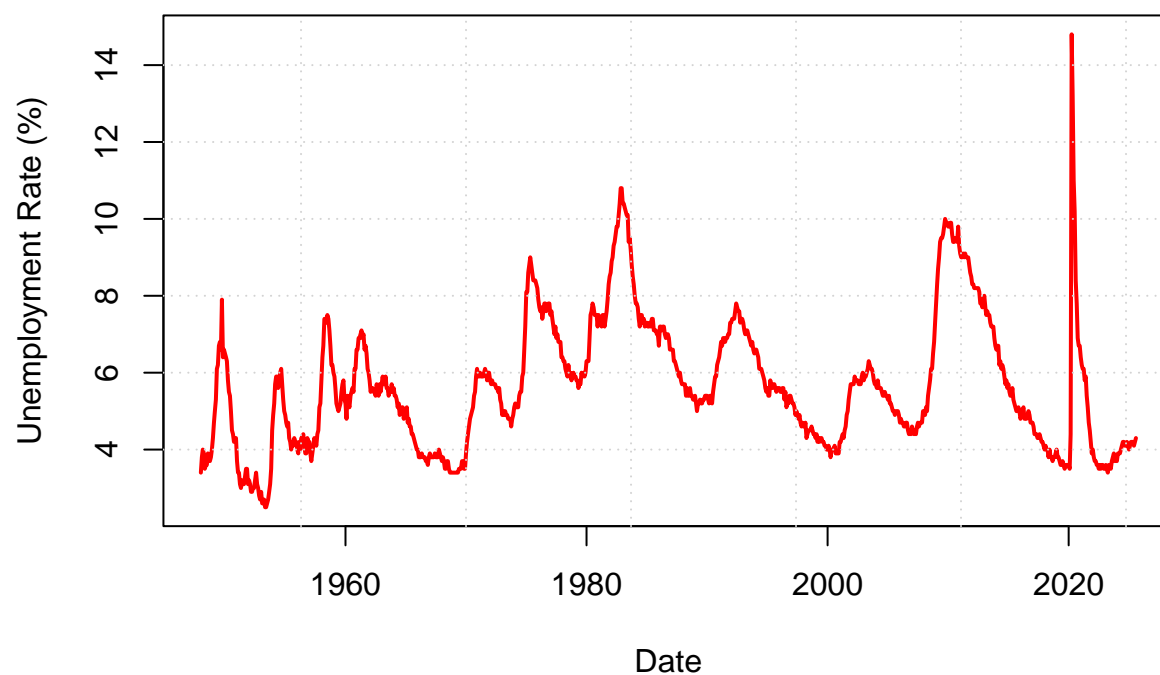
To clean the data we ran a function to convert the observation date to the Date data type using `as.Date()`. We did this for all the data sets. At the same time we also changed the column names to something more appropriate. Lastly we wanted to be able to make better plots with the data so we decided to merge them.

Visualization



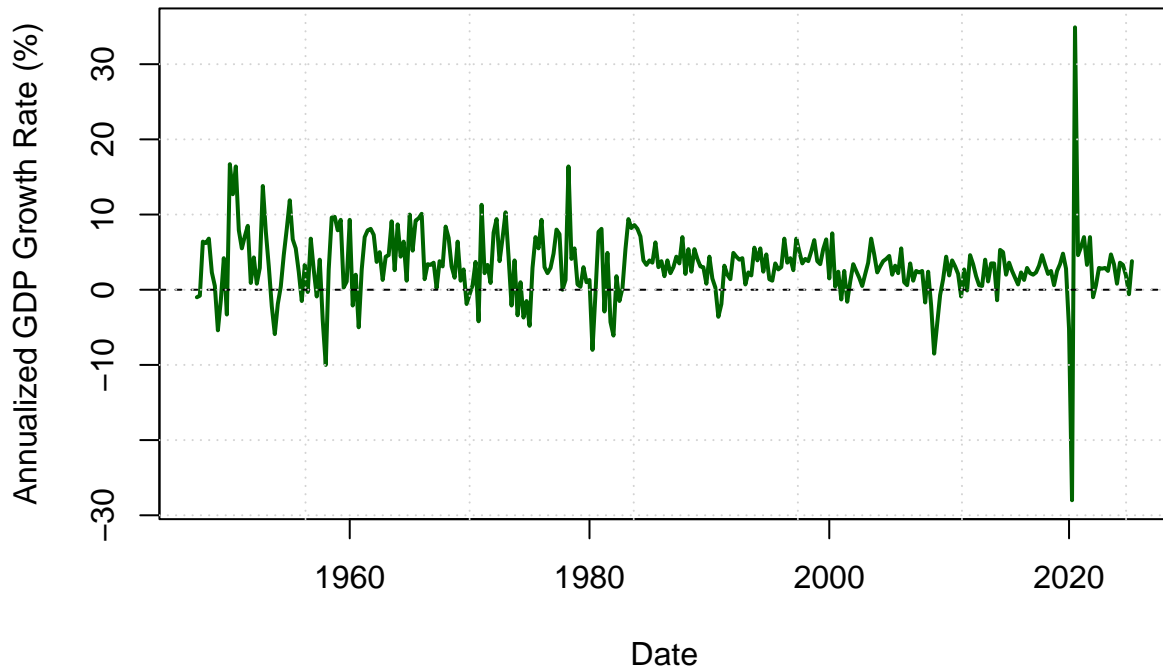
This visualization shows the Federal Fund Rate by month. We can see that the Federal Fund's Rate declines majorly during recessions (2001, 2008, 2020) which reflects the fed attempting to stimulate the economy. They do this by making borrowing rates cheaper, which makes money easier to borrow in order to incentivize the American people to borrow money.

Unemployment Rate Over Time (Monthly)



This plot shows the unemployment rate by month. We can again see that during recession times (2001, 2008, 2020), unemployment skyrockets. We notice that during 2020 especially unemployment reaches an all time high, which is most likely due to the Covid pandemic forcing mass layoffs across the country.

GDP Growth Rate Over Time (Quarterly)

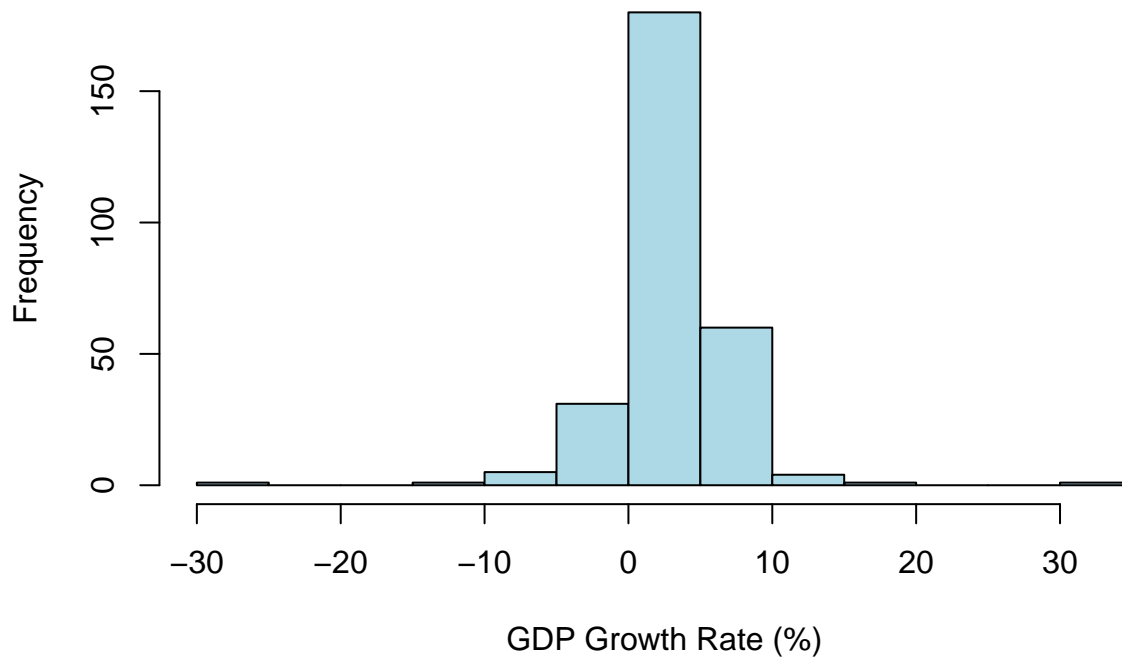


This visualization shows the GDP growth by quarter. We can see that GDP growth falls sharply during major recessions, (2001, 2008, 2020) where an extreme negative shock is followed by a rapid rebound. These downturns align with periods of rising unemployment and declining interest rates, suggesting that GDP growth and monetary policy are closely linked during times of economic downturn.

```
## observation_date    Fed_Funds_Rate    GDP_Growth_Rate    Unemployment_Rate
## Min.      :1954-07-01    Min.      : 0.050    Min.      : -28.000    Min.      : 3.400
## 1st Qu.:1972-03-09    1st Qu.: 1.758    1st Qu.:  1.375    1st Qu.: 4.575
## Median :1989-11-16    Median : 4.275    Median :  3.100    Median : 5.600
## Mean   :1989-11-15    Mean   : 4.605    Mean   :  3.126    Mean   : 5.828
## 3rd Qu.:2007-07-24    3rd Qu.: 6.125    3rd Qu.:  4.800    3rd Qu.: 6.900
## Max.   :2025-04-01    Max.   :19.080    Max.   : 34.900    Max.   :14.800
##      Is_Crisis
## Crisis      : 20
## Non_Crisis:264
##
##
##
##
```

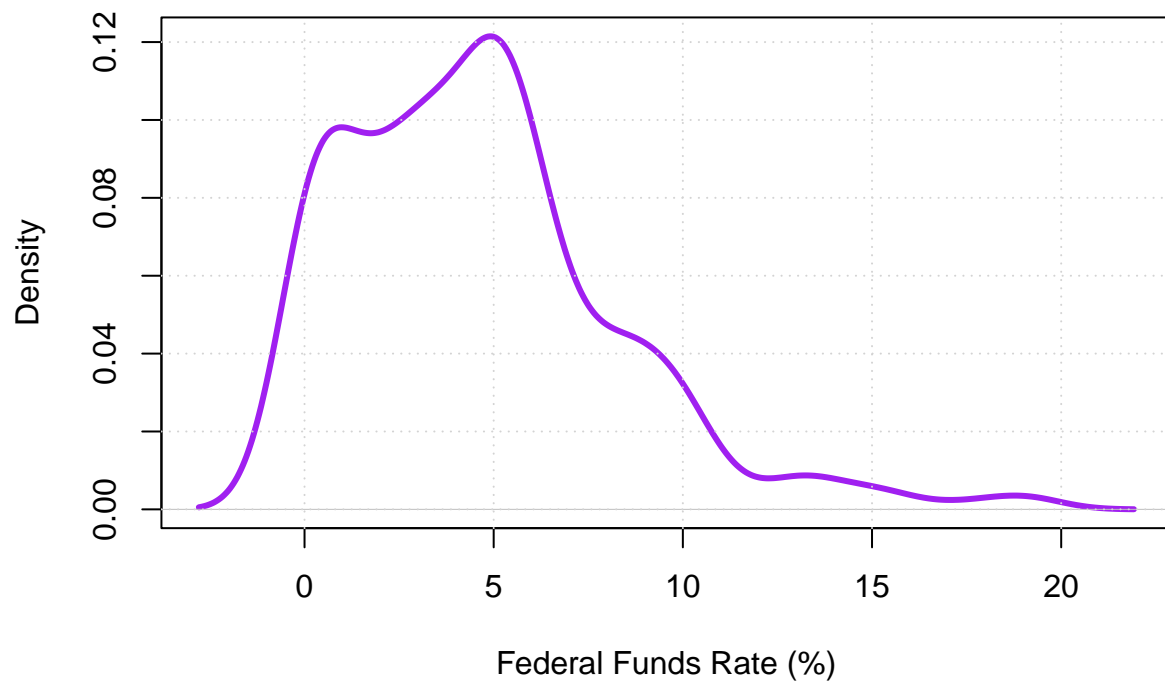
This summary table provides descriptive statistics for all of the variables in the combined dataset, including Federal Funds Rate, GDP Growth Rate, and Unemployment Rate. It shows that GDP growth mostly falls between 0% and 5%, while federal funds rates are generally below 10%.

Histogram of GDP Growth Rate



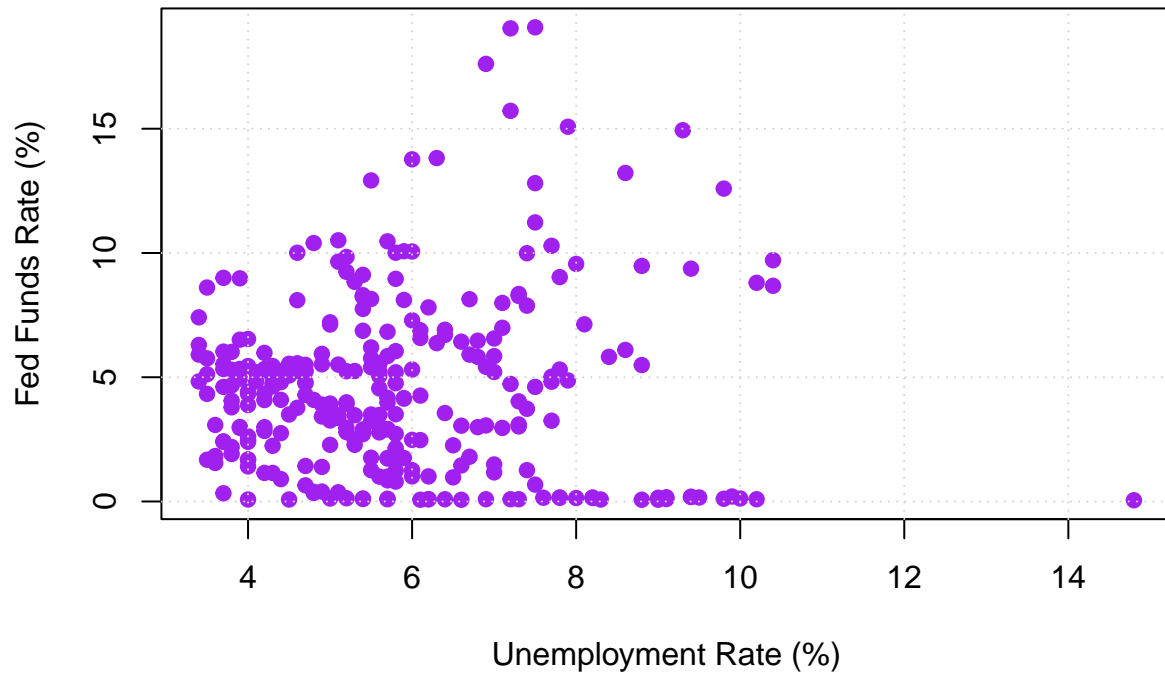
This visualization is a histogram of the GDP growth rate. We can see that most U.S. GDP growth rates fall between 0% and 5%, indicating that the economy typically expands at a modest pace. Occasional negative values represent recession periods where economic output declined. A few extreme highs and lows appear, reflecting rare events such as severe downturns or unusually strong recoveries.

Density Plot of Federal Funds Rate



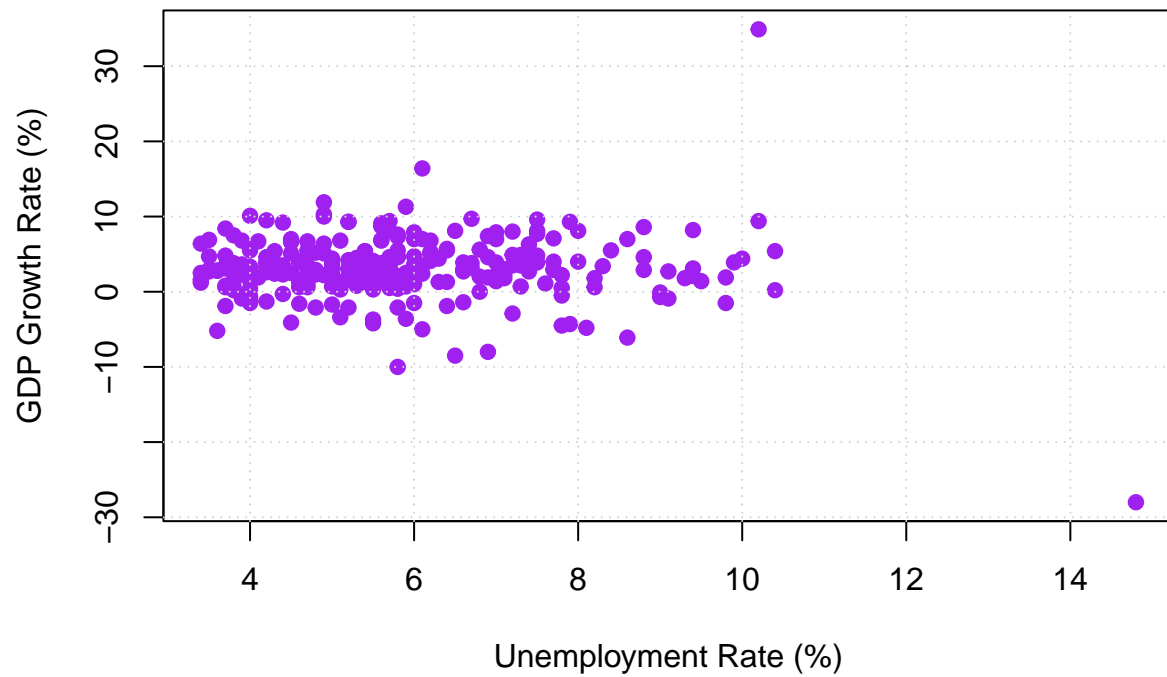
This graph shows a Density plot of federal funds rate. We can see that U.S. federal funds rates most frequently fall in the low-to-moderate range, with the highest concentration around roughly 4–6%. Rates above 10% occur much less often, indicating that very high interest-rate environments are historically rare. Overall, the distribution is right-skewed, meaning low and moderate rates are far more common than extremely high ones.

Federal Funds Rate vs. Unemployment Rate



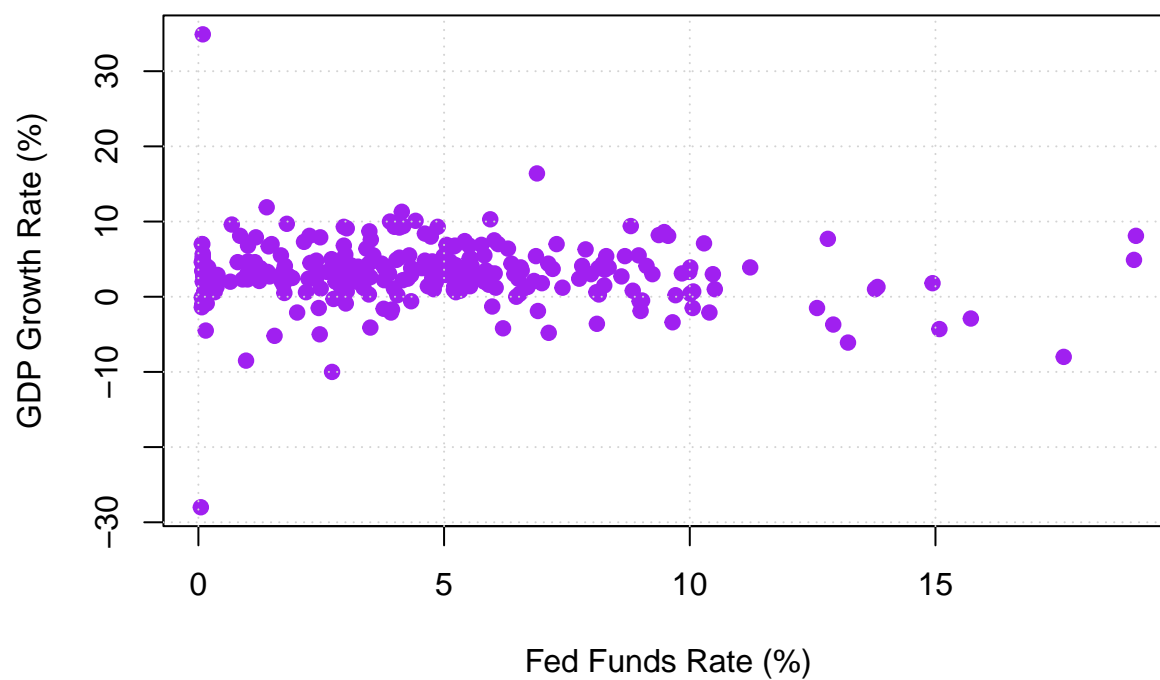
This graph is a scatter plot showing the Federal Funds Rate vs. Unemployment Rate. It shows the relationship between the U.S. federal funds rate and the unemployment rate. There is no strong linear relationship, though higher unemployment rates often coincide with lower federal funds rates, reflecting monetary policy easing during weak labor markets. Overall, most observations cluster around moderate unemployment (4-8%) with fed funds rates below 10%.

GDP Growth Rate vs. Unemployment Rate



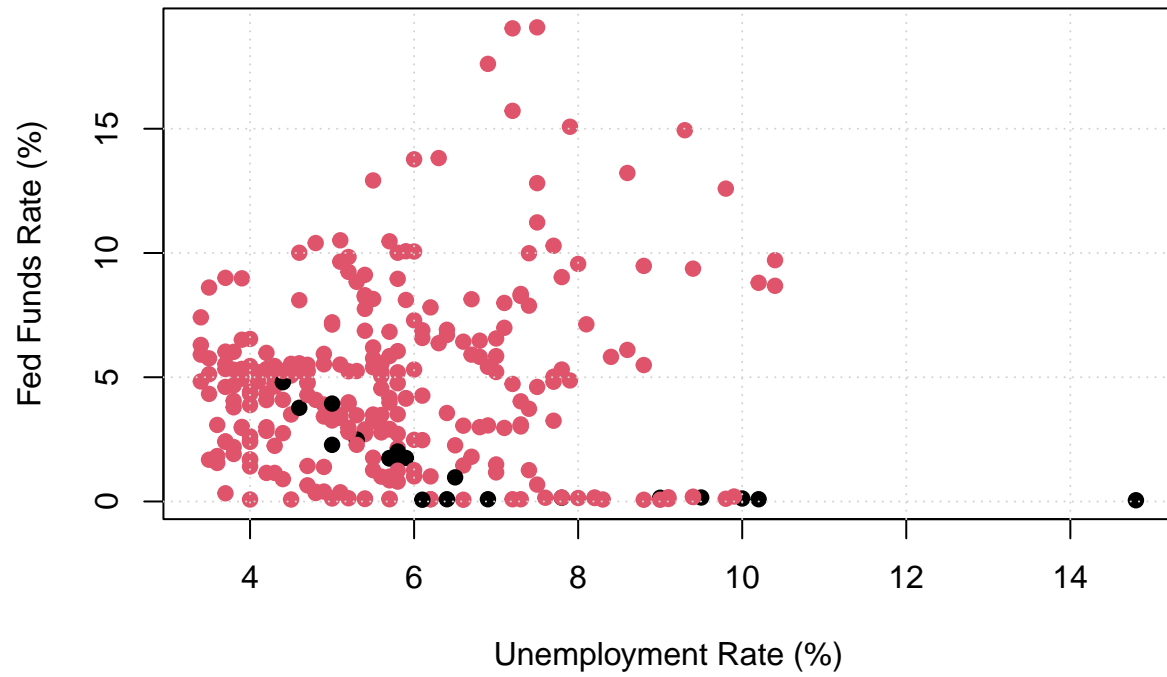
This visualization is a scatterplot of the GDP Growth Rate vs. Unemployment Rate. It shows the relationship between U.S. GDP growth and unemployment rates. There is no clear linear pattern, though higher unemployment generally corresponds to lower or negative GDP growth, consistent with economic downturns. Most observations cluster around moderate unemployment (4–8%) and modest GDP growth (0–5%), with only a few extreme outliers.

GDP Growth Rate vs. Federal Funds Rate



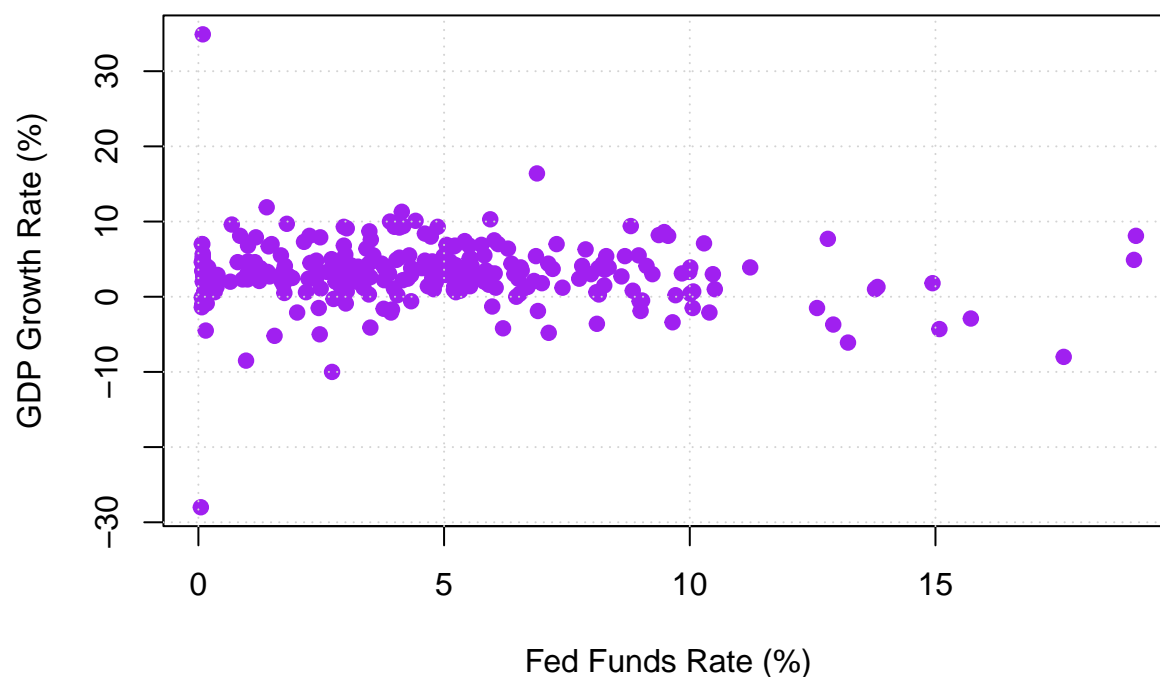
This scatter plot visualizes GDP growth vs. federal funds rate. There is a slight positive trend during non-recession periods, while low rates during recessions correspond to negative GDP growth.

Unemployment vs. Fed Funds Rate (Colored by Crisis)



This scatter plot shows unemployment vs. federal funds rate, with points colored by crisis periods. During recessions, higher unemployment aligns with lower rates, indicating the Fed's economic response.

GDP Growth Rate vs. Federal Funds Rate



Linear Model

```
##
## Pearson's product-moment correlation
##
## data: combined_data$Unemployment_Rate and combined_data$Fed_Funds_Rate
## t = 0.88757, df = 282, p-value = 0.3755
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.06400475 0.16813903
## sample estimates:
##          cor
## 0.05278019

##
## Pearson's product-moment correlation
##
## data: combined_data$GDP_Growth_Rate and combined_data$Fed_Funds_Rate
## t = -1.362, df = 282, p-value = 0.1743
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.19539630 0.03588629
## sample estimates:
##          cor
```

```
## -0.08084313
```

These correlation values indicate the linear relationships between unemployment and federal funds rate (cor_unrate_fedfunds) and GDP growth and federal funds rate (cor_gdp_fedfunds). Essentially, negative correlation for unemployment demonstrates rate cuts during high unemployment, while GDP correlation shows how rates track economic growth.

```
##
## Call:
## lm(formula = Fed_Funds_Rate ~ Unemployment_Rate, data = crisis_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.7011 -0.5219 -0.1386  0.1918  2.3607
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      4.1689      0.7515   5.547 2.89e-05 ***
## Unemployment_Rate -0.3931      0.1009  -3.895  0.00106 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.121 on 18 degrees of freedom
## Multiple R-squared:  0.4573, Adjusted R-squared:  0.4271
## F-statistic: 15.17 on 1 and 18 DF, p-value: 0.001062

##
## Call:
## lm(formula = Fed_Funds_Rate ~ Unemployment_Rate, data = non_crisis_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -6.0871 -2.3152 -0.1307  1.6647 13.7068
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      2.9408      0.8224   3.576 0.000416 ***
## Unemployment_Rate  0.3323      0.1381   2.406 0.016837 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.572 on 262 degrees of freedom
## Multiple R-squared:  0.02161, Adjusted R-squared:  0.01788
## F-statistic: 5.787 on 1 and 262 DF, p-value: 0.01684
```

These linear model summaries show how well federal funds rate predicts GDP growth during crisis (lm_crisis) and non-crisis (lm_non_crisis) periods. Coefficients, standard errors, and p-values are all indicators of whether or not interest rates significantly predict GDP growth as well as if relationships differ by economic conditions.

Analysis

Using U.S. data on interest rates, GDP growth, and unemployment, we began by visually exploring how these variables behaved during the three major recessions of 2001, 2008, and 2020. The density plot of the federal funds rate shows that most rates tend to fall between about 4–6%, while very high rates are rare. The histogram of GDP growth suggests that the U.S. usually experiences modest growth, but growth becomes negative during recession years. When comparing interest rates and unemployment on a scatterplot, we see that periods of higher unemployment typically align with lower interest rates, which is consistent with the Federal Reserve lowering rates to stimulate the economy. The scatterplot of GDP growth and unemployment shows a wide spread of points, meaning higher unemployment does not always correspond directly to lower GDP growth, though extreme unemployment does tend to occur during times of very poor growth.

To quantify these relationships, we calculated Pearson correlations across all periods: Unemployment Rate vs. Fed Funds Rate: correlation = 0.053, p-value = 0.376 This indicates almost no linear association across the data set.

GDP Growth Rate vs. Fed Funds Rate: correlation = -0.081, p-value = 0.174

While just slightly negative, the correlation is weak and not statistically significant.

We then ran separate linear regressions for crisis and non-crisis periods: The R² value for crisis periods was 0.457, meaning that during recessions, higher unemployment reliably predicts lower interest rates. The R² value for non-crisis periods was 0.022, meaning that unemployment explains essentially none of the variability in interest rates.

The results that we got from the regressions confirm what our visualizations suggested: during recessions, monetary policy shows a stronger and more predictable relationship with unemployment, while in non-crisis periods, the connection is weak and inconsistent.

Going forward, we plan to run separate simple linear regression models for each recession to test whether interest rates help predict GDP growth during those periods. This will allow us to see whether the strength of the relationship between the two variables changes across crises. If interest rates are significant predictors, it would support the idea that monetary policy plays an important role during economic downturns. We also plan to examine whether unemployment shows any statistical relationship with interest rates or GDP growth by looking at correlations and summary statistics.

Conclusions

All in all, our research led us to make several conclusions in regards to interest rates, GDP growth, and unemployment: - During recessions, the Federal Reserve lowers interest rates in response to rising unemployment. This relationship is statistically significant and explains a moderate proportion of the variability in rates. - Across all periods, unemployment on its own does not accurately predict interest rates or GDP growth. Economic dynamics in stable periods are influenced by multiple factors aside from just unemployment. - Recessions, specifically the COVID-19 pandemic, introduce extreme values in GDP growth, unemployment, and interest rates. For this reason, it is important to model each economic decline individually rather than using a singular model.

In the future, we may combine the data from all three recessions into a single model and compare it to the individual recession models. If the combined model performs worse, this would confirm that each crisis behaves differently and needs to be studied individually. Overall, our findings suggest that interest rates move in a predictable pattern during economic downturns. However, these relationships are complex and vary depending on the crisis. Therefore, analyzing each recession individually provides a better understanding of the impact of monetary policy on the economy.

Contributions

Gokul Giridharan: Did the Data Filtering and Merging. Worked on coding the Visualizations and Models.

Connor Huang: Found the Datasets. Worked on the Analysis and Conclusion.

Arjun Singh: Worked on the descriptions for the visualizations and the Analysis and Conclusions. Also helped with the coding for the visualizations.