

**Analyzing the United States Federal Reserve’s Dual Mandate – Final Draft**

**DATA 698 Analytics Master’s Research Project**

David Simbandumwe

November 28, 2023

Table of Contents

[Abstract 4](#_Toc151938169)

[Introduction 4](#_Toc151938170)

[Literature Review 6](#_Toc151938171)

[Economic Discomfort Index 6](#_Toc151938172)

[Taylor Rule 7](#_Toc151938173)

[Composition of the Federal Open Market Committee 8](#_Toc151938174)

[Research Question 9](#_Toc151938175)

[Hypothesis 9](#_Toc151938176)

[Methodology 10](#_Toc151938177)

[Dataset 10](#_Toc151938178)

[Models 14](#_Toc151938179)

[Discussion of Results 15](#_Toc151938180)

[Concept 1: Full Model 15](#_Toc151938181)

[Concept 2: Modified Taylor Rule 17](#_Toc151938182)

[Concept 3: Recession Model 21](#_Toc151938183)

[The Composition of the Federal Open Market Committee 23](#_Toc151938184)

[Conclusion 25](#_Toc151938185)

[Appendix A: Model Performance 28](#_Toc151938186)

[Concept 1: Full Model 28](#_Toc151938187)

[Lasso Regression Model 28](#_Toc151938188)

[Concept 2: Modified Taylor Rule 31](#_Toc151938189)

[OLS Regression Model 32](#_Toc151938190)

[Lasso Regression Model 33](#_Toc151938191)

[Concept 3: Recession Model 36](#_Toc151938192)

[OLS Regression Model 37](#_Toc151938193)

[Lasso Regression Model 37](#_Toc151938194)

[Concept 4: Simplified Model 40](#_Toc151938195)

[References 41](#_Toc151938196)

[Figures 44](#_Toc151938197)

# 

# Abstract

The role of a central bank is a balancing act between competing monetary policy objectives. In the United States, the Federal Reserve System articulates this goal as its dual mandate of price stability and full employment. The official stated position of the Federal Reserve is that it weighs both components of the dual mandate equally when it conducts monetary policy. This paper provides insight into the Federal Reserve's deliberation process when setting the target range for the Federal Funds Rate by exploring models based on the concepts behind the Taylor Rule in order to quantify the predictive power of each component of Federal Reserve’s dual mandate.

# Introduction

On December 23, 1913, the United States Congress passed the Federal Reserve Act, establishing the Federal Reserve System, outlining the central bank's structure, and articulating its monetary policy objectives. Section 2A of the Federal Reserve Act states the following:

*The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates.*

(United States Congress, 1913)

These objectives have come to be interpreted as the Federal Reserve's dual mandate of price stability and full employment. Over the Federal Reserve’s 109-year history, the dual mandate has been the source of a healthy debate within academic, industrial, and political circles with differing opinions regarding the role of the central bank and how much emphasis it should place on these competing goals.

In 2012, the Federal Reserve reaffirmed its commitment to its statutory mandate from Congress and a balanced approach to monetary policy based on its dual mandate. The Federal Open Market Committee (FOMC) minutes include the following statement on Longer-Run Goals and Monetary Policy Strategy:

*Monetary policy is the primary determinant of inflation over the longrun it was determined that a long run target for inflation at 2 percent would be consistent with the long run objectives. The employment rate is however determined by the structure and dynamics of the labor markets hence establishing a long term unemployment rate is not appropriate.*

(Federal Open Market Committee, 2012)

In 1970, Arthur Okun succinctly captured the importance of this balancing act by the Federal Reserve in the concept of the Economic Discomfort Index (EDI). The EDI, which is often referred to as the Misery Index, is an economic indicator that seeks to quantify the economic health of the average citizen. The index is the sum of seasonally adjusted unemployment and the annual inflation rate. The EDI postulates that higher unemployment and higher inflation adversely affect the economic health of the average citizen (Cohen, Ferretti, & McIntosh, 2014).

Adding to the complexity of the Federal Reserve’s balancing act is the uneven impacts of unemployment at the margins and price inflation on individual consumption profiles. Unemployment rates and the impact of monetary policy will differ by population segment, while individual consumers will experience inflation rates that can vary substantially from the Consumer Price Index (CPI). In balancing its dual mandate, the Federal Reserve directly affects the well-being of individuals in the economy through the risk of unemployment or degradation of living standards caused by rising prices.

# Literature Review

## Economic Discomfort Index

The formula for the EDI and its historic values are explored in the article *“Economic Discomfort and Consumer Sentiment.”* (Lovell & Tien, 1999). The formula for the EDI is captured in Figure 1.

p\* - annual rate change, CPI

U – unemployment rate

Figure : Economic Discomfort Index Formula

Figure 2 illustrates the EDI over time. It is noteworthy that the two components of the EDI are impacted differently by changes in the Federal Funds Rate. When the Federal Reserve wants to combat inflationary pressure, it will raise the Federal Funds Rate, slowing economic growth, decreasing the inflationary pressures in the economy, and decreasing the demand for labor. When the Federal Reserve wants to reduce the unemployment rate, it will decrease the Federal Funds Rate, stimulating the economy and increasing the labor demand and increasing inflationary pressures in the economy (Board Of Governors Of The Federal Reserve System, 2020).

A graph showing the growth of the stock market

Description automatically generated

Figure : Economic Discomfort Index (EDI)

## Taylor Rule

In a two-part research paper titled ***Is the Fed Following a “Modernized” Version of the Taylor Rule? (Part 1 / Part 2)*** Kliesen (2019a, 2019b) explores the Fed’s decision-making process in the context of the Taylor Rule. From the perspective of the FOMC, a rule-based approach for balancing the competing priorities of inflation and unemployment when setting the short-term interest rates is illustrated in the Taylor Rule. The Taylor Rule is a widely used academic theory for research on monetary policy. The standard formulation (Figure 3) uses a combination of nominal interest rates, the Gross Domestic Product (GDP) gap, and the Inflation Target Gap to determine the federal funds rate (2019a; 2019b).

A black text with a square and a square symbol

Description automatically generated with medium confidence

- is the nominal federal funds rate

r\* - equilibrium real interest rate

π - current rate of inflation

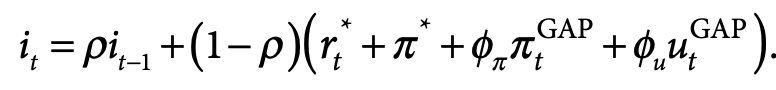
y - real GPB

π \* - Fed’s inflation target

Figure 3: Taylor Rule Formula

(Kliesen, Is the Fed Following a ‘Modernized’ Version of the Taylor Rule? Part 1, 2019)

Kliesen goes on to discuss a modernized version of the Taylor Rule that considers three major developments in monetary policy: (1) the relatively low-interest rate regime that the economy is enjoying; (2) the achievement of stable low inflation rates; and (3) the flattening of the Phillips Curve. Kliesen’s analysis concludes that during the current expansion, the Federal Funds Effective Rate has been lower than what would be predicted by the Taylor Rule. Kliesen proposes that the Fed may be following a variation on the Taylor Rule (Figure 4) to inform its decision-making on monetary policy. (Kliesen, Is the Fed Following a “Modernized” Version of the Taylor Rule? Part 2, 2019)



- nominal federal funds rate

𝘱 - one quarter lag term for the federal funds target rate with a fixed coefficient

- equilibrium real interest rate over time

π \* - Fed’s inflation target

- output inflation gap with a fixed coefficient

- unemployment gap with a fixed coefficient

Figure 4: Modified Taylor Rule

At the time of Kliesen’s publication in 2019, the economy was experiencing historically low interest rates and low levels of inflation. Since early 2021, there has been a reversal as the inflation rate increased and interest rates began to rise. In light of the economic conditions since 2021, it will be interesting to revisit the shape of the Philips Curve and the alignment of the Taylor Rule with the prevailing Federal Funds Effective Rate.

## Composition of the Federal Open Market Committee

The composition of the FOMC has changed overtime. Wilson (2019) analyzed the tenure of Federal Reserve Chairs from William McChesney to Janet L. Yellen using the Unemployment Rate, the EDI, and the Taylor Rule to score the tenures of individual Chairs in terms of the relative importance placed on each component of the dual mandate. Wilson found that the approach to monetary policy has changed over time. Furthermore, he found the Yellen-led Federal Reserve to be the most dovish in history regarding short-term interest rates relative to inflation. Wilson was not able to conclude if behavioral changes are a function of changing macroeconomic dynamics or changes in how the decision-making members view the role of the Federal Reserve as a whole.

# Research Question

This analysis does not evaluate the relative merits of the dual mandate but focuses instead on how the Federal Reserve balances the dual mandate when setting monetary policy. I measure the relative importance of full employment and price stability in the Federal Reserve’s decision-making process, using regression to evaluate the relative strength of the relationship between the federal funds rate, inflation, and unemployment.

To comprehensively analyze the Federal Reserve's decision-making process, I explore the impacts of economic stress and the composition of the open market committee on its decision-making. The periods of economic stress include the stagflation era of the 1970s, the financial crisis of 2007, and the 2020 pandemic economy. During these times, the Federal Reserve took extraordinary measures to safeguard the economic system. To simplify the analysis, I used the Federal Reserve Chair as a proxy for FOMC composition. In future studies, it would be interesting to analyze each member of FOMC, but that is beyond the scope of this paper.

# Hypothesis

The analysis focus on the inputs and outputs of the FOMC's monetary policy decision-making process. Specifically, on the economic indicators for inflation and unemployment as inputs to the FOMC decision. The output of the deliberations is the Federal Funds Effective Rate. Each decision by the FOMC is aligned with economic indicators that reflect one aspect of the dual mandate. Regression analysis quantifies the relative impact of inflation and unemployment on the Federal Funds Effective Rate. Regression models built to predict the actions of the FOMC based on the level of inflation or the unemployment rate. The accuracy and performance of the individual models reflect the weight that the FOMC assigns to the individual components of the dual mandate.

This research question is broken down into the following hypotheses:

* H0 - The Federal Reserve applies equal weights to inflation and employment targets when determining its monetary policy.
* H1 - The Federal Reserve emphasizes its inflation targets when determining monetary policy.
* H2 - The Federal Reserve emphasizes the employment rate when determining monetary policy.

# Methodology

## Dataset

The FOMC meets eight times a year. The output of the FOMC meetings includes meeting minutes and a target range for the Federal Funds Effective Rate with an upper and lower bound. The Federal Reserve uses open market operation to influence the Federal Funds Rate to achieve the target range identified during the FOMC meeting. The analysis uses the monthly Federal Funds Effective Rate (FEDFUNDS) as the target variable for the regression models (Board of Governors of the Federal Reserve System (US), 2023).

There are numerous sources for Federal Reserve-related data. I leveraged the time series data from the Federal Reserve Economic Data (FRED) project for this analysis. FRED is a project by the Economic Research Department of the Federal Reserve Bank of St Louis. It is a comprehensive collection of U.S. and international economic time series data. Figure 5 captures an example of the time series data available from FRED. The Federal Funds Effective Rate from the previous period (FEDFUNDS-1) is calculated as the time shifted value of the previous periods Federal Funds Effective Rate.

A graph showing the value of a federal fund

Description automatically generated

Figure : Federal Funds Effective Rate Timeseries

The real interest rate or R\* is the interest rate that is expected to prevail when the economic output is at its full sustainable level. For this analysis, I selected the Holston, Laubach, and Williams estimate (Measuring the Natural Rate of Interest, 2017). The real interest rate time series is presented in figure 6.

A graph showing a line graph

Description automatically generated with medium confidence

Figure : Real Rate of Interest

Full employment is characterized as the economy's unemployment rate aligning with the natural rate of unemployment, which is often estimated to be around 5%. The U-3 measure of labor underutilization, as calculated by the U.S. Bureau of Labor Statistics (UNRATE), is used as the measure of unemployment in this analysis. I will note that some academics take issue with this measure of unemployment because it undercounts the true unemployment rate by omitting discouraged workers and underemployed workers(U.S. Bureau of Labor Statistics, 2023). The Modified Taylor Rule uses the gap between the unemployment rate when the economy is at full employment and the observed unemployment rate. Figure 7 below captures the federal unemployment rate and the unemployment rate gap as a time series.

A graph showing a line of a graph

Description automatically generated with medium confidence

Figure : Gap Unemployment Rate Timeseries

The Taylor Rule uses the GDP Gap to measure full employment indirectly. The GDP Gap measures current economic activity versus potential economic activity—the difference representing economic slack or excess capacity that can be applied to sustained economic growth. Figure 8 below depicts the GDP Deflator and the calculated GDP Gap.

A graph showing the growth of economic indicators

Description automatically generated

Figure : GDP Gap Timeseries

The measure of price stability used in this analysis is based on the change from 1 year ago of the Consumer Price Index for All Urban Consumers: All Items in U.S. City Average (CPIAUCSL) or (CPIAUCSL\_PC1).

A graph showing a line graph

Description automatically generated

Figure : Consumer Price Index (CPIAUCSL\_CH1) Timeseries

The recession timeframes (Figure 10) use the business cycle turning points determined by the National Bureau of Economic Research (NBER). The business cycle time series is available on FRED for download.

A graph showing a line of a graph

Description automatically generated with medium confidence

Figure : Recession Time Series

For this analysis, I use the Fed Chair as a proxy for the FOMC composition (Figure 11). In future papers, it might be worthwhile to explore the individual members of FOMC and how their composition has changed over time (Federal Reserve, 2023).

A graph showing the value of a stock market

Description automatically generated

Figure : Fed Chair Overtime

The timeseries datasets for this analysis was constructed using a combination of FRED API calls and downloaded csv files from <https://fred.stlouisfed.org>.

## Models

The relationship between inflation, unemployment, and the Federal Funds Effective Rate can be explored by comparing the performance of models based on the concepts behind the Taylor Rule. I constructed regression models to predict the Federal Funds Effective Rate as the response variable using the same predictor variable from the Taylor Rule and the Modified Taylor Rule. The performance of the models was measured using the Adj-R2 evaluation metrics. The relative model performance and the analysis of the coefficients assigned to predictor variables indicate each economic measure's impact on the FOMC's decision-making process.

For this analysis, I selected the following linear regression models and decision tree models:

* Ordinary Least Squares (OLS) model from statsmodels
* Generalized Linear Model (GLM) from statsmodels
* Lasso regularization model from scikit learn
* LGBM Regression model from LightGBM
* XGBoost Regression model from dmlc XGBoost
* AdaBoost Regression model form scikit learn

# Discussion of Results

### Concept 1: Full Model

The literature regarding the Federal Reserve dual mandate includes numerous options for predictor variables. I explored the Taylor Rule and its derivations in this paper; however, many other models exist, including the Balanced-Approach Rule, the ELB-Adjusted Rule, and the First-Difference Rule. These rules uniformly include concepts of inflation, interest rates, employment, historic federal funds rate rates, or GDP levels.

As a starting point I selected:

* Federal Funds Effective Rate from the previous period (FEDFUNDS-1)
* Inflation Gap (gap\_inf) as the PCEPILFE\_CH1 – Target Inflation rate. (Target Inflation is 2% for the purpose of this analysis)
* GDP Gap (gap\_gdp) as percentage difference between GDP and Potential GDP (GDPC1 – GDPPOT) / GDPPOT.
* Unemployment Gap (gap\_ue) as the difference between full employment and current unemployment rate. (Full Employment is 5% for the purpose for this analysis)
* Recession Flag (recession\_flag)
* Real Interest Rate (Real\_Interest\_Rate)

The Lasso Model with regularized coefficients generates Figure 12. The most important feature for predicting Federal Funds Effective Rate is the t-1 Federal Funds Effective Rate (t-1) from the previous period. The next most impactful feature is the recession flag, followed by the Gap in GDP. One interesting thing to note is that the Taylor Rule uses the GDP Gap and Inflation Gap while the Modified Taylor Rule uses the Inflation Gap and the Unemployment Gap. This generates slightly different coefficients; however, the models generated by the Modified Taylor Rule are better suited for our analysis since they include the Unemployment Gap directly.

A graph with blue squares

Description automatically generated

Figure : Feature Importance - Lasso Model

The regularization process shrinks the Real-Interest Rate, Unemployment Rate, and CPI coefficients to near zero. The remaining features are used as a starting point for the initial models. Concept 1 is the Full Model that includes all features identified during the feature selection process. This translates to all features with a non-zero coefficient after the regularization process of the Lasso model fit. The resulting model includes the following features:

* Federal Funds Effective Rate Previous Period
* GDP Gap
* Inflation Gap
* Unemployment Gap
* Recession Flag

With an Adj-R2 of 0.8863 for the test data the Lasso Regression model is the only model tested that outperforms the Naïve model on the testing dataset. The complete diagram of model performance and exploration of model assumptions can be found in Appendix A.

Fitting the model with an alpha of 0.0011, results in the coefficients highlighted in the figure below. There are a few interesting outcomes to note from this model. First, the coefficient associated with the Federal Funds Effective Rate (t-1) is the largest in the model. This level of importance is consistent with the modified Taylor Rule that uses a 𝘱 = 0.85 as the coefficient for the Federal Funds Effective Rate (t-1). The terms associated with the Federal Reserve's dual mandate, GPP Gap, unemployment, and inflation have relatively smaller coefficients in the model (less than 0.2)

A graph of a graph

Description automatically generated with medium confidence

Figure 13: Concept 1 - Lasso Model Coefficients Graph

A screenshot of a computer code

Description automatically generated

Figure 14: Concept 1 - Lasso Model Coefficients

This model is consistent with the Federal Reserve's incremental approach to interest rate adjustments. Ben Bernanke summed up this approach in a 2004 speech on gradualism. "As a general rule, the Federal Reserve tends to adjust interest rates incrementally, in a series of small or moderate steps in the same direction" (Bernanke, 2004).

### Concept 2: Modified Taylor Rule

The Taylor Rule is the best-known formula that prescribes how policymakers should adjust short-term interest rates in response to economic variables (Policy Rules and How Policymakers Use Them, 2018). The Taylor Rule uses deviations from inflation targets and potential economic output to prescribe the target Federal Funds Effective Rate. The most significant difference between the Taylor Rule and the modified Taylor Rule is the existence of the auto regression term for the previous periods. The Federal Funds Effective Rate (t-1) from the last period, when coupled with the þ coefficient of 0.85, significantly improves the Modified Taylor rule's predictive power.

As can be observed from Figure 13 the Modified Taylor Rule (ffef\_tr2) as a model has more predictive power than the Original Taylor Rule (ffef\_tr1). This finding aligns with the conclusions presented by Kliensen (2019b).

A graph showing the value of a stock market

Description automatically generated

Figure : Taylor Rule vs Federal Funds Effective Rate

The table in Figure 16 summarizes the model performance of the Taylor Rule, the Modified Taylor Rule and the naïve Model.

A screenshot of a table

Description automatically generated

Figure : Model Performance Taylor Rule, Modified Taylor Rule and Naive Model

Using the formula in Figure 17 as a starting point, I can generate a feature list for this concept.

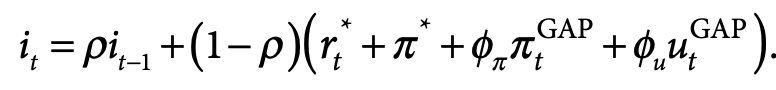


Figure 17: Modified Taylor Rule Formula

* - is the nominal federal funds rate or the Federal Funds Effective Rate. This is the response variable in the models.
* 𝘱 – is the one quarter lag term for the federal funds target rate with a fixed coefficient or the Federal Funds Effective Rate (t-1)
* - is the equilibrium real interest rate over time. Taylor suggested that the equilibrium real interest rate should be invariant at 2.0% however overtime policy makes have adopted equilibrium real interest rate that varies overtime (Kliesen, Is the Fed Following a ‘Modernized’ Version of the Taylor Rule? Part 1, 2019). For this analysis I use the equilibrium real interest rate calculated by the Federal Reserve Bank of New York (Federal Reserve Bank of New York, n.d.)
* π \* - Fed’s inflation target. This is set to 2.0% (Ferguson & Lahiri, 2023)
* – is the output inflation gap with a fixed coefficient. GDP Gap (gap\_gdp) is calculated as percentage difference between GDP and Potential GDP (GDPC1 – GDPPOT) / GDPPOT.
* - is the unemployment gap with a fixed coefficient. For this analysis I use the difference between full employment and current unemployment rate. (Full Employment is set at 5% for the purpose for this analysis)

The regression analysis explores alternate coefficients for the Federal Funds Effective Rate (t-1), the Inflation Gap, and the Unemployment Gap. The relative size of these coefficients in the fitted models provide insight into the FOMC’s decision-making process. The regression models uses the following variables:

* FEDFUNDS – is the Federal Funds Effective Rate in the () in Modified Taylor Rule
* FEDFUNDS-1 – is the Federal Funds Effective Rate from the previous period
* Real\_Interest\_Rate – is the equilibrium real interest rate over time ( in the Modified Taylor Rule
* gap\_inf – is the inflation gap in the current period
* gap\_ue – is the unemployment gap in the current period ()
* Constants – The Fed’s inflation target is a constant so it is omitted from the predictor variables
* Coefficients – The model coefficients provide estimates for 𝘱, and

The only models that outperformed the naïve model are that OLS Linear Regression Model and the Lasso Linear Regression Model. The OLS model has an Adj-R2 of 0.9227 for the test data set which is well about the Adj-R2 for the Naïve model at 0.8830. However, when reviewing the model summary for the linear model the intercept, the coefficient for the Unemployment Gap and the coefficient for the Real Interest rate were not statistically significant. A detailed review of the model summary is captured in Appendix A.

The Lasso Linear Regression model had a slightly lower Adj-R2 at 0.9226. However, it was higher than the naïve model. Interestingly, the Federal Funds Effective Rate (t-1) has the highest coefficient by a factor of 10, and the Inflation Gap has a coefficient roughly two times the size of the coefficient for the Unemployment Gap

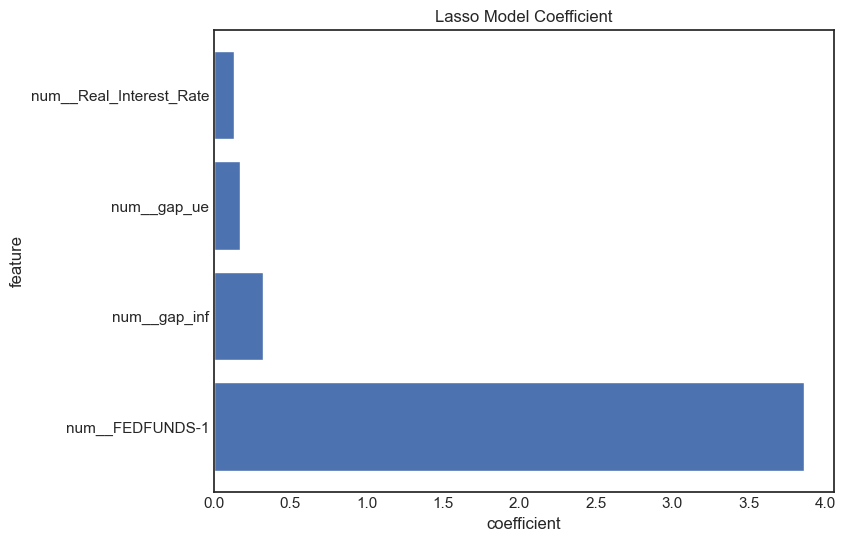


Figure 18: Concept 2 - Lasso Model Coefficients Graph

The SHAP summary plot below highlights the impact of each variable on the Effective Federal Funds Rate.

A graph with different colored dots

Description automatically generated

Figure 19: Concept 2 Feature SHAP Summary Plot

The Lasso Model based on the Modified Taylor Rule supports the theory that FOMC focus more on the inflation component of the Federal Reserve’s dual mandate.

### Concept 3: Recession Model

The Recession Model starts with the concepts of the Modified Taylor Rule and then adds a recession flag. This model includes all four features used as variables in the Modified Taylor Rule and adds a boolean variable for an economic downturn or recession:

* Federal Funds Effective Rate Previous Period
* Inflation Gap
* Unemployment Gap
* Real Interest Rate
* Recession Flag

The only models outperforming the Naïve models were the OLS Linear Regression Model and the Lasso Linear Regression model. The Adj-R2 for the two models are 0.8981 and 0.8996, respectively. A detailed review of the summary of the two models, including the model assumptions, is captured in Appendix A.

Although the OLS model had a relatively high Adj-R2 compared to the other models in this analysis, the model summary indicates that the Real Interest Rate predictor variable coefficient is not statistically significant.

The Lasso Linear Regression model had the highest Adj-R2 of the models included in this analysis. Adding the recession flag to the model increases the importance of the Federal Funds Effective Rate (t-1) relative to the Inflation Gap and the Unemployment Gap. Also, interesting to note, is that the relative size of the coefficients for the Inflation Gap and the Unemployment Gap is smaller when the recession flag is included in the model. And finally, the coefficient for the Real Interest Rate is shrunk to 0.0380.

A graph with blue squares

Description automatically generated

Figure 20: Concept 3 - Lasso Model Coefficients Graph

This model reinforces the theory that the Federal Reserve emphasizes the target inflation rate and price stability.

### The Composition of the Federal Open Market Committee

The FOMC composition analysis focuses on the Fed Chair but could be extended to include another member of the FOMC in the future. Figure 16 depicts the Effective Federal Funds Rate, plotted against the Economic Discomfort Index, and aligned to the tenure of the Fed Chair.

A graph showing the value of a stock market

Description automatically generated

Figure : Economic Discomfort Index vs. Federal Funds Effective Rate

There is a stark contrast between the tenures of Volker, Miller, Powell, and Yellen. It is interesting to note the peaks in the EDI during the tenure of Burns and Powel. The unemployment rates between the tenure of Yellen (5.06), Greenspan (5.53), and Miller (5.89) are not too dissimilar; however, all three faced very different inflation rates and Effective Federal Funds Rates.

A screenshot of a graph

Description automatically generated

Figure 22: Economic Indicators by Fed Chair

It is worth considering the EDI in the abstract. The formulation of the EDI is simplistic in nature and includes assumptions regarding the marginal rate of substitution between unemployment and the impacts of inflation. It assumes that individuals would be willing to trade off 1.0% point of inflation for 1.0% percentage point of unemployment.

The EDI provides a simple trade-off function between inflation and unemployment. However, does this formulation also transfer to the FOMC deliberations? Figure 16 graphs the EDI against Federal Funds Effective Rate. The regression analysis in this paper explores the linkages between economic indicators and the Federal Reserve's decision-making process.

When I apply Lasso regularization to the model that includes Federal Reserve Chairs, the Lasso Model shrinks the dummy variables associated with each Chair to 0 except for Volcker, which has a positive coefficient of 0.0725.

A graph with blue squares

Description automatically generated

Figure 23: Fed Chair - Lasso Model Coefficients Graph

The shape value impact for XGB Regression Model includes feature importance for Burns and Volker and very slight feature impacts for Greenspan, Bernanke, and Miller.

A graph with blue and red dots

Description automatically generated

Figure 24: Fed Chair Feature SHAP Summary Plot

From the analysis, it is unclear that the Federal Reserve Chair significantly impacts FOMC's decision-making. This analysis does not support Wilson’s (2019) conclusions. Wilson's paper is based on the Original Taylor Rule; further exploration of his conclusion using the Modified Taylor Rule would be beneficial.

The Federal Reserve (the Fed) has a unique configuration among modern central banks. It includes both public and private organizations in a distributed monetary control system (Journal of Regulation, 2023).

# Conclusion

The results were surprising; I expected better performance from the boosted decision tree models. The decision tree models posted good Adj-R2 scores for the in-sample data set, but the individual model accuracy dropped off significantly when predicting out-of-sample data. This is in stark contrast to the Lasso models that performed well across the different model concepts.

One of the challenges with modeling the FOMC's decision-making using historical data is the unprecedented nature of the Federal Reserve's Monitory Policy over the past 16 years. The Federal Reserve pursued a zero-interest rate policy from the end of 2008 through October 2014. The models based on the Modified Taylor rule performed better than those using the Original Taylor Rule; however, as a class, the decision tree models underperformed when predicting against the test data set. The Lasso model proved resilient and outperformed the naïve model on three of the four variable formulation concepts analyzed here. I use the naïve model as the hurdle rate for this analysis. If the model in question cannot perform better than a t-1 model of the Federal Funds Effective Rate, then I am dropping the model from the analysis. The resulting hurdle rate and model assumptions filter out all models except for the Lasso model.

Figure 17 below highlights the performance of each model and the associated coefficients for the Inflation Gap and the Unemployment Gap. The coefficients are for normalized predictor variables with a mean of 0 and a standard deviation of 1, which have the same scale and thus can be compared directly.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Concept | Description | Adjusted R-Squared | Dual Mandate | Coefficient |
| Concept 1: Full Model | | | | |
| Lasso | * FEDFUNDS-1 * gap\_inf * gap\_ue * gap\_gdp * recession\_flag | 0.8842 | gap\_ue | - 0.2860 |
| gap\_inf | 0.3332 |
| Concept 2: Modified Taylor Rule | | | | |
| Lasso | * FEDFUNDS-1 * gap\_inf * gap\_ue * gap\_gdp * Real\_Interest\_Rate | 0.9226 | gap\_ue | - 0.1688 |
| gap\_inf | 0.3222 |
| Concept 3: Recession Model | | | | |
| Lasso | * FEDFUNDS-1 * gap\_inf * gap\_ue * gap\_gdp * Real\_Interest\_Rate * recession\_flag | 0.8996 | gap\_ue | 0.2420 |
| gap\_inf | 0.3863 |

Figure 25: Model Performance

For each model analyzed, the Inflation Gap coefficient is larger than the coefficient for the Unemployment Gap. This holds true even in the Concept 3: Recession Model. In Concept 3, the Unemployment Gap has a positive coefficient, contrary to expectations, but may be explained by the interaction between the Unemployment Gap and the Rescission Flag. Overall, the relative size of the coefficients for Unemployment Gap and the Inflation Gap is consistent and points to an emphasis by the Federal Reserve on Price Stability.

The research question posed for this analysis focused on evaluating the relative emphasis that the Federal Reserve places on the individual components of its dual mandate. This research question is broken down into the following hypotheses:

* H0 - The Federal Reserve applies equal weights to inflation and employment targets when determining its monetary policy.
* H1 - The Federal Reserve emphasizes its inflation targets when determining monetary policy.
* H2 - The Federal Reserve emphasizes the employment rate when determining monetary policy.

The initial exploration of the concepts behind the EDI and the Taylor Rule resulted in poorly fit models with negative Adj-R2. The shift to the Modified Taylor Rule with the autoregressive term improved the model performance.

There is evidence in several of the models that the Federal Reserve places a greater emphasis on price stability than full employment when conducting monetary policy. In the three surviving models that outperform the naïve model and align to their respective model assumptions, the coefficient for the Inflation Gap is larger than the coefficient for the Unemployment Gap. Since I am using normalized predictor variables, the coefficients are comparable. Given the observed model performance, even when I control for economic cycles and changes in the Real Interest Rate, I can reject the null hypothesis in favor of alternate hypothesis H1.

There are a couple of areas of further exploration. First, the dataset used for this analysis is quarterly. The consistent duration of each time period simplifies that modeling a more accurate analysis would incorporate the FOMC meeting calendar into the analysis. This adds complexity but better aligns the analysis with the decision-making timelines I am modeling. Second, the analysis is based on historical data. It implicitly assumes that the relevant GDP, unemployment, and inflation data is available within the prediction timeframe. This implicit assumption must consider reporting lags and restatements/recalculations of the economic indicators.

# Appendix A: Model Performance

## Concept 1: Full Model

This Concept includes all features that had a non-zero coefficient when fit using the Lasso Regression Model. These features included:

* Federal Funds Effective Rate Previous Period
* GDP Gap
* Inflation Gap
* Unemployment Gap
* Recession Flag

The Lasso Linear Regression model was the only model that outperformed the Naïve model.

A table of numbers and symbols

Description automatically generated

### Lasso Regression Model

The following section explores the assumptions behind the Lasso Regression Model.

1. Linearity – For this model the linear relationship between the predictor variables and response variables holds. As can be seen in the graph below that plots predicted values vs target values, the values fall along a diagonal line indicating a linear relationship.

A graph with a red line and blue dots

Description automatically generated

1. Homoscedasticity – The constant variance of residuals across the predicted values holds for this model. As can be observed in the scatterplot below there is only a slight pattern in the relationship between residuals and predicted values.

A graph with blue dots and a red line

Description automatically generated

1. Independence of Residuals – The Durbin-Watson Test statistic of 1.812 is close to the 2 indicates minimal autocorrelation in the model residuals. The Autocorrelation Function (ACF) chart indicates potential statistically significant autocorrelation lags.

A graph with blue dots and lines

Description automatically generated

1. Multicollinearity – The regularization process in the Lasso model addresses multicollinearity. As part of the feature selection process variables that exhibited multicollinearity were eliminated. Each of the features in the model has a positive coefficient.

A graph with blue squares

Description automatically generated

## Concept 2: Modified Taylor Rule

This concept is based on the Modified Taylor Rule and includes all four features used as variables in the Modified Taylor Rule.

* Federal Funds Effective Rate Previous Period
* Inflation Gap
* Unemployment Gap
* Real Interest Rate

The relative model performance for in sample and out of sample data is presented in the table below. The OLS Linear Regression model and the Lasso Linear Regression are the only models that outperformed the Naïve model.

A table of numbers and letters

Description automatically generated

### OLS Regression Model

The model summary shows a Adj-R2 of 0.928 however the coefficients associated with the Unemployment Gap and the Real Interest Rate predictor variables are not statistically significant. The coefficient p-values for the Unemployment Gap and the Real Interest Rate are above the 0.05 significance level.

A screenshot of a computer

Description automatically generated

### Lasso Regression Model

The following section explores the assumptions behind the Lasso Regression Model.

1. Linearity – For this model the linear relationship between the predictor variables and response variables holds. As can be seen in the graph below that plots predicted values vs target values, the values fall along a diagonal line indicating a linear relationship.

A graph of a red line with blue dots

Description automatically generated

1. Homoscedasticity – The constant variance of residuals across the predicted values does not holds for this model. As can be observed in the scatterplot below there is a slight pattern increasing trend in the relationship between residuals and predicted values.

A graph with blue dots and a red line

Description automatically generated

1. Independence of Residuals – The Durbin-Watson Test statistic of 1.525 is close to 2 but indicates some autocorrelation in the model residuals. The Autocorrelation Function (ACF) chart confirms the results of the Durbin-Watson Test.

A graph with blue dots and lines

Description automatically generated

1. Multicollinearity – The regularization process in the Lasso model addresses multicollinearity. The coefficients for the Real Interest Rate and the Unemployment Gap while not 0 are lower than the coefficients for Federal Funds Effective Rate (t-1) and the Inflation Gap.A graph with blue squares

   Description automatically generated

## Concept 3: Recession Model

The Recession Concept starts with the features from the Modified Taylor Rule concept then adds a Recession Flag. This model based on this concept includes all four features used as variables in the Modified Taylor Rule and adds a boolean variable for an economic downturn or recession.

* Federal Funds Effective Rate Previous Period
* Inflation Gap
* Unemployment Gap
* Real Interest Rate
* Recession Flag

The relative model performance for in sample and out of sample data is presented in the table below. The OLS Linear Regression model and the Lasso Linear Regression was the only models that outperformed the Naïve model.

A table of numbers and letters

Description automatically generated

### OLS Regression Model

The model summary shows a Adj-R2 of 0.935 however the coefficients associated with the Real Interest Rate predictor variables is not statistically significant. The coefficient p-values for the Real Interest Rate is above the 0.05 significance level.

A screenshot of a data

Description automatically generated

By dropping the Real Interest Rate predictor variable from the OLS Linear Model. The fitted model include all statistically significant coefficients however the Adj-R2 drops below the threshold set by the Naïve model.

A screenshot of a computer

Description automatically generated

### Lasso Regression Model

The following section explores the assumptions behind the Lasso Regression Model.

1. Linearity – For this model the linear relationship between the predictor variables and response variables holds. As can be seen in the graph below that plots predicted values vs target values, the values fall along a diagonal line indicating a linear relationship.

A graph with a red line and blue dots

Description automatically generated

1. Homoscedasticity – The constant variance of residuals across the predicted values does not holds for this model. As can be observed in the scatterplot below there is a slight pattern increasing trend in the relationship between residuals and predicted values.

A graph with blue dots and red line

Description automatically generated

1. Independence of Residuals – The Durbin-Watson Test statistic of 1.7195 is close to 2 indicating minimal autocorrelation in the model residuals. The Autocorrelation Function (ACF) chart indicates potential statistically significant autocorrelation lags.

A graph with blue dots and lines

Description automatically generated

1. Multicollinearity – The regularization process in the Lasso model addresses multicollinearity. The coefficients for the Real Interest Rate while not 0 was shrunk to 0.0380.

A graph with blue squares

Description automatically generated

## Concept 4: Simplified Model

The concept is a simplified model that includes the minimal features needed to create an effective model while limiting the VIF. The minimal features for this model include:

* Federal Funds Effective Rate Previous Period
* Inflation Gap
* Unemployment Gap

For this combination of predictive variables none of the tested models performed better than the Naïve model on the test data.

A screenshot of a table with numbers

Description automatically generated

# References

Bernanke, B. (2004, May 20). *Remarks by Governor Ben S. Bernanke*. Retrieved from Federal Reserve: https://www.federalreserve.gov/boarddocs/speeches/2004/200405202/default.htm

Board of Governors of the Federal Reserve System (US). (2023). Federal Funds Effective Rate (FEDFUNDS).

Board Of Governors Of The Federal Reserve System. (2020, August 27). *How does the Federal Reserve affect inflation and employment?* (B. O. System, Producer) Retrieved from Federal Reserve: https://www.federalreserve.gov/faqs/money\_12856.htm

Castelnuovo, E. (2003, May). Describing the Fed's conduct with simple Taylor rules: is interest rate smoothing important? *Europena Central Bank Working Paper Series*(232), p. 12.

Cohen, I. K., Ferretti, F., & McIntosh, B. (2014, November 19). Decomposing the misery index: A dynamic approach. *Cogent Economics & Finance, 2*(1).

Federal Open Market Committee. (2012). Minutes of the Federal Open Market Committee, January 24-25, 2012. Washington, D.C: Federal Reserve.

Federal Reserve. (2023, 9 13). *Board of Governors Members, 1914 - Present*. Retrieved from Federal Reserve.gov: https://www.federalreserve.gov/aboutthefed/bios/board/boardmembership.htm

Federal Reserve Bank of Atlanta. (2023, September 13). *Sticky Price Consumer Price Index less Food and Energy (CORESTICKM157SFRBATL)*. Retrieved from FRED Economic Data St. Louis FED: https://fred.stlouisfed.org/series/CORESTICKM157SFRBATL

Federal Reserve Bank of Cleveland. (2023, September 13). *1-Month Real Interest Rate (REAINTRATREARAT1MO)*. Retrieved from FRED Economic Data St. Louis FED: https://fred.stlouisfed.org/series/REAINTRATREARAT1MO

Federal Reserve Bank of New York. (n.d.). *Measuring the Natural Rate of Interest*. Retrieved from www.newyorkfed.org: https://www.newyorkfed.org/research/policy/rstar

Ferguson, R., & Lahiri, U. (2023, 06 15). *The History and Future of the Federal Reserve’s 2 Percent Target Rate of Inflation*. Retrieved from Council on Foreign Relations: https://www.cfr.org/blog/history-and-future-federal-reserves-2-percent-target-rate-inflation-0

Journal of Regulation. (2023). *Federal Reserve System (FED) | United States of America | the Journal of Regulation*. Retrieved from The Journal of Regulation: https://thejournalofregulation.com

Kliesen, K. L. (2019, January 15). Is the Fed Following a ‘Modernized’ Version of the Taylor Rule? Part 1. *ECONOMIC SYNOPSES, 2*.

Kliesen, K. L. (2019, January 125). Is the Fed Following a “Modernized” Version of the Taylor Rule? Part 2. *Economic Synopses, 2*.

Lovell, M. C., & Tien, P.-L. (1999, July). Economic Discomfort and Consumer Sentiment.

Mankiw, G. N. (2010). *Marcroeconomics.* New York, NY: Worth Publishers.

*Measuring the Natural Rate of Interest*. (2017). (Holston, Laubach, & Williams, Producers) Retrieved from New York Fed.org: https://www.newyorkfed.org/research/policy/rstar

*Policy Rules and How Policymakers Use Them*. (2018, March 8). Retrieved from Federal Reserve: https://www.federalreserve.gov/monetarypolicy/policy-rules-and-how-policymakers-use-them.htm

Poole, W. (1999, March / April). Monetary Policy Rules? *Review*.

U.S. Bureau of Labor Statistics. (2023, September 1). *Unemployment Rate (UNRATE)*. Retrieved from FRED Economic Data St. Louis FED: https://fred.stlouisfed.org/series/UNRATE

United States Congress. (1913). *Federal Reserve Act : Public Law 63-43, 63d Congress, H.R. 7837: An Act to Provide for the Establishment of Federal Reserve Banks, to Furnish an Elastic Currency, to Afford Means of Rediscounting Commercial Paper, to Establish a More Effective Supervision.* Washington DC: United States. Congress.

Wilson, L. (2019, October 9). A Dove to Hawk Ranking of the Martin to Yellen Federal Reserves. *58*, p. 13.

# Figures

[Figure 1: Economic Discomfort Index Formula 6](#_Toc151938908)

[Figure 2: Economic Discomfort Index (EDI) 6](#_Toc151938909)

[Figure 3: Taylor Rule Formula 7](#_Toc151938910)

[Figure 4: Modified Taylor Rule 8](#_Toc151938911)

[Figure 5: Federal Funds Effective Rate Timeseries 10](#_Toc151938912)

[Figure 6: Real Rate of Interest 11](#_Toc151938913)

[Figure 7: Gap Unemployment Rate Timeseries 12](#_Toc151938914)

[Figure 8: GDP Gap Timeseries 12](#_Toc151938915)

[Figure 9: Consumer Price Index (CPIAUCSL\_CH1) Timeseries 13](#_Toc151938916)

[Figure 10: Recession Time Series 13](#_Toc151938917)

[Figure 11: Fed Chair Overtime 14](#_Toc151938918)

[Figure 12: Feature Importance - Lasso Model 16](#_Toc151938919)

[Figure 13: Concept 1 - Lasso Model Coefficients Graph 17](#_Toc151938920)

[Figure 14: Concept 1 - Lasso Model Coefficients 17](#_Toc151938921)

[Figure 15: Taylor Rule vs Federal Funds Effective Rate 18](#_Toc151938922)

[Figure 16: Model Performance Taylor Rule, Modified Taylor Rule and Naive Model 19](#_Toc151938923)

[Figure 17: Modified Taylor Rule Formula 19](#_Toc151938924)

[Figure 18: Concept 2 - Lasso Model Coefficients Graph 21](#_Toc151938925)

[Figure 19: Concept 2 Feature SHAP Summary Plot 21](#_Toc151938926)

[Figure 20: Concept 3 - Lasso Model Coefficients Graph 23](#_Toc151938927)

[Figure 21: Economic Discomfort Index vs. Federal Funds Effective Rate 24](#_Toc151938928)

[Figure 22: Economic Indicators by Fed Chair 24](#_Toc151938929)

[Figure 23: Fed Chair - Lasso Model Coefficients Graph 25](#_Toc151938930)

[Figure 24: Fed Chair Feature SHAP Summary Plot 26](#_Toc151938931)

[Figure 25: Model Performance 27](#_Toc151938932)