DATA 201 Final Project Report

Title: Inflation and Monetary Policy: A Time Series Analysis of U.S. Macroeconomic Dynamics (1980–2025)

1. Introduction

This project investigates how U.S. inflation responds to changes in monetary policy, particularly shifts in the Federal Funds Rate (FFR), from 1980 to 2025. Our primary analysis uses the full sample (1980–2025) to capture long-run interactions under changing macroeconomic regimes. We then look at a comparative analysis of two contrasting policy eras: The Volcker Era (1980–1992), defined by aggressive monetary tightening, and The Great Moderation (1993–2007), marked by low and stable inflation. By combining univariate and multivariate approaches, this study provides both statistical and economic insights into the effect of monetary policy on inflation.

2. Literature Review

The relationship between monetary policy and inflation is a core topic in macroeconomics. Vector Autoregressions (VARs) have become a key tool for analyzing this relationship, offering a flexible, data-driven way to trace the effects of interest rate changes on inflation and output. Stock and Watson (2001) highlight VARs' advantages over earlier models, particularly their use of impulse response functions to study policy shocks. However, they note limitations such as reliance on identification assumptions and policy instability.

A second source of literature focuses on inflation targeting, where central banks commit to explicit inflation goals. Common during the Great Moderation, this approach improved policy predictability and inflation expectations, leading VARs to show weaker inflation responses to shocks. This underscores how monetary transmission mechanisms evolve over time — a key theme in comparing the Volcker era to the Great Moderation (Bernanke & Mishkin, 1997).

3. Data Description

This analysis uses monthly U.S. macroeconomic data from January 1980 to January 2025, drawn from two publicly available sources:

- **Consumer Price Index for All Urban Consumers (CPI-U)**: a measure of monthly inflation, obtained from the Federal Reserve Economic Data (FRED) series CPIAUCNS.

- **Federal Funds Rate (FFR)**: the effective interest rate targeted by the Federal Reserve, obtained from FRED series FEDFUNDS.

To prepare the data for time series analysis:

- Inflation was computed as the month-over-month percentage change in CPI, multiplied by 100.
- Monetary policy shocks were proxied by the first difference of the Federal Funds Rate (FFR_diff), capturing unexpected monthly changes in policy stance.

The resulting dataset contains 539 monthly observations. For extended analysis, we divide the full sample into two key subperiods: Volcker Era (1980–1992) and Great Moderation (1993–2007).

4. Model

This project applies a sequence of time series methods to investigate the relationship between inflation and monetary policy:

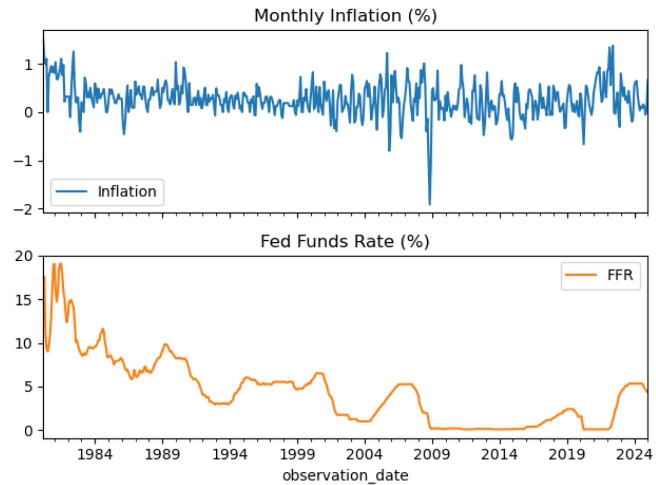
- **Stationarity Testing:** We begin by testing for unit roots using the Augmented Dickey-Fuller test.
- **Granger Causality Test**: To assess directional predictability, we apply Granger causality tests between inflation and FFR_diff.
- **ARIMA and SARIMA Models (Full Sample)**: We model inflation using ARIMA and seasonal ARIMA to account for potential persistence and seasonality in the univariate inflation series. Model selection is guided by ACF/PACF plots and, later, by auto_arima.
- **VAR Model (Full Sample):** A reduced-form Vector Autoregression (VAR) is estimated using the inflation and FFR_diff series. The joint dynamics allow us to model feedback between the two variables.
- **Subsample Analysis (Volcker Era vs. Great Moderation)**: For deeper insight, we repeat the ARIMA and VAR analyses on two distinct subsamples. This allows us to examine whether the inflation response to monetary policy shocks has changed across regimes.

5. Empirical Analysis

Part 1: Modeling Inflation and Interest Rate Interaction (1980–2025)

Preliminary Visualization and Stationarity Tests

We begin by visualizing the two primary time series: monthly inflation (calculated from the percentage change in CPI) and the Federal Funds Rate (FFR).



As shown above, inflation exhibits considerable volatility in the early 1980s, gradually stabilizing after the mid-1990s. In contrast, the FFR shows a strong downward trend over the same period, particularly during the post-2008 low-interest-rate environment and the COVID-19 recovery years. First, we conduct ADF tests to evaluate stationarity. The results indicate that while inflation is stationary (p-value ≈ 0.0001), FFR is not (p-value ≈ 0.072). The first difference of FFR is stationary (p-value ≈ 0.0000). These results confirm that inflation can be modeled directly, while the first difference of FFR must be used for analysis.

Granger Causality Test

We examine whether changes in the Federal Funds Rate Granger-cause inflation. This helps establish whether past values of interest rate changes provide predictive power for inflation, beyond inflation's own lags. Using lags from 1 to 6 months, we find that: Granger causality is statistically significant at lag lengths of 3–6 ($p < 0.05$). The strongest evidence appears at lag 3 ($p = 0.009$) and lag 6 ($p = 0.014$), suggesting that it takes several months for monetary policy changes to influence inflation. This provides preliminary evidence for a lagged policy transmission mechanism.

ARIMA

To model the persistence and structure of U.S. monthly inflation, we first fit an ARIMA model to the full sample (1980–2025).

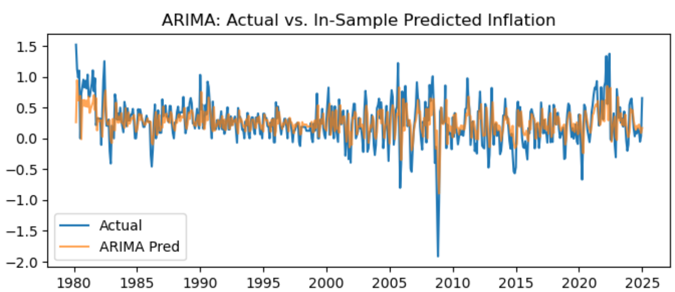
Model Selection and Diagnostics

Based on ACF and PACF plots showing spikes at lag 1 and around lag 12, and given stationarity confirmed by the ADF test, we fit an ARIMA(1,0,1) model to capture the short-run dynamics of monthly U.S. inflation over the full 1980–2025 period.

The model includes three key components:

- The **AR(1)** term (autoregressive) of 0.36 implies that about 36% of last month's inflation "carries over" into this month's inflation.
- The **MA(1)** term (moving average) shows that 26% of last month's unexpected inflation shocks are still influencing this month's inflation.
- The constant term (≈ 0.26) means that if nothing else happens, inflation would naturally grow at about 0.26% per month.

The model fits the data well in-sample.



As shown above, the ARIMA predictions closely follow the actual inflation series, capturing general trends and volatility, though the model smooths out extreme spikes (such as during the 2008 crisis and 2020–21 post-COVID rebound). This is expected, as ARIMA models are designed for capturing predictable dynamics, not large shocks.

Seasonal ARIMA

Model Selection and Diagnostics

While the ARIMA model captures short-run inflation dynamics, its inability to account for regular calendar-based seasonal fluctuations—evident from recurring ACF and PACF spikes at lag 12—motivates the use of a SARIMA model that incorporates both seasonal and non-seasonal components. Therefore, we fit a SARIMA (1, 0, 1) × (1, 0, 1)[12] model to monthly U.S. inflation data.

AR(1) and MA(1) capture short-run dynamics:

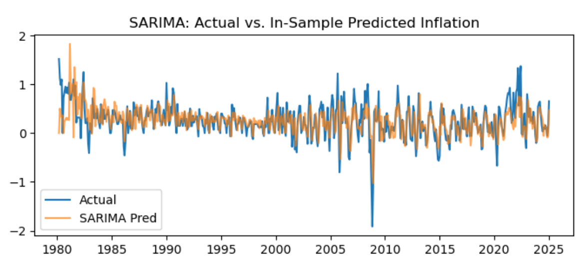
- AR(1) = 0.33 shows a moderate dependence of this month's inflation on the previous month.
- MA(1) = 0.23 implies that recent shocks still affect inflation, indicating persistence.

Seasonal AR(12) and Seasonal MA(12) account for yearly patterns:

- Seasonal AR(12) = 0.98 shows strong yearly persistence; inflation tends to resemble the same month last year.
- Seasonal MA(12) = –0.86 implies that reversal of inflation shocks after one year, suggesting seasonal correction or base effects.

All coefficients are significant at $p < 0.001$, reinforcing the importance of both regular and seasonal dynamics in explaining inflation behavior.

The model confirms that inflation is both persistent and influenced by predictable seasonal cycles, underscoring the need to consider both short-run and annual components in monetary analysis.



As shown above, the SARIMA model's predictions track the actual inflation series very closely. Compared to the plain ARIMA model, SARIMA better captures recurring seasonal peaks and troughs, especially in recent years. The model still smooths over extreme volatility (e.g., in 2008–09 and 2020), but its overall fit is visibly improved.

VAR Modeling

To jointly model the interaction between inflation and monetary policy, we estimate a VAR using monthly inflation and the first difference of the Federal Funds Rate. VAR allows each variable to be regressed on its own lags and the lags of the other variable, providing a flexible structure to capture dynamic interdependencies.

We use the Bayesian Information Criterion (BIC) to select the optimal lag length. Among models with 1 to 12 lags, lag 2 had the lowest BIC value (–4.979), making it the preferred specification.

The estimated VAR(2) system is:

$$\begin{aligned} \text{Inflation}_t = {} & 0.142 + 0.594 * \text{Inflation}_{t-1} - 0.147 * \text{Inflation}_{t-2} + 0.014 * \text{FFR}_{\text{diff},t-1} \\ & + 0.047 * \text{FFR}_{\text{diff},t-2+\varepsilon_{1,t}} \end{aligned}$$

$$\begin{aligned} \text{FFR}_{\text{diff},t} = {} & -0.013 + 0.008 * \text{Inflation}_{t-1} + 0.028 * \text{Inflation}_{t-2} + 0.494 * \text{FFR}_{\text{diff},t-1} \\ & - 0.138 * \text{FFR}_{\text{diff},t-2+\varepsilon_{1,t}} \end{aligned}$$

<u>Inflation Equation:</u>

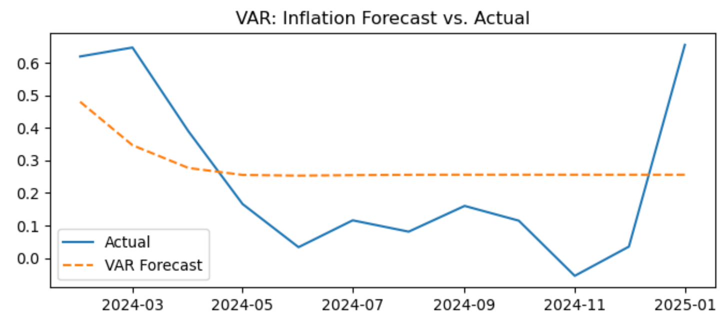
- Inflation is highly persistent: the AR(1) coefficient (0.594) is large and statistically significant.
- Lagged inflation at t –2 has a modest negative effect, suggesting some correction after strong increases.
- FFR_diff at t−1 is not statistically significant, but t−2 shows a marginally significant positive effect (p = 0.078), indicating policy changes may take a few months to influence inflation.

<u>FFR_diff Equation:</u>

- Monetary policy changes are strongly autocorrelated, with a significant AR(1) coefficient of 0.494 and a negative adjustment at lag 2.
- Lagged inflation terms are not statistically significant, suggesting that policy responses are not driven by very recent inflation values in this setup.
- The residual correlation (0.107) between the two equations is low, supporting the notion that the VAR reasonably separates the innovation processes.

<u>In-Sample Forecast Evaluation</u>

To assess the predictive power of the VAR(2) model, we generate a 12-month out-of-sample forecast for inflation and compare it against actual observed values.



The model captures the general downward trend in inflation from early to mid-2024 but underpredicts the sharp rebound in late 2024. This underreaction is expected in VAR models, which rely on lagged information and struggle with unexpected shocks or rapid turnarounds.

Part 2: Regime Comparison

We focus our regime analysis on two periods—1980–1992 (Volcker Era) and 1993–2007 (Great Moderation)—and intentionally exclude the post-2007 era. This is because of several reasons. First, the visualization of the Federal Funds Rate shows a prolonged flat period near zero after 2008, corresponding to the Federal Reserve's zero lower bound (ZLB) policy, during which the traditional interest rate channel of monetary transmission was constrained. Second, the post-2007 period introduces complex structural changes: the global financial crisis, unconventional monetary policies, and pandemic-related shocks—all of which introduce multiple overlapping influences on inflation and interest rates that are not easily isolated in standard time series models. By focusing on the pre-2008 regimes, we can study the inflation-interest rate relationship under more stable and interpretable policy frameworks.

Also, Impulse Response Functions (IRFs) are used in this part to trace how shocks to inflation or interest rates unfold over time, offering a dynamic perspective beyond what Granger causality or SARIMA models provide. In this project, IRFs help compare the effectiveness and persistence of monetary policy across regimes—revealing, for example, how long inflation responds to a rate hike and how actively the Fed adjusts rates in return. This makes IRFs essential for understanding the temporal structure of policy transmission in each era.

- **Volcker Era (1980–1992)**

Granger Causality Tests

Granger causality tests during the Volcker period show strong and statistically significant predictive power of interest rate changes on inflation starting at lag 2: $p = 0.005$ at lag 2, $p = 0.001$ at lag 3, $p = 0.000$ at lag 6.

This suggests that monetary policy had clear short-term effects on inflation, with impacts becoming visible within 2–3 months—consistent with aggressive Fed interventions during this high-inflation period.

SARIMA

"Please refer to Figure A1.1 and Figure A1.2 for SARIMA plots"

The best-fitting model for inflation was SARIMA(1,1,1)(1,0,1)[12], selected using auto_arima.

- The AR(1) term (0.51, $p < 0.001$) implies moderate momentum in inflation changes — suggesting persistence in how inflation evolves.
- The MA(1) coefficient is estimated at –1.00, but with a huge standard error (SE ≈ 130), suggesting it's not reliably estimated — likely due to overfitting or identification issues in a short sample.
- The Seasonal AR(12) and MA(12) terms are statistically insignificant, indicating that seasonal structure is weak or unstable in this period — consistent with chaotic inflation behavior and aggressive policy shifts under Volcker.
- Forecast performance: MAE = 0.106, RMSE = 0.135.

Residual diagnostics show some mild autocorrelation (Ljung–Box $p = 0.045$), and the model slightly underpredicts large inflation swings but performs well near the end of the period.

The Actual vs. Fitted plot shows that the SARIMA model tracks medium-term fluctuations well but slightly underreacts to large early-period inflation swings. The forecast vs. actual plot confirms the model performs well near the end of the Volcker era, though it struggles slightly with sharp turns.

Impulse Response Functions (VAR)

"Please refer to Figure A1.3 for the plot"

VAR IRFs using Cholesky decomposition (Inflation ordered first) reveal:

- Inflation → Inflation: Inflation shocks are highly persistent, causing sustained increases in future inflation before gradually fading — evidence of strong self-propagation.
- FFR_diff → Inflation: Rate hikes lead to a short-lived rise in inflation (peaking at month 2), but the effect quickly dissipates and becomes insignificant — possibly due to policy lag.
- Inflation → FFR_diff: Rising inflation triggers a significant and rapid policy response — the Fed raises rates within 2–3 months, consistent with aggressive tightening.
- FFR_diff → FFR_diff: Interest rate shocks are persistent, indicating that once policy shifts occur, the Fed maintains the new rate path for several months.

The Fed reacted aggressively to inflation spikes, while interest rate changes had limited short-run influence on inflation, likely due to delayed transmission and credibility gaps.

- **Great Moderation (1993–2007)**

Granger Causality Tests

Granger causality was weaker and less consistent during the Great Moderation: Only lag 3 ($p = 0.039$) and lag 4 ($p = 0.033$) showed significance. Lags 2 and 6 were not significant ($p > 0.10$).

This reflects a regime where inflation expectations were well-anchored, and policy changes were smaller and more predictable—reducing short-term causality captured by lagged interest rate movements.

SARIMA

“Please refer to Figure A2.1 and Figure A2.2 for SARIMA plots”

The selected model was SARIMA(0,0,3)(1,0,1)[12] (still using auto_arima).

- MA(1) = 0.34 ($p < 0.001$): positive, short-term momentum in shocks.
- MA(2) = –0.23 and MA(3) = –0.20: corrective terms indicating slight overreaction followed by reversal.
- The Seasonal AR(12) ≈ 1.02 and Seasonal MA(12) ≈ –0.95 are both highly significant, showing a strong and stable 12-month seasonal cycle.
- Forecast performance: MAE = 0.211, RMSE = 0.276.

Despite structural clarity, prediction accuracy was lower, suggesting small, subtle fluctuations were harder to model.

The Actual vs. Fitted plot indicates that the SARIMA model successfully captures the general direction and seasonality of monthly inflation during the Great Moderation, though it sometimes lags behind rapid fluctuations. The forecast vs. actual plot shows that the model maintains a reasonable short-term predictive ability toward the end of the sample, albeit with higher volatility and occasional underestimation during sharp inflation movements.

Impulse Response Functions (VAR)

“Please refer to Figure A2.3 for the plot”

IRFs from the Great Moderation VAR reveal:

- Inflation → Inflation: Inflation shocks have a brief, weak effect that fades quickly, indicating low persistence and well-anchored expectations.
- FFR_diff → Inflation: Interest rate hikes cause a small, short-lived bump in inflation, but the effect is statistically insignificant and quickly disappears.
- Inflation → FFR_diff: Inflation increases prompt a mild and delayed policy response; the Fed reacts more gradually and with less intensity than in the Volcker era.
- FFR_diff → FFR_diff: Rate shocks persist briefly but normalize within 6 months, reflecting smoother and more predictable policy adjustments.

This reflects a credibility-driven, stable policy regime, where inflation shocks were quickly absorbed and the Fed responded gradually and predictably.

- **Regime Comparison**

Criteria	Volcker Era (1980–1992)	Great Moderation (1993–2007)
Granger Causality	Strong evidence of ΔFFR. Inflation at lags 2–6 ($p < 0.01$), indicating a clear and timely policy effect.	Weak and inconsistent causality; significance only at lags 3–4 ($p \approx 0.03$–0.04), suggesting diminished short-run transmission.
SARIMA	The model captures volatility and non-stationarity. Seasonal terms were statistically weak, reflecting unstable or irregular inflation cycles. Despite high volatility, the model had lower forecast error (MAE = 0.106), likely due to clearer structural shifts.	The model reflects inherent stationarity and well-anchored inflation. Strong seasonal terms suggest stable, calendar-driven inflation patterns, but the model showed higher forecast error (MAE = 0.211), possibly due to subtle, low-variance shocks that are harder to predict with lagged values alone.

Shock -> Response	Volcker Era (1980–1992)	Great Moderation (1993–2007)
Inflation → Inflation	Strong and persistent; effect remains positive for many months	Much weaker and short-lived; slight overshooting into negative territory
FFR_diff → Inflation	Short-term positive impact; fades quickly.	Similar short-term bump, but smaller and less significant
Inflation → FFR_diff	Sharp, significant policy tightening	Small and positive; response is weaker and borderline insignificant
FFR_diff → FFR_diff	Highly persistent; rate shocks have long memory	Less persistent; quicker return to baseline (suggest smoother policy)

Key takeaway

- Monetary policy had stronger short-run influence on inflation during the Volcker Era, as evidenced by significant Granger causality and sharp impulse responses from inflation to interest rate changes. The Fed responded quickly and aggressively to inflation shocks in this high-volatility environment.
- Inflation dynamics were structurally different across regimes: the Volcker Era required differencing and showed weak seasonal structure, reflecting unstable inflation behavior,

while the Great Moderation featured stationary inflation with strong annual seasonality, consistent with credible inflation targeting.

- SARIMA models captured this contrast, with the Volcker model excelling despite volatility (lower MAE) and the Great Moderation model underperforming due to subtle, less predictable fluctuations—highlighting a trade-off between volatility and predictability.
- VAR-based impulse responses showed greater persistence and responsiveness in the Volcker Era, while responses in the Great Moderation were smaller, shorter-lived, and often insignificant—indicating improved inflation anchoring and more inertial policy adjustments.
- The results reflect a clear macroeconomic transformation: from an era of reactive, high-stakes policy maneuvers to one of anticipatory and rule-based monetary strategy.

6. Conclusion

This project explored the dynamic relationship between U.S. inflation and the Federal Funds Rate (FFR) from 1980 to 2025, with particular focus on two contrasting periods: the Volcker Era (1980–1992) and the Great Moderation (1993–2007). By employing a range of time series models—ARIMA, Seasonal ARIMA, Granger causality testing, and VAR—we assessed inflation dynamics, policy responsiveness, and the transmission of monetary shocks across regimes.

Main Findings

<u>Full-period analysis (1980–2025):</u>

- Inflation was found to be stationary while the FFR required first-differencing.
- Granger causality tests showed significant predictive power of interest rate changes on inflation at longer lags (3–6 months).
- ARIMA and SARIMA models captured inflation reasonably well, with SARIMA providing better seasonal structure and lower residual autocorrelation.
- VAR modeling revealed persistent inflation dynamics and limited short-run reaction of interest rates to inflation shocks.

<u>Regime comparison:</u>

- In the Volcker Era, SARIMA models performed well (MAE ≈ 0.11), and Granger causality showed strong monetary policy impact on inflation. VAR IRFs indicated aggressive policy responses to inflation and persistent rate shocks.
- In the Great Moderation, the same models yielded higher forecast errors (MAE ≈ 0.21), and Granger results showed weaker and less consistent monetary transmission. IRFs suggested inflation was more stable and policy was more inertial.

References

Bernanke, B. S., & Mishkin, F. S. (1997). Inflation targeting: A new framework for monetary policy? (NBER Working Paper No. 5893). National Bureau of Economic Research. https://doi.org/10.3386/w5893

Stock, J. H., & Watson, M. W. (2001). Vector autoregressions. Journal of Economic Perspectives, 15(4), 101–115. https://doi.org/10.1257/jep.15.4.101

Appendix A: Figures and Visualizations

A1. Volcker Era (1980–1992)

Figure A1.1. SARIMA(1,1,1)(1,0,1)[12] – Actual vs. Fitted plot.

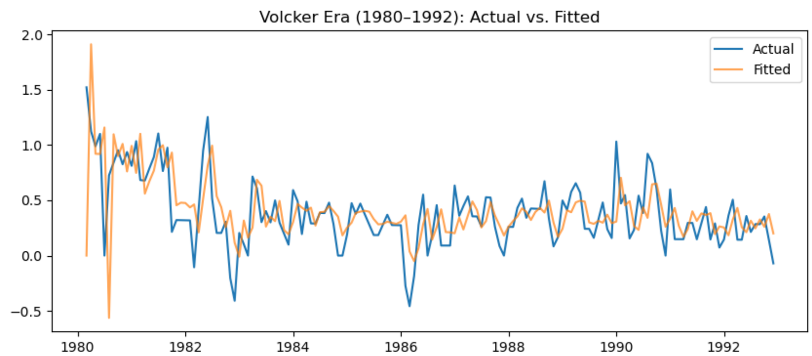


Figure A1.2. SARIMA(1,1,1)(1,0,1)[12] – Forecast vs. Actual plot.

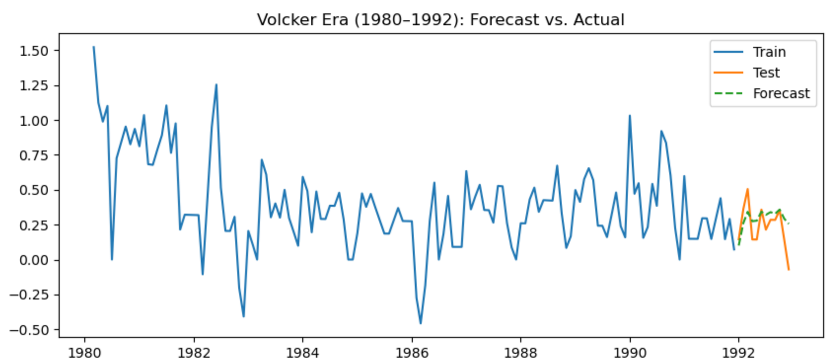
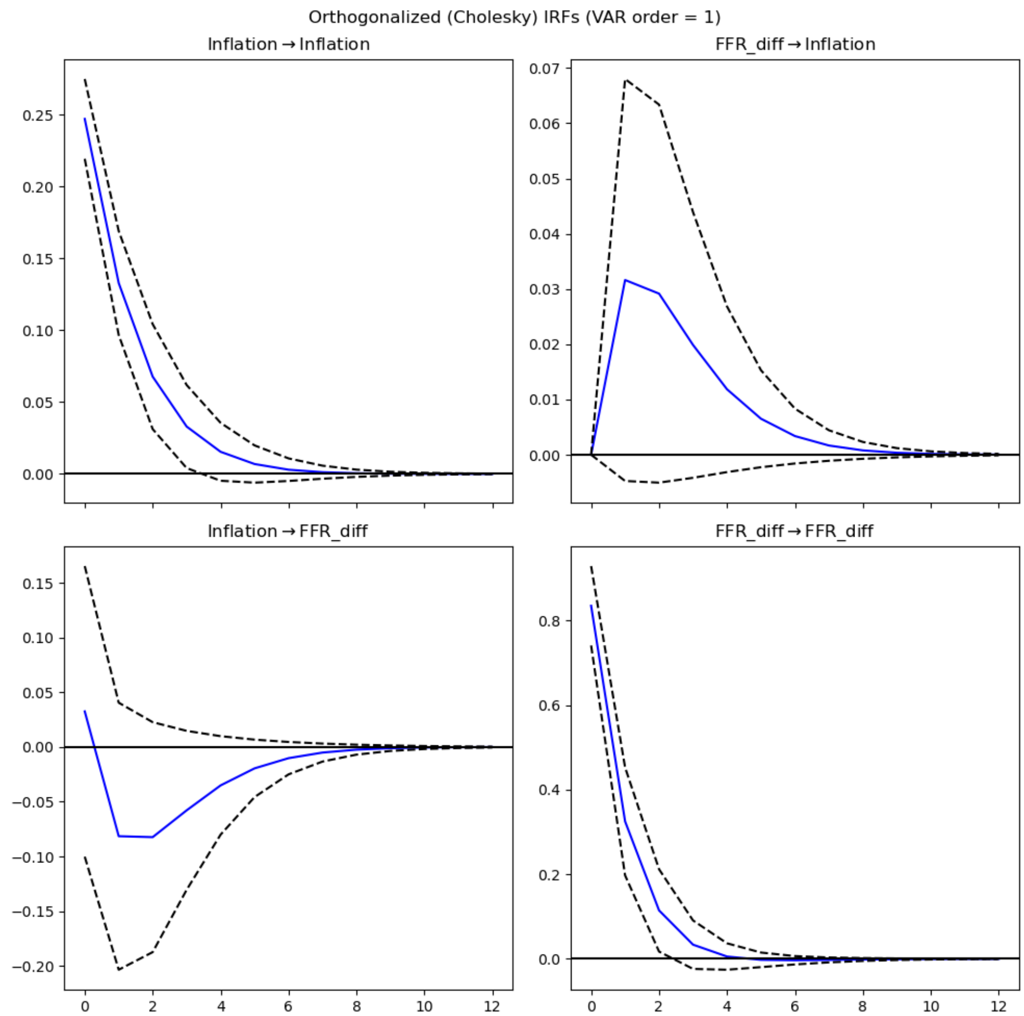


Figure A1.3. VAR Impulse Response Functions (Volcker Era)._



A2. Great Moderation (1993–2007)

Figure A2.1. SARIMA(0,0,3)(1,0,1)[12] – Actual vs. Fitted plot.

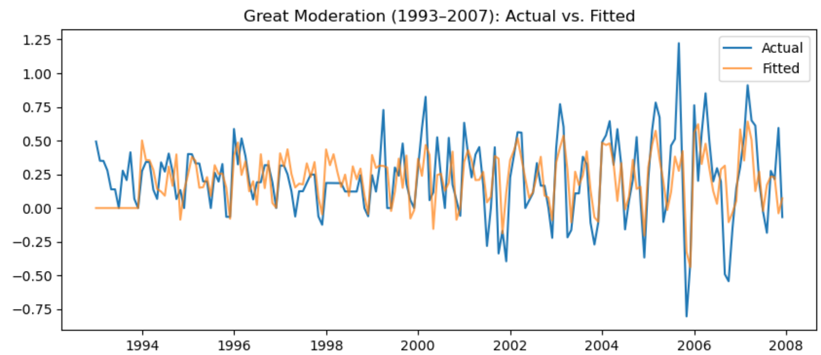


Figure A2.2. SARIMA(0,0,3)(1,0,1)[12] – Forecast vs. Actual plot.

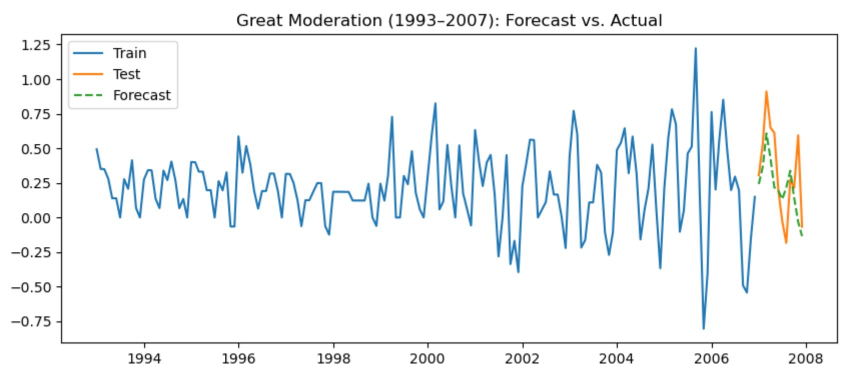
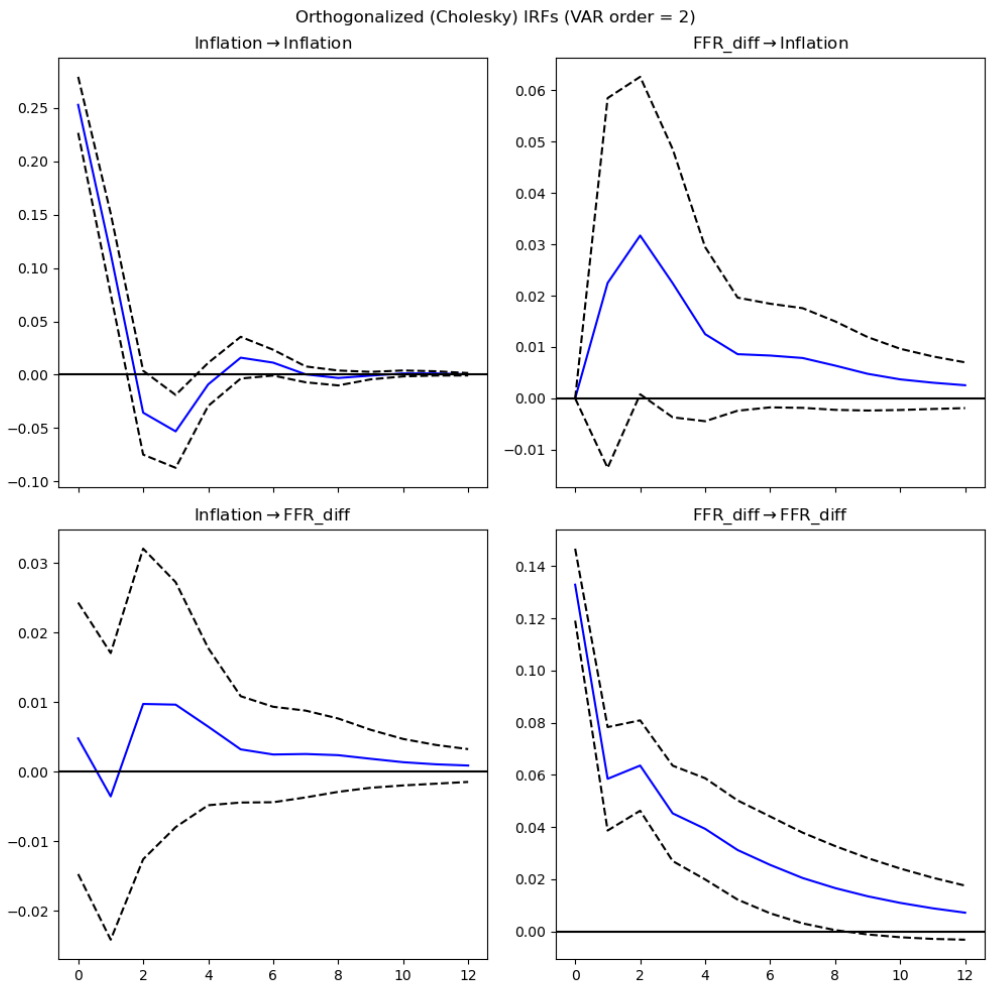


Figure A2.3. VAR Impulse Response Functions (Great Moderation)._



Orthogonalized (Cholesky) IRFs (VAR order = 2)
Inflation → Inflation
FFR_diff → Inflation
Inflation → FFR_diff
FFR_diff → FFR_diff