AN EMPIRICAL INVESTIGATION OF THE IMPACT OF MONETARY POLICY ON THE ECONOMIC ACTIVITY OF ALASKA

Scott Benninger

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University of California San Diego

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1. Introduction

This paper seeks to determine if short-term nominal interest rates controlled by the Federal Reserve Bank cause any effects on two measures of economic activity at the State level: real GDP growth and the unemployment rate. To conduct such analysis, interest rates, Alaska's real GDP, and unemployment data from 1997 q1 to 2022 q4 will be used.

Understanding the causal relationship between interest rates and state-level economic indicators can be extremely valuable as it can help guide policymakers in their efforts to stabilize the economy. Changes in interest rates are seen to have implications on consumer investment and consumption, as well as employment. But, the extent to which interest rates impact economic activity at the state level, particularly in a unique economy like Alaska's, remains unclear. This analysis will explore these dynamics and the limitations of employed models.

To answer this question, a Vector Autoregression model is applied to Alaska's real GDP and unemployment data, following the approach proposed by Christopher Sims (1980). This model addresses the endogeneity problem that arises from the simultaneous interactions between economic variables and monetary policy. The model is estimated, subsequent impulse response functions are evaluated, and robustness checks are performed to determine whether interest rate changes have a significant effect on the chosen economic indicators. Ultimately, results suggest that the influence of interest rate changes on Alaska's real GDP growth is minimal, with only weak delayed effects. For unemployment, the impact of interest rate shocks is both delayed and minimal as well.

The remainder of this paper is structured as follows: Section 2 discusses the empirical challenges of measuring the effects of monetary policy and the VAR methodology that solves this endogeneity issue. Section 3 presents the data and the VAR model estimation results, highlighting the ACF/PACF analysis and the selection of the VAR model. Section 4 provides evidence on the effects of monetary policy based on the impulse response functions, while Section 5 discusses the limitations and a revamped look at the analysis.

2. Monetary Policy Effectiveness: Empirical Challenges.

Endogeneity can be summarized by a situation of contemporaneous causality to which occurs when variables influence one another simultaneously, assisting with the creation of a two-way feedback loop. It is such that changes in the short-term nominal interest rates imposed by the Federal Reserve can influence real GDP growth and unemployment rates while these same economic outcomes also influence the Federal Reserve's decisions to increase or decrease nominal rates. Such a feedback loop can be hypothesized in our context of monetary policy and state-level economic activity. In a state of recession, GDP across states will tend to decline below trend and unemployment will tend to rise, enacting a response from the Federal Reserve to lower interest rates. They would do this with the intention of stimulating economic activity by encouraging the general public to borrow at cheaper rates and to invest it right back into the economy. So, as interest rates decline, this boost to consumer spending increases real GDP and decreases unemployment. This feedback loop continues as economic conditions elicit a monetary policy response, and such change influences the economic conditions. This interplay of variables makes it clear why endogeneity is a real threat that imposes empirical challenges due to its complication of being able to isolate causal effects.

With the existence of this contemporaneous causality problem, an Ordinary Least Square estimate will always be biased and inconsistent. This means that even with a large sample size, the estimated coefficients will not converge to their true values, and the coefficient estimate will remain inaccurate. OLS regression is inadequate in this context because it assumes that interest rates (explanatory variables) are exogenous and uncorrelated with the error term. However, the presence of the simultaneity problem with monetary policy and economic activity violates this strong assumption. Essentially, OLS incorrectly equates changes in economic activity solely to monetary policy changes without accounting for the feedback loop that Christopher Sims addressed in 1980.

So, to ultimately deal with the endogeneity problem of estimating the effects of monetary policy on economic activity, Sim's approach is one in which the reduced form for Vector Autoregression is transformed into a structural model. The fundamental issue with this reduced model is that it does not account for contemporaneous relationships between variables, resulting once again in biased and inconsistent estimates. The VAR reduced form equations are:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} + \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$$

yt represents the interest rate and xt represents either real GDP growth rate or the unemployment rate. The contemporaneous effect of yt and xt on one another is essential for understanding the true causal relationships but is not present. So, to identify the structural parameters and capture these contemporaneous effects, the structural VAR model is used:

$$\begin{bmatrix} y_t \\ x_t \end{bmatrix} = \begin{bmatrix} 0 & \alpha_x \\ \alpha_y & 0 \end{bmatrix} \begin{bmatrix} y_t \\ x_t \end{bmatrix} + \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} e_{ty} \\ e_{tx} \end{bmatrix}$$

αx and αy represent the contemporaneous effects of the economic variables on each other. Now, the fundamental issue arriving when converting from the reduced form to the structural model is that typically there is one more unknown parameter to estimate than there are equations. To address this, a restriction needs to be imposed on either αx or αy. The reasonable assumption is that changes in interest rates (yt) have no immediate effect on real GDP (xt). While the Federal Reserve can change the interest rate immediately after seeing a change in unemployment or GDP, it takes time for any change in interest rate to have an economic effect. Thus, αx can be set to 0.

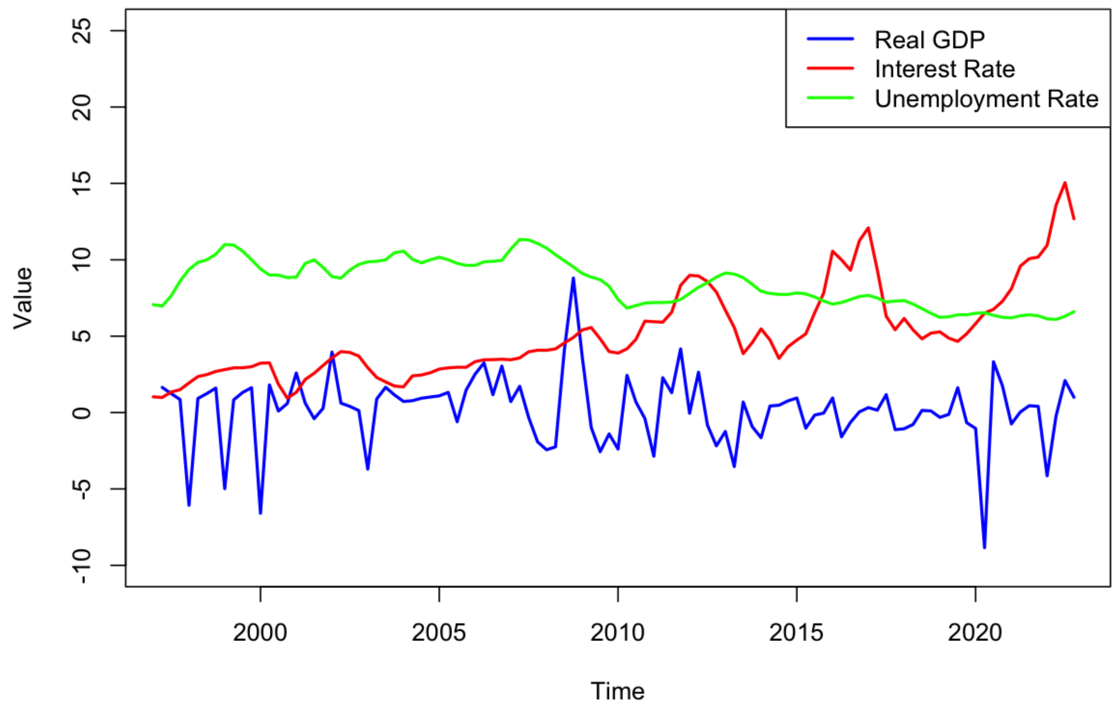
Imposing this restriction and the overall approach addressed endogeneity through this implicit instrumental variable. With the assumption that $\alpha x=0$, αy can be estimated and the structural parameters can be derived. In this structural model, and under the assumption that the restriction is valid, implicitly, the residuals from one equation in the VAR estimate are interpreted as an instrument for the other equation. When actually performing the analysis on the data, setting the *ortho* option to *TRUE* in R makes the shocks independent from each other, and so the impulse response functions will show the true causal effects on these shocks. This process ultimately addresses the endogeneity problem and allows for a causal interpretation of monetary policy and its effects on Alaska's real GDP growth and unemployment rate.

The use of Sim's approach is entirely based on the previously described assumption that while the Federal Reserve can adjust interest rates in immediate response to changes to economic changes such as unemployment or GDP growth, the effect of interest rates changes on those same variables are delayed and not immediately observable. This aligns with the understanding that monetary policy impacts on economic variables are not immediate. This is personally found to be reasonable because when the Federal Reserve lowers interest rates, it is under the intention of making borrowing cheaper. This in turn should encourage consumer spending and businesses investing; however, consumers and businesses will not always immediately react to this change. These big decisions might take months for a business to weigh the pros and cons of expanding or for a consumer to take out a loan for a big purchase. Even more evident, the effect interest rates have on employment levels would be delayed because businesses typically need to observe more than solely an interest rate and need to examine broader economic trends and their own financial performance before adjusting hiring practices. So, this lag assumption allows the model to account for the delayed impact of policy changes on economic conditions.

However, this assumption could also be overlooking how monetary policy may have an immediate effect on economic conditions. For instance, an interest rate adjustment that is either extreme or differs from general consensus might quickly influence consumer spending or spur impromptu business investments Additionally, during periods of high economic volatility or one of financial crises, the immediate impact of interest rate changes might be significant. For example, in a financial crisis, a sudden rate adjustment could quickly influence market sentiment. Thus, it must be noted that the model's assumption of there not existing a contemporaneous effect might not fully capture potential immediate responses, complicating conclusions about the true impact of monetary policy.

3. Data and VAR Model Estimation

Upon initial examination of the overlaid data in the data provided, it is generally evident that Alaska's unemployment rate exhibits an inverse relationship with interest rates. As interest rates have increased over the last 25 years, the unemployment rate has tended to decrease. In contrast, Alaska's real GDP appears to follow the trend of interest rates more closely. Despite this apparent correlation, the real GDP data itself does not exhibit a strong trend over time.



Before estimating, the autocorrelation function (ACF) in Figure 2 is examined to understand the dependencies of the variables in the time series. The ACF for real GDP indicates there to be no significant autocorrelation at any lags suggesting that there is no trend over time and so past values of real GDP are not useful for predicting future values. Contrarily, interest rates indeed appear to depend on previous lags. This indicates that past values of interest rates have an influence on current values. The bottom-left graph of the ACF plots the correlation between current real GDP and future interest rates. It shows that these correlations are statistically insignificant and so there is no evidence that current real GDP predicts future interest rates. Similarly, the top-right diagram, which shows the correlation between real GDP and past interest rates, also reveals statistically insignificant results. This indicates that past interest rates do not significantly impact current real GDP.

The unemployment ACF in figure 3 shows that there is a strong correlation between unemployment rates and previous lags. The top right ACF of the unemployment rate and interest rate shows a significant negative correlation at all lags. This indicates a strong negative autocorrelation, meaning that high interest rates are likely an indication of low unemployment rates just as low interest rates are likely an indication of high unemployment rates. The bottom left ACF of interest rate & unemployment is the correlation between unemployment and future interest rates. The ACF remains negative for about 3 lags, meaning that when we have a large unemployment rate, it is likely that the future interest rate is going to be large and negative for a while—at least 12 quarters.

To determine the preferred VAR model, the Partial Autocorrelation Function (PACF) is examined. For the real GDP and interest rates series, the PACF reveals nothing more than two significant lags at 4 and 12, suggesting these lags capture meaningful dynamics. To select the optimal model, the VARSELECT command is run in R. The Akaike Information Criterion (AIC) selects a VAR model with 4 lags VAR(4) to be most optimal, while the Bayesian Information Criterion (BIC) suggests a model with 3 lags VAR(3) to be most optimal. Given that the goal is to understand causal relationships rather than to make forecasts, the AIC's recommendation for VAR(4) is preferred. This choice aligns with the need to capture the most detailed structure in the data, even if it is less parsimonious.

In regards to the unemployment rate and interest rates, the PACF shows that lags 4 and 5 are particularly relevant since these lags are statistically significant. When applying the

VARSELECT command, the AIC suggests that a VAR model with 5 lags VAR(5) is optimal, BIC calculates a model with 4 lags VAR(4). Again, given the focus is on capturing the underlying dynamics rather than achieving the most parsimonious model, VAR(5) is selected for estimation based on the AIC's recommendation.

Running the VAR command gives an equation for real GDP and one for interest rates. Each equation shows how the variable depends on its own past values and the past values of the other variable, allowing for interactions between them to be evaluated. Seen in the table on the left, the real GDP equation, only the coefficient for GDP at lag 3 and the constant term are statistically significant at the 95% confidence level. The coefficient for GDP at lag 3 is -0.22966, which is significant with a p-value of 0.0222, indicating a possible delayed negative impact on current GDP. The constant term is also significant, with an estimate of 1.04951 and a p-value of 0.0440. In contrast, the right table is the interest rate equation which shows that coefficients for lags 1 through 4, as well as the constant term, are significant. Specifically, the coefficients for lags 1, 2, 3, and 4 have p-values less than 0.05 and thus are significant at the 95% confidence level, highlighting that past interest rates carry significant weight in determining current interest rates.

Estimation Results for Equation: rgdp

	Coefficients	P_values
rgdp.l1	0.081	0.422
int.l1	0.104	0.738
rgdp.l2	-0.093	0.345
int.l2	-0.023	0.967
rgdp.l3	-0.230	0.022
int.l3	-0.072	0.902
rgdp.l4	0.050	0.627
int.l4	-0.179	0.592
const	1.050	0.044

Estimation Results for Equation: int

	Coefficients	P_values
rgdp.l1	-0.022	0.506
int.l1	1.677	0
rgdp.l2	0.012	0.721
int.l2	-1.311	0
rgdp.l3	-0.027	0.403
int.l3	0.992	0.00000
rgdp.l4	-0.046	0.179
int.l4	-0.422	0.0002
const	0.380	0.027

For the unemployment rate equation, the coefficients for unemployment at lags 1, 2, 3, and 4, as well as the constant, are statistically significant at the 95% confidence level. The coefficients are 2.007, -1.824, 1.222, -0.545, and 0.429, respectively. This suggests a complex lagged relationship where both positive and negative lagged values of unemployment impact its current value. In contrast, for the interest rate equation, the coefficients for interest rates at lags 1, 2, 3, and the constant term are also statistically significant. The respective coefficients are 1.518, -1.108, 0.716, and 3.425, indicating that past interest rates strongly influence current rates, particularly at the shorter lags. These results highlight the lack of dependence between unemployment and interest rates over time.

Estimation Results for Equation: unem

	Coefficients	P_values
unem.l1	2.007	0
int.l1	0.024	0.469
unem.l2	-1.824	0
int.l2	-0.050	0.422
unem.l3	1.222	0.00002
int.l3	0.026	0.708
unem.l4	-0.545	0.017
int.l4	0.039	0.547
unem.l5	0.099	0.329
int.l5	-0.058	0.103
const	0.429	0.087

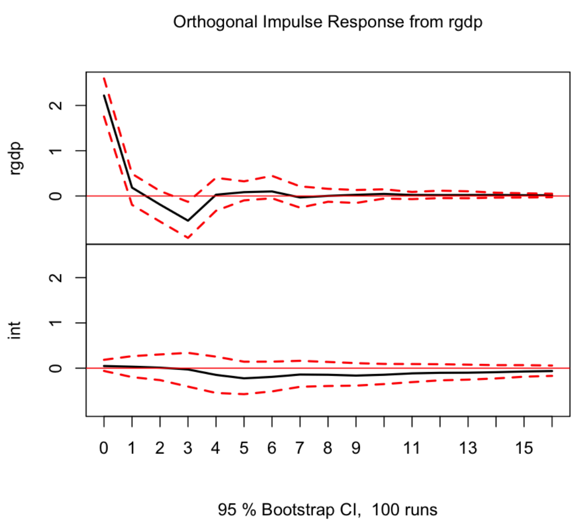
Estimation Results for Equation: int

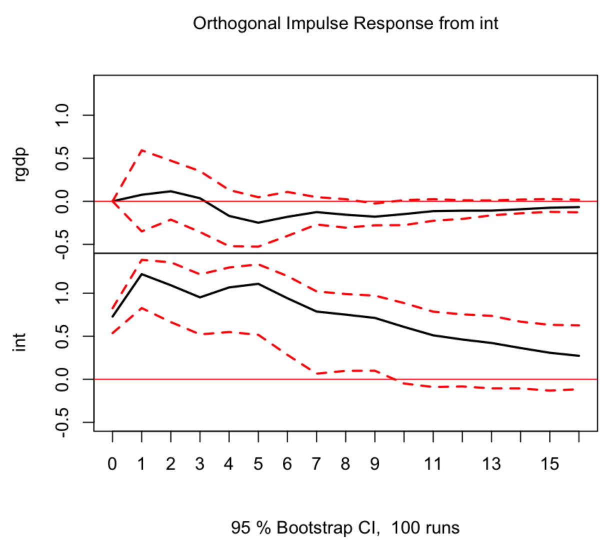
	Coefficients	P_values
unem.l1	-0.370	0.290
int.l1	1.518	0
unem.l2	0.409	0.593
int.l2	-1.108	0.00000
unem.l3	-0.626	0.487
int.l3	0.716	0.002
unem.l4	0.797	0.286
int.l4	-0.115	0.590
unem.l5	-0.498	0.137
int.l5	-0.196	0.095
const	3.425	0.0001

4. Evidence of Effect of Monetary Policy on Economic Activity

The left set of impulse response graphs illustrate the response of real GDP and interest rates to an innovation in the real GDP equation. The results show that a shock to real GDP has an immediate and positive impact on itself, which decays quickly after one lag. However, the response of interest rates to this shock is not statistically significant, suggesting that fluctuations in real GDP do not lead to significant changes in interest rates. This implies that while real GDP is responsive to its own shocks, these shocks do not influence the interest rate in a statistically significant manner.

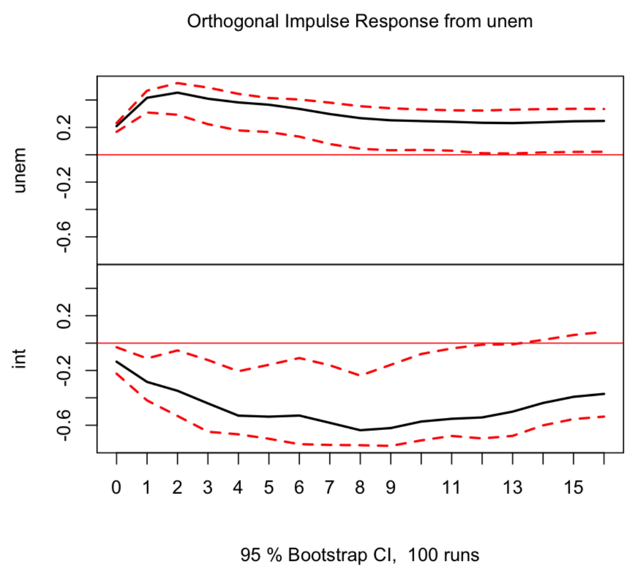
The right set of graphs illustrate the response of real GDP and interest rates to an innovation in the interest rate equation. The results indicate that a shock to interest rates leads to a large and immediate increase in interest rates, which gradually decays to zero over time. However, the response of real GDP to this shock is minimal, with only a slight negative effect emerging around lag 9, which is only marginally significant at a 95% confidence interval. This suggests that while interest rates are strongly influenced by their own shocks, these shocks have only a delayed and minimal impact on real GDP, elucidating a weak relationship between interest rates and Alaska's real GDP.

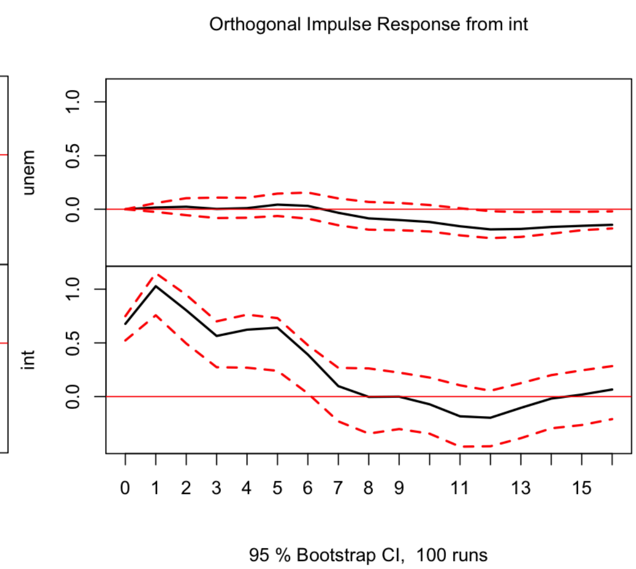




When examining the unemployment rate, the left set of impulse response graphs shows the response of unemployment and interest rates to an innovation in the unemployment equation. The results reveal that a shock to unemployment has a persistent and statistically significant increase in unemployment across multiple lags. Interest rates, however, respond negatively to this shock, with the impact becoming increasingly negative until about eight lags, after which the effect diminishes and is no longer statistically significant around lag 12. This indicates that shocks to unemployment have a sustained positive impact on itself and a persistent negative impact on interest rates.

The right set of graphs show the response of unemployment and interest rates to an innovation in the interest rate equation. The findings indicate that the response of unemployment is not statistically significant for the first 12 lags. However, from lag 12 to lag 16, there is a slight negative impact on unemployment that is marginally statistically significant at a 95% confidence level. Meanwhile, interest rates show a large initial positive response to their own shocks, which rapidly decays to zero by around lag 6. This suggests that while shocks to interest rates have an immediate and pronounced impact on interest rates themselves, their effect on unemployment is very delayed and minimal.





The empirical evidence suggests that the impact of monetary policy through the Federal Reserve's adjustments in short-term nominal interest rates, on Alaska's real GDP growth and unemployment rate is limited. Real GDP shows minimal sensitivity to interest rate shocks evident through the delayed and weak response, indicating that interest rate changes do not significantly impact economic growth in the state. Similarly, the effect of interest rate shocks on unemployment is both delayed and minimally negative, highlighting that changes in interest rates are not a strong determinant of unemployment levels. Therefore, the findings indicate that monetary policy has a relatively weak influence on these key indicators of economic activity in Alaska and so it is likely to be the case that other factors besides monetary policy have a more influential role on state's economic activity.

5. Discussion of Limitations, Robustness, and Extensions

The main limitation to the interpretation given to the empirical results lies in the assumption made in the VAR model that changes in the short-term nominal interest rate do not have an immediate effect on real GDP or unemployment. This assumption could be an oversimplification of the complex dynamics at play between the variables. Additionally, the time period chosen for the analysis is another potential limitation, as it may not be able to fully reflect longer-term trends or structural changes in the economy that could influence the results and conclusions that were formulated. herefore, while the results do offer valuable insights, they should be interpreted with caution, considering these limitations and the potential for alternative explanations.

To address the time period concern, figure 1 shows that the interest rate, unemployment rate, and real GDP data do not all cover the same time frame. For consistency, the analysis was constrained to the period covered by the variable with the least data (real GDP).However, since the interest rate and unemployment rate data extend further back, the VAR model and impulse response functions can be re-estimated using data from 1976 Q1 to 2024 Q2, whereas the previous analysis was limited to the period from 1997 Q1 to 2022 Q4. With this expanded dataset, a VAR(3) model was chosen, and previously significant effects of unemployment lags unem.l2 and unem.l3 are no longer statistically significant. The impulse response analysis also shows that the interest rate's relationship with unemployment is now statistically indistinguishable from zero, essentially eliminating the previously observed correlation.

The Engle-Granger approach confirmed that real GDP, interest rates, and unemployment rates are stationary, with p-values of 0.01, 0.24, and 0.01, respectively. This means that real GDP and interest rates are not cointegrated, nor are the unemployment rate and interest rates, as cointegration requires both variables to be non-stationary. Without cointegration, there is no need for an error correction mechanism, and this robustness check supports the initial VAR results, indicating that the chosen model, which does not account for an equilibrium relationship, remains appropriate.

While this robustness check strengthens confidence in the initial findings on the relationship between interest rates and economic activity, a key limitation remains Alaska's unique economic structure. The state's distinct economic characteristics may still affect the results, potentially making them less generalizable to other states. Alaska may not be a fair representation of how monetary policy affects state-level economic activity, so while the robustness check addresses methodological concerns, it does not eliminate structural factors specific to Alaska that could influence the interpretation of the result.

Appendix – Data

Figure 1: Real GDP growth, Interest rate, & unemployment rate from 1954 Q3 to 2024 Q3

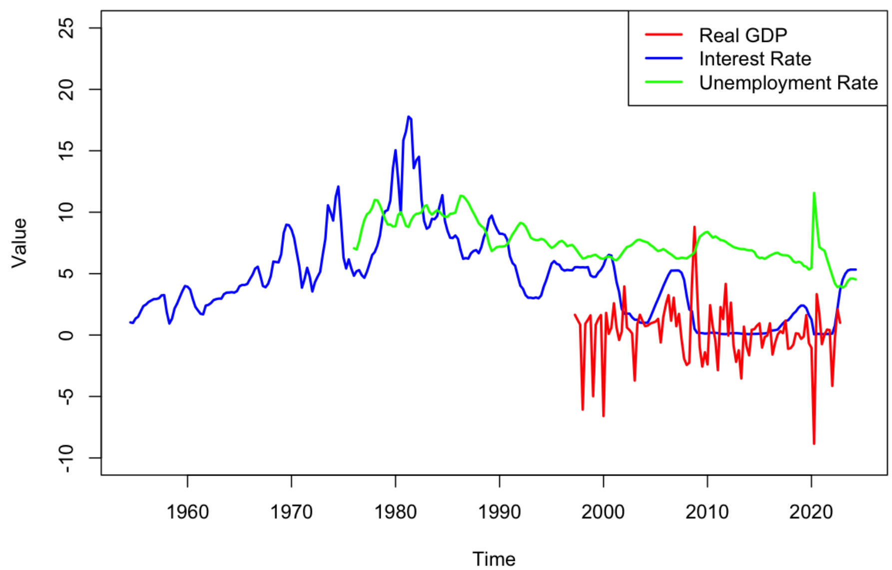


Figure 2: Autocorrelation Function (ACF) Plots for Real GDP & Interest Rates

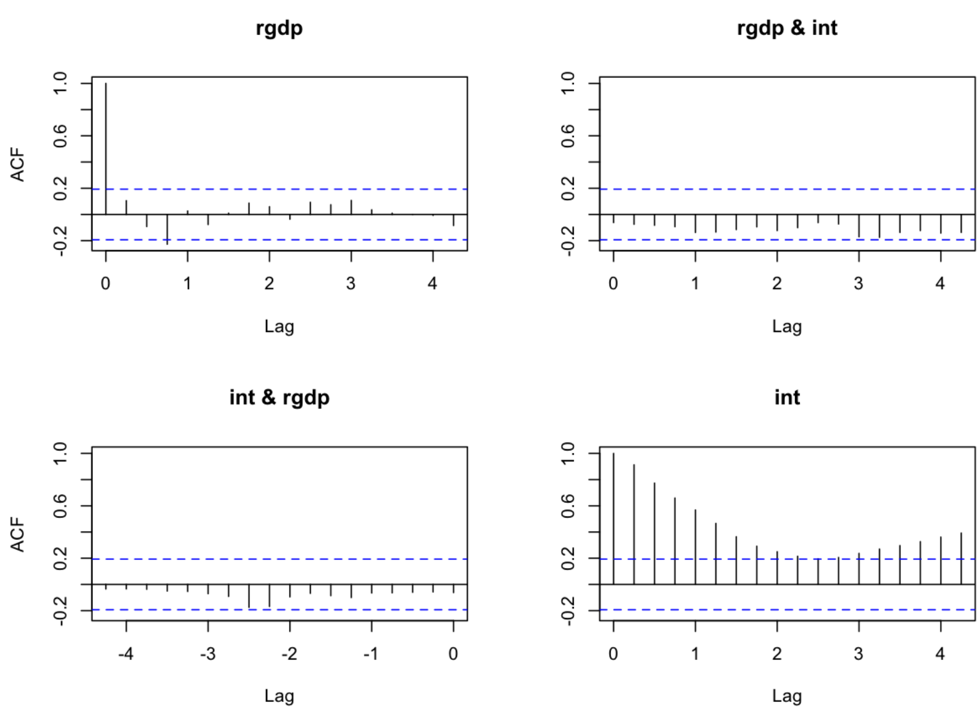


Figure 3: Autocorrelation Function (ACF) Plots for Unemployment Rates & Interest Rates

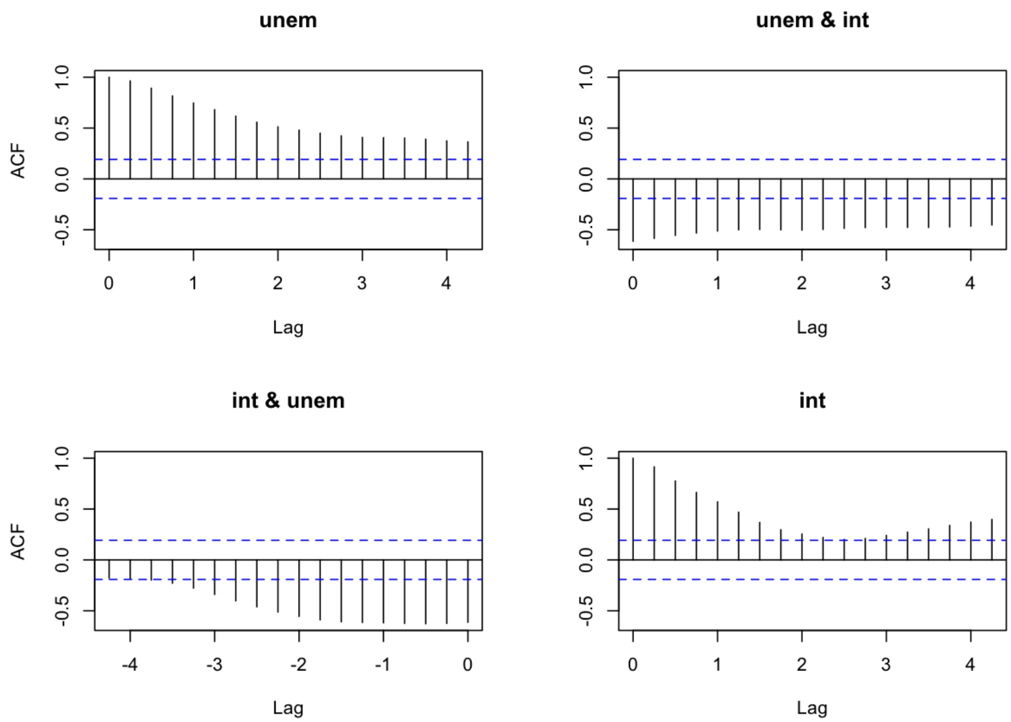


Figure 4: VAR Model Estimation Results for Real GDP on Real GDP & Interest Rates

	Dependent variable:	
	Real GDP	
	(1)	(2)
RealGDP.l1	0.0812	-0.0221
	(0.1007)	(0.0331)
InterestRate.l1	0.1040	1.6772^{***}
	(0.3101)	(0.1021)
RealGDP.l2	-0.0933	0.0116
	(0.0983)	(0.0324)
InterestRate.l2	-0.0234	-1.3109^{***}
	(0.5711)	(0.1879)
RealGDP.l3	-0.2297^{**}	-0.0273
	(0.0987)	(0.0325)
InterestRate.l3	-0.0716	0.9921^{***}
	(0.5772)	(0.1900)
const	0.0502	-0.0459
	(0.1029)	(0.0339)
int.l4	-0.1795	-0.4217^{***}
	(0.3338)	(0.1099)
const	1.0495^{**}	0.3796^{**}
	(0.5137)	(0.1691)
Observations	99	99
R^2	0.1083	0.9424
Adjusted R^2	0.0291	0.9373
Residual Std. Error (df = 90)	2.2188	0.7303
F Statistic (df = 8; 90)	1.3670	184.0389^{***}
Note:	*p<0.1; **p<0.05; ***p<0.01	

Figure 5: VAR Model Estimation Results for Unemployment on Unemployment & Interest Rates

	Dependent variable:	
	Unemployment Rate	
	(1)	(2)
Unemployment Rate.l1	2.0069***	-0.3704
	(0.1051)	(0.3477)
Interest Rate.l1	0.0238	1.5178***
	(0.0328)	(0.1085)
Unemployment Rate.l2	-1.8241***	0.4094
	(0.2308)	(0.7634)
Interest Rate.l2	-0.0496	-1.1078***
	(0.0614)	(0.2032)
Unemployment Rate.l3	1.2215***	-0.6264
	(0.2714)	(0.8978)
Interest Rate.l3	0.0260	0.7164***
	(0.0693)	(0.2291)
const	-0.5450**	0.7974
	(0.2247)	(0.7432)
int.l4	0.0389	-0.1151
	(0.0643)	(0.2128)
unem.l5	0.0985	-0.4981
	(0.1004)	(0.3322)
int.l5	-0.0577	-0.1956*
	(0.0351)	(0.1160)
const	0.4293*	3.4249***
	(0.2483)	(0.8213)
Observations	99	99
R^2	0.9831	0.9496
Adjusted R^2	0.9812	0.9439
Residual Std. Error (df = 88)	0.2088	0.6908
F Statistic (df = 10; 88)	512.5655***	165.7854***
Note:	*p<0.1; **p<0.05; ***p<0.01	

Figure 6: Estimation Results for Unemployment equation with expanded data

	Coefficients	P_values
unem.l1	1.015	0
int.l1	0.020	0.651
unem.l2	-0.193	0.063
int.l2	-0.005	0.946
unem.l3	0.125	0.090
int.l3	-0.022	0.618
const	0.424	0.101

Figure 7: Estimation Results for Interest Rate equation with expanded data

	Coefficients	P_values
unem.l1	0.011	0.929
int.l1	1.243	0
unem.l2	-0.003	0.984
int.l2	-0.467	0.00005
unem.l3	-0.021	0.865
int.l3	0.175	0.017
const	0.396	0.352

Figure 8: Impulse Response of Unemployment Rate and Interest Rates to an innovation in the Unemployment Equation with expanded data

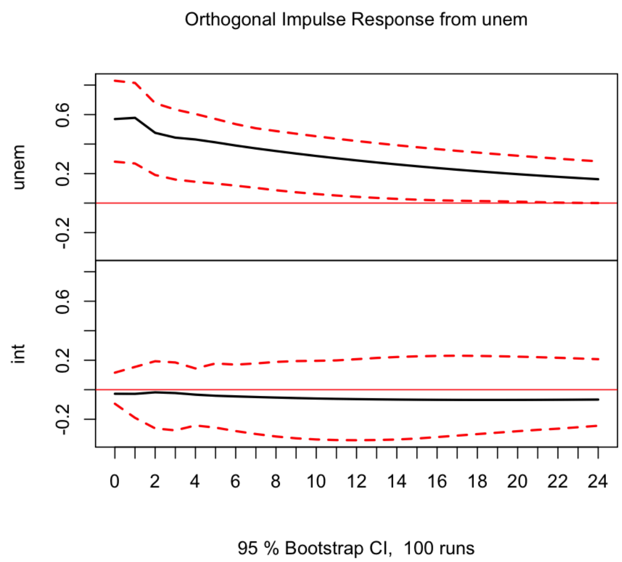


Figure 9: Impulse Response of Unemployment Rate and Interest Rates to an innovation in the Interest Rate Equation with expanded data

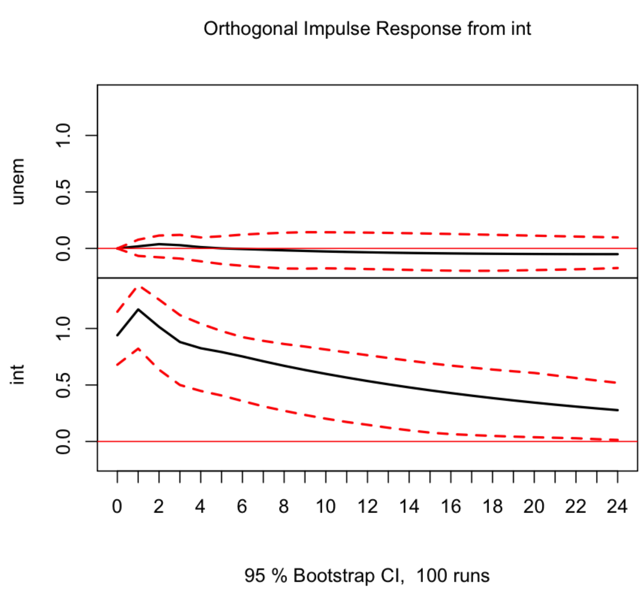


Figure 10: Augmented Dickey-Fuller Test Results.

ADF Test for Unemployment Rate

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        Augmented Dickey-Fuller Test

data:  unem
Dickey-Fuller = -3.965, Lag order = 5, p-value = 0.01217
alternative hypothesis: stationary
```

ADF Test for Interest Rates

```
        Augmented Dickey-Fuller Test

data:  int
Dickey-Fuller = -2.7985, Lag order = 5, p-value = 0.2419
alternative hypothesis: stationary
```

ADF Test for Real GDP

```
        Augmented Dickey-Fuller Test

data:  rgdp
Dickey-Fuller = -5.6197, Lag order = 4, p-value = 0.01
alternative hypothesis: stationary
```