VAR Analysis of Economic Activity, Unemployment, and Inflation during Periods Preceding Recessions in the United States: COVID-19

Noah T. Wessels

Abstract:

This study investigates the impact of Economic Activity, Unemployment, and Inflation on each other during periods preceding recessions. The COVID-19 pandemic has caused governments to implement stay-at-home orders to combat the spread of the virus. These orders have increased unemployment levels within the United States. Therefore, this research attempted to create a VAR model to forecast the values of these economic indicators with a negative shock to Unemployment. The research results were statistically insignificant.

1. Introduction:

The first positive case of COVID-19 in the United States that was not caused by international travel occurred on February 26th, 2020. States responded to this crisis in a variety of ways, but by the end of March 2020 states with major cities like New York, California, Illinois, and Virginia had issued stay-at-home orders to combat the spread of the virus (Wu 2020). Due to the government stay-at-home orders, assessments of the labor market have deteriorated. The unemployment rate increased from 4.4% to 14.7% in the first two quarters of 2020 (U.S. Bureau of Labor Statistics 2020). With an increase in unemployment rate, an increasing number of workers are left jobless and without stable income. The coronavirus pandemic has created a shift in business and practices: no longer can meetings be conducted in person rather for the sake of public health they must be conducted virtually. While virtual meetings are necessary now, not all fields can realistically make this transition. As a result, unemployment has risen by 26 million applications from the beginning of the pandemic to April 23rd (Cohen, 2020). The uncommon spike in jobless claims is reminiscent of The Great Recession of the late 2000's. After seeing the

microeconomic effects of a traumatic global experience firsthand, I decided to study exactly how these complex economic relationships indicate periods of economic growth or contraction. There are striking similarities between the current economic state and the one preceding The Great Recession, particularly a negative demand shock that decreases the aggregate demand curve while the monetary policy curve is upwards sloping due to the proximity of the Federal Funds rate to the zero-lower bound. The question I would like to explore is: Comparing current economic activity data, unemployment data and prices levels to their respective levels in 2007, is the economy headed towards another big recession?

The modern Phillips Curve suggests a negative relationship between inflation and unemployment. According to adaptive expectations, as the public notices a decrease in inflation, they will expect continued decreases based on previous time periods; this theory is exactly how I would like to approach my research. This paper will explore the relationship between unemployment (UR), economic activity (GDP), and inflation (INF). The model I plan to estimate will be a Vector Auto Regression model to forecast the future magnitude of change of prices, economic activity, and unemployment on each other.

This research finds the magnitude of the forecast was relatively unreliable. The model performs poorly and is misspecified. No statistically significant conclusions can be drawn from the VAR model, yet the examination of the trend of the variables of interest has led to a concerning perspective on the state of the United States economy. At the beginning of this research, May 2020, it was unclear how certain a recession was. With new economic data, it has become clear that the United States economy is in a recessionary period.

2. Literature Review:

Economic Activity, Unemployment, and Inflation have been vigorously studied by economists. A.W. Phillips (1958) first concluded the statistical significance of the negative relationship between unemployment and inflation rates. These variables are highly connected, Phillips maintained "that much more detailed research into the relations between unemployment, wage rates, prices and productivity" was needed. Then, Okun posited there is a negative relationship between output and unemployment (Knotek 2007). Although, Knotek (2007) found that this relationship is not as accurate as one might be led to believe. He found that this relationship varies between recessionary and expansionary periods, thus forecasting these values can be improved by using a model that is not as restrictive.

Blanchard and Quah (1988) conduct an analysis of supply and demand shocks and their resulting consequences. They use gross national product as a proxy for economic activity and unemployment rate within a VAR model. The resulting conclusion: there are two types of shocks, supply shocks and demand shocks. The former effects output levels up to about five years and the latter will effect output levels in the short run. Specifically, they find the demand shocks contribute largely to the fluctuations in economic activity "at short- and medium-term horizons." In relation to the coronavirus pandemic, this is concerning as there is both a negative supply shock due and a negative demand shock.

Pilström and Pohl (2009) conduct a similar analysis of economic activity using a theoretical Vector Autoregression framework to forecast values in the Baltic States. The study uses similar variables including quarterly GDP growth, the HICP index as a proxy for inflation, and the unemployment rate. They conclude that smaller scale VAR models were able to perform well up to the horizon of t+12 lags. Their forecasts were less accurate than desirable and could

have been improved through a larger sample size. This is a factor that could play into my research as the sample size for my model is 82.

Bayoumi and Eichengreen (1992) further interrogate the previously stated conclusion regarding supply and demand shocks. They conduct multiple bi-variate VAR models using price and output data within the European Union. Their research primarily identifies and isolates the result of shocks between states. Their conclusion that autonomous monetary policy can aide in adjusting to shocks within the economy. The Federal Reserve implemented their monetary policy actions a few months after the coronavirus pandemic caused lockdowns across the United States (Wu 2020). The speed in decision-making could result in a faster counteraction to the negative shocks imposed by the pandemic. This research contributes to the pre-existing literature through attempting to further understand the relationship between these variables and attempting to provide recessionary policy insight based on statistically significant forecasts.

3. Data Visualization:

There are three variables I will explore: 1) I will use consumer price index data as a proxy for inflation as it is a figure that is commonly used to measure relative purchasing power between different periods of time; 2) I will use gross domestic product data as a proxy for economic activity as it measures total output withing the United States; 3) I will use the unemployment rate. This data comes from the Federal Reserve Economic Database (FRED). The data will be based in the year 2000 to include periods of economic growth and contractions.

To help further understand the source of the data; it comes from the Federal Reserve Economic Database. The variable INF is a measure of inflation. As previously stated, it refers to the Seasonally Adjusted Consumer Price Index for All Urban Consumers: All Items in U.S. City Average. The units for this variable are the quarterly percent changes from a year ago. The

variable GDP is a measure of economic activity. As mentioned above, it refers to Seasonally

Adjusted Real Gross Domestic Product. The units for this variable are the quarterly percent

changes from a year ago. Finally, the variable UR is a measure of unemployment rates. It refers

to the Seasonally Adjusted Unemployment Rate. The unit for this variable is quarterly
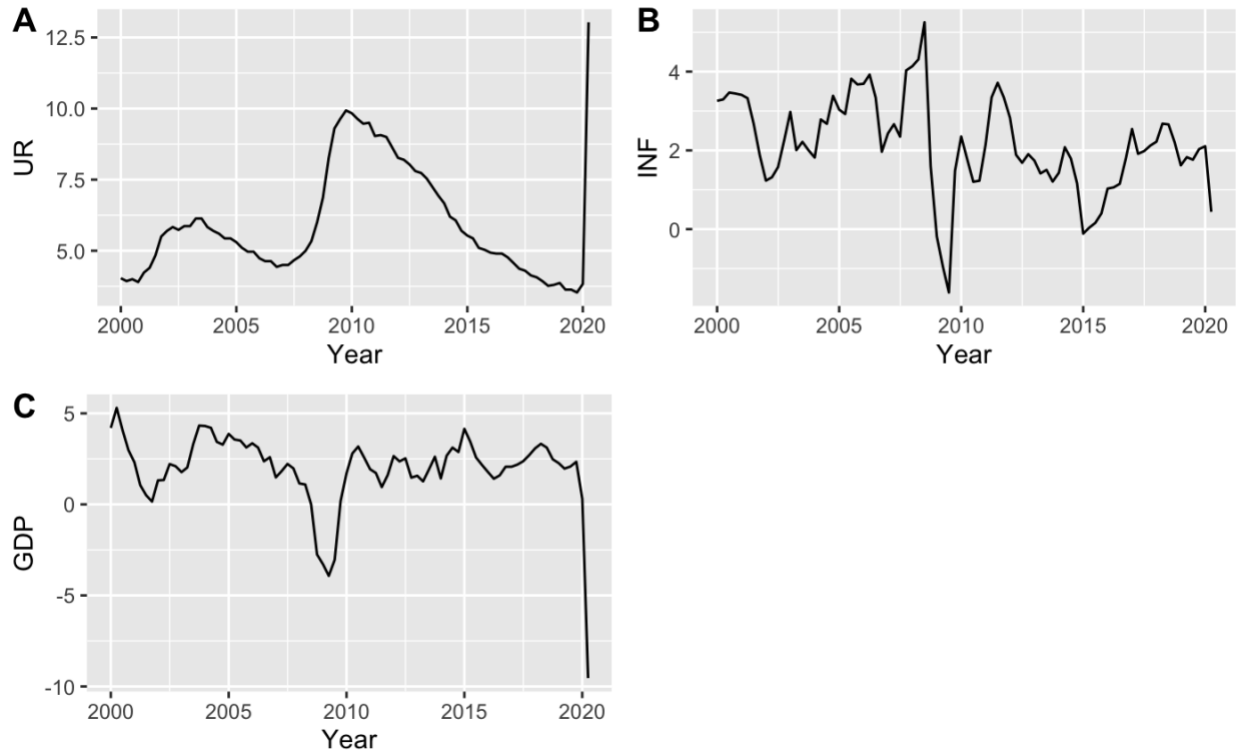
percentage.

Table 1: Summary Statistics

Variables of Interest	Overall (N=82)
INF	
Mean (SD)	2.15 (1.20)
Median [Min, Max]	2.06 [-1.61, 5.25]
GDP	
Mean (SD)	1.94 (2.05)
Median [Min, Max]	2.22 [-9.54, 5.30]
UR	
Mean (SD)	5.94 (1.97)
Median [Min, Max]	5.43 [3.53, 13.0]

Source: Data from FRED

Table 1 displays the summary statistics of the variables of interest. Regarding inflation, it

appears that the Federal Reserve has done anR effectively achieved their target rate of inflation

throughout the 21st century. The target rate of inflation remains 2% (Federal Reserve 2020).

Furthermore, the Gross Domestic Product and Unemployment should be further interpreted with

a line plot to determine the health of the economy.
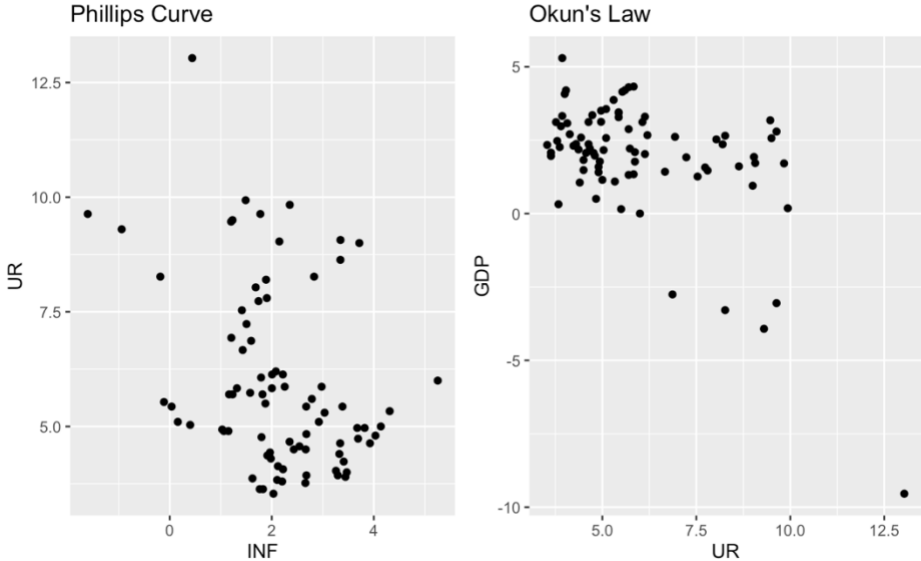
Figure 1: Line Plot

Source: Data from FRED

The preceding graphics show the trends in the Inflation, Unemployment Rate, and Gross Domestic Product from Quarter 1 in the year 2000 to Quarter 2 in the year 2020. During the Great Recession of 2008, the United States Federal Reserve began using non-conventional monetary policy. Specifically, they used forward guidance and quantitative easing to help facilitate recovery through "reducing interest rate volatility and uncertainty" (Rudebusch 2018). Presently the recessionary period induced by the coronavirus, the Federal Reserve has taken a similar approach to monetary policy action. On June 10th, 2020, the federal reserve convened for a Federal Open Market Committee meeting. In this meeting they decided to use forward guidance as a monetary policy tool; the implemented policy is reminiscent of expansionary policy in 2008. The policy begins, "to hold interest rates steady at near-zero" (Cheung 2020). Thus, the Federal Reserve holds the intention of assisting the economy throughout the pandemic and for the foreseeable future by "keeping rates at the lower bound through at least 2022"

(Cheung 2020). This commitment to a lower interest rate is meant to stimulate long-term economic growth.
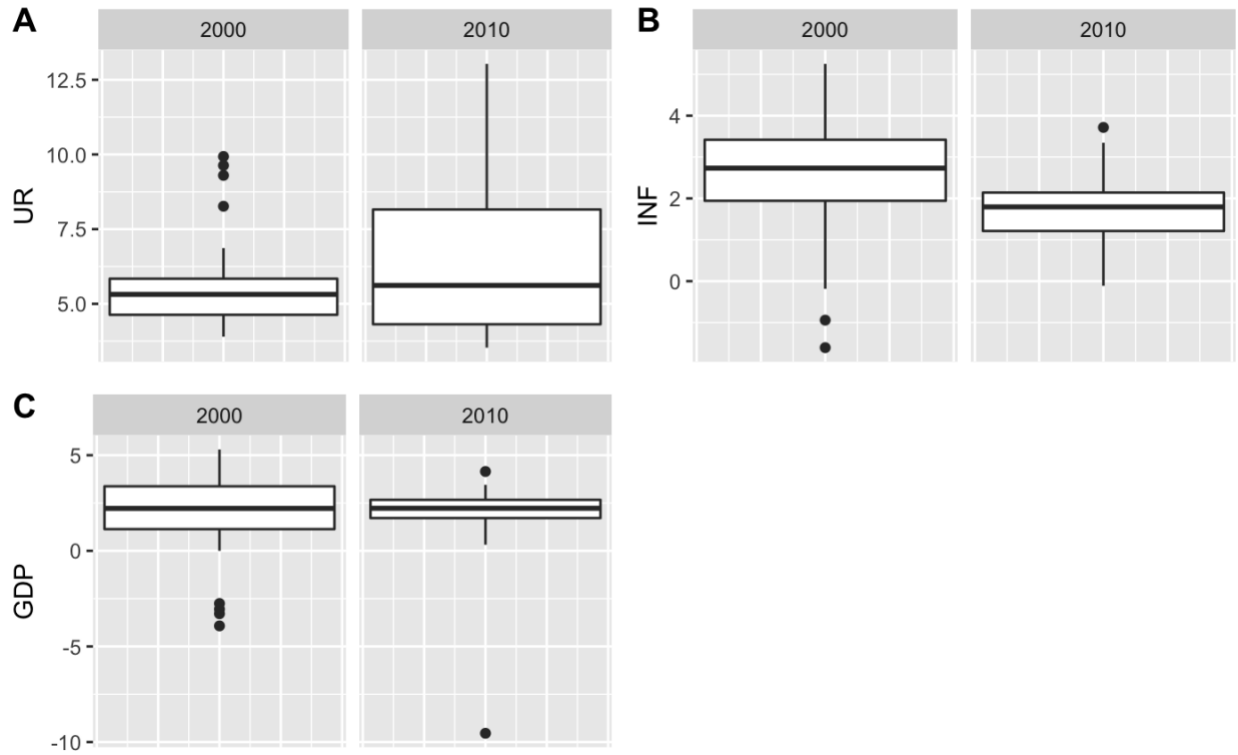
Figure 2: Scatterplots

Source: Data from FRED

Considering the above scatterplots, one deduces there to be a negative relationship between Unemployment Rate and Inflation during the 21st century. Visually, this supports previous findings backing Phillips Curve theory. Additionally, there appears to be a slightly negative relationship between Economic Activity and Unemployment Rate, which supports previous findings backing Okun's Law. These observations can be understood superficially, but for my research understanding the visually apparent relationship between the two sets of variables is important to denote preceding the progression of this research.
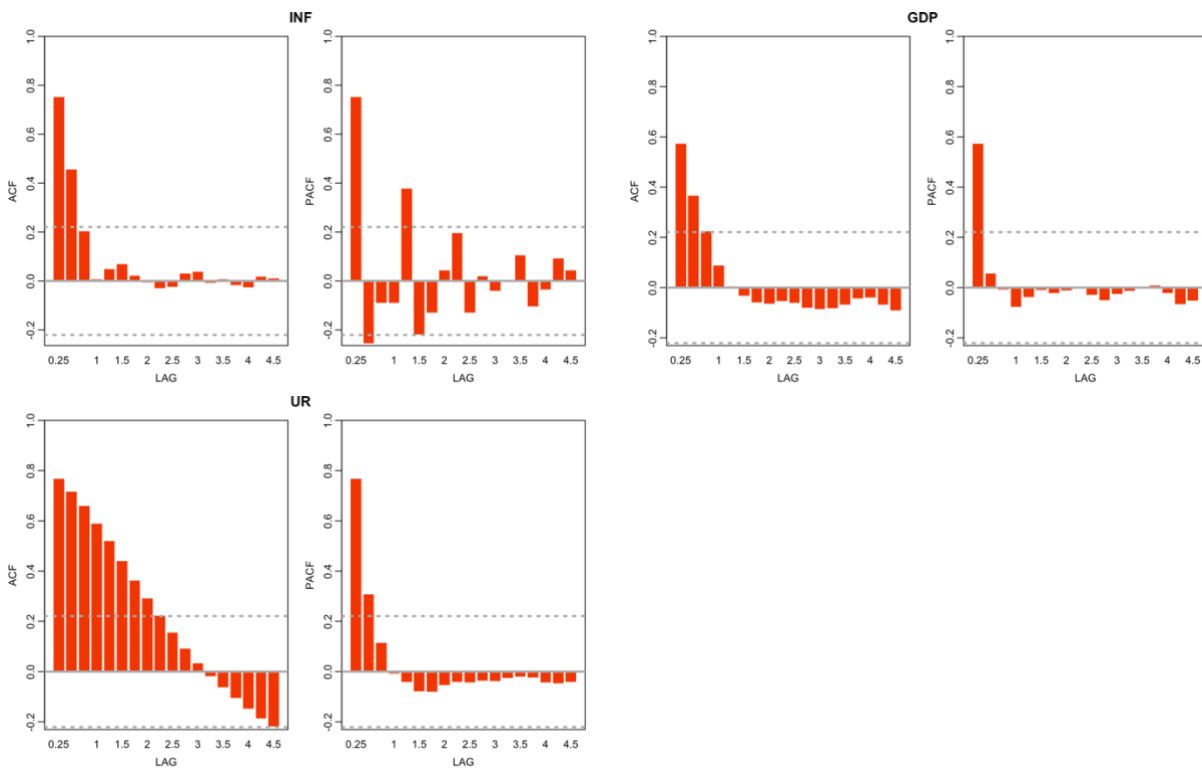
Figure 3: Boxplots by Decade

Source: Data from FRED

I identified several outliers within the data using boxplots. Within the Unemployment Rate data, there is one outlier dated for the second quarter of 2020, which I included here to analyze a particular period of interest. Within the GDP data, there are five different outliers. The first four occur from the fourth quarter of 2008 until the third quarter of 2009. These outliers are caused by the Global Recession and the collapse of the global economy. Finally, the last outlier is from the second quarter of 2020. Negative shocks to the economy, those which I have researched, caused these GDP outliers. Within the inflation data there are three outliers; all three of these outliers occurred during the Global Recession. This information indicates a trend for periods after the coronavirus pandemic has been resolved. Due to the pandemic the United States will see decreased inflation, increased unemployment, and a decrease in economic activity; this idea informed my hypothesis on the resulting period. Obviously, stay-at-home orders halt economic activity thus affecting the labor market and in turn decreasing inflation.

4. Identification Strategy:

I select a Vector Autoregressive model because of the causality relationship between unemployment and inflation as well as Unemployment and Economic Activity. The VAR model can run without levying any structures on the variables. This is a more appropriate approach because of the underlying relationships between Economic Activity and Unemployment Rates. As Knotek (2007) found, the forecasts will be improved by unrestricting the relationships between dependent and independent variables. One of the first aspects of the data that needs to be addressed is the stationarity of the data.

Figure 4: ACF and PACF

Source: Data from FRED

To determine the persistence of the model, I ran autocorrelation (ACF) and partial autocorrelation functions (PACF). The PACF for GDP only returns a significantly different value from zero for the first lag, whereas the ACF returns significantly different values from zero

for the first four lags and then diminishes. Thus the indirect effects of this variable on future lags is greater than the direct effects. The PACF for this variable indicates, however, that GDP does not appear to be a effective factor into this model. The ACF for UR returns statistically different values from zero for the first ten lags; the PACF for UR returns statistically different values from zero for the first two lags. Therefore, the unemployment rate has a notable effect on the current value when more than one lag behind such value. Finally, the ACF for INF displays significantly different values from zero three lags and then decreases. The PACF for INF displays several statistically different values from zero up to the sixth lag in both the positive and negative direction. The inflation variable is a notable factor to include within the model.

Next, I will determine the appropriate lag selection for this model. According to the Akaike Information Criterion and Final Prediction Error tests, the number of lags within the model should be nine. The Hannan-Quinn and Schwarz Criterion tests result in the number of lags identified in the model being one. As I began to run the analysis with lag nine, it resulted in an inability to produce impulse response functions and forecasts. This is due to a small sample size and the lack of persistence within the model. Therefore, I returned to this step and began running the analysis with one lag; the issue with this pathway is that it potentially indicates a misspecified model, which resulted in the following VAR model:

VAR (1): (1) $GDP_T = \alpha + \beta_1 GDP_{T-1} + \beta_2 GDP_{T-2} + \cdots \beta_j GDP_{T-j} + \gamma_1 UR_{T-1} + \gamma_2 UR_{T-2} +$

$$\cdots \gamma_j UR_{T-j} + \delta_1 INF_{T-1} + \delta_2 INF_{T-2} + \cdots \delta_j INF_{T-j} + \mu_T$$

Which then implies:

$$GDP_T = \alpha + \sum_{j=1}^{k} \beta_j GDP_{T-j} + \sum_{j=1}^{k} \beta_j UR_{T-j} + \sum_{j=1}^{k} \beta_j INF_{T-j} + \mu_T$$

Within this equation, GDP at time *T* refers to the current value of gross domestic product, and it is derived from previous values of gross domestic product, unemployment rate, and

inflation. The k denotes the number of lags used to forecast the current value. Additionally, β, γ, and δ all refer to the coefficients attributed to each of the individual variables. The j refers to the start and end of the series, thus the series begins and j and ends at the lag length of k. Finally, μ represents the error term associated with the model.

Table 2: Vector Autoregression Estimates

Variables of Interest	GDP	INF	UR
INF (-1)	-0.1888 (0.0906) [0.1721]	0.7095 (0.0773) **[0.0000] *****	0.0.782 (0.1025) [0.4481]
GDP (-1)	1.0853 (0.1044) **[0.0000] *****	0.1546 (0.0590) **[0.0105] ***	-0.2865 (0.0782) **[0.0004] *****
UR (-1)	0.2064 (0.0906) **[0.0254] ***	0.0279 (0.0511) [0.5863]	0.8333 (0.0678) **[0.0000] *****
Constant	-1.1462 (0.7331) [0.1221]	0.1097 (0.4139) [0.7917]	1.5150 (0.5489) **[0.0072] ****
R^2	0.5947	0.6219	0.7555
Adj R^2	0.5789	0.6072	0.7460
P-Value	0.0000	0.0000	0.0000

*denotes estimates that are significant at the 5% level

**denotes estimates that are significant at the 1% level

***denotes estimates that are significant at the 0% level
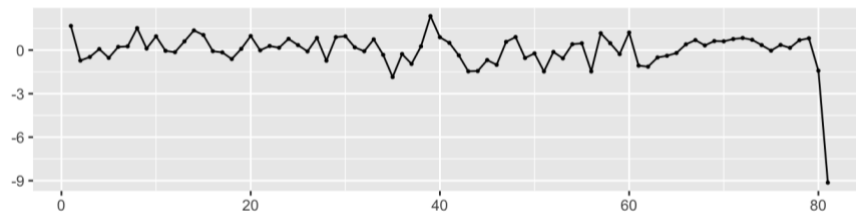
Source: Data from FRED

The preceding table presents the estimation results for the VAR model. The typical application of a VAR model would not be understood in the same sense as a traditional Ordinary Least Squares regression. Therefore, I will not interpret the results of the estimation. These estimates will be sued in producing plots for further analysis. The most critically minded method of interpretation is impulse response functions. I will analyze the effects of shocks from Unemployment and Inflation on GDP, but first I will analyze a few of the model diagnostics tests.
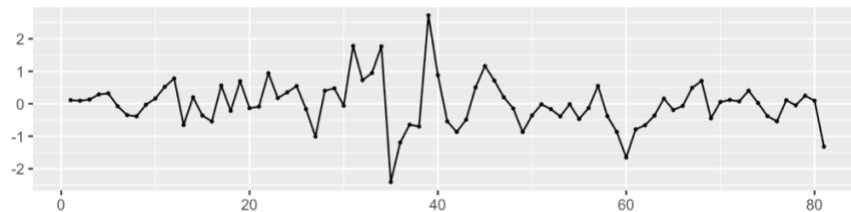
5. Model Diagnostics:

In the following section I will test for several things: Serial Correlation within the model, whether or not the residuals are considered white noise, heteroskedasticity within the model, and the distribution of the residuals.

First, I perform an asymptomatic Portmanteau's Test in order to test for serial correlation within the model. I specified the lags used for the test to be 12. Typically, the lags used within this test are typically greater than the lags selected by the model. The p-value returned from this test is 0.6668, which is greater than the alpha of 0.05. I can thus conclude that there is no serial correlation within the model.
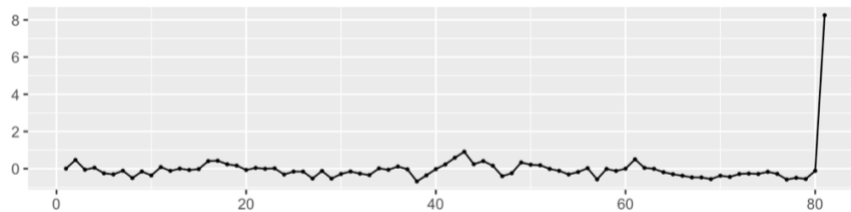
GDP Residuals

INF Residuals

UR Residuals

Source: Data from FRED

The preceding plots display the residuals of each variable plotted over time. In order for the residuals to be considered white noise, they should be close to zero. They will not exactly be

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zero as there is some random variation. The first plot, *GDP Residuals*, I can determine that there is a significant structural break in the residuals of this variable in the most recent data. This is due to the classification of these data points as extreme outliers. The second plot, INF Residuals, I can determine that the data points around the 2007 Global Recession signify that they are not white noise within the data. Finally, the last plot, UR Residuals, I can determine that there is a significant structural break in the residuals of this variable in the most recent data. Thus, there are portions of the residuals that are not considered white noise. This will negatively affect the precision and accuracy of the model. Therefore, the impulse response functions and fan forecasts will not be as accurate as possible.

Then, I perform an ARCH effects test in order to deny the existence of heteroskedasticity. The lags specified within this test is once again 12. The p-value returned from this test is 0.7252, which is greater than the alpha of 0.05. Thus I conclude that there is no heteroskedasticity, or periods of volatility, within the model.

I perform several normality tests in order to test if the residuals of this model are normally distributed. The Jarque-Bera test will measure for goodness-of-fit and whether the residuals match the normal distribution. The resulting p-value from this test is 0.0000, which is less than the alpha of 0.05. Thus, I can conclude that the residuals are not normally distributed. I then ran a Skewness test which examines normality but does so through the overall shape of the model. The p-value returned from this test is 0.000, which is less than the alpha of 0.05. I conclude that based on the overall shape of the model, once again the residuals are not normally distributed. Finally, I perform a Kurtosis test: a normality test based on the shapes of the tails of the distribution. The p-value returned from this test is 0.0000, which is less than the alpha of 0.05. I conclude that based on the shape of the tails of the distribution, the residuals are not

normally distributed. According to all of this information, the residuals of the model do not follow a normal distribution. I might still continue towards forecasting the data.

6. Analysis:

In this section, I will conduct Granger Causality tests and produce impulse response functions and forecast fan charts. A Granger Causality test examines whether or not there is a unidirectional correlation, multidirectional correlation, or no correlation. Impulse Response Functions will depict how a variable will react, a number of periods from today, if there is a shock within the system.
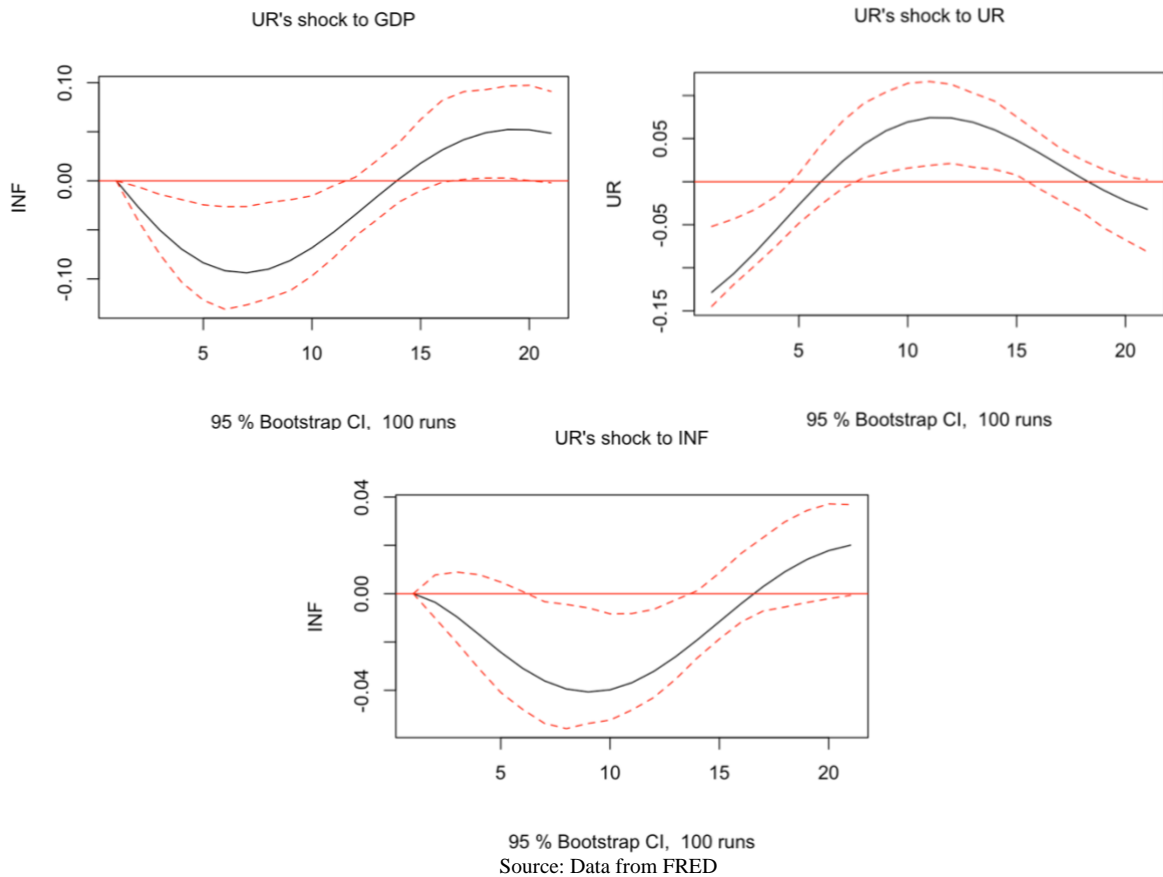
The first Granger Causality test I run is on GDP. This test will determine whether or not GDP granger-causes UR or INF. The result of this test is a p-value of 0.0003, which is less than the alpha of 0.05, which means that I conclude at the 95% confidence level that GDP does in fact granger-cause Unemployment and Inflation.

The next Granger Causality test I run is on UR. This test will determine whether or not UR granger causes GDP or INF, which could support Okun's Law. The result of this test is a p-value of 0.0754, which is greater than the alpha of 0.05. Thus, I cannot conclude that at the 95% confidence level that UR granger-causes GDP and Inflation. The result does not support Okun's Law.

Finally, the last Granger Causality test I run is on INF. This test will determine whether or not INF granger causes GDP or UR. The result of this test is a p-value of 0.2816, which is greater than the alpha level of 0.05. Therefore, I cannot conclude that at the 95% confidence level that INF granger causes GDP and UR.
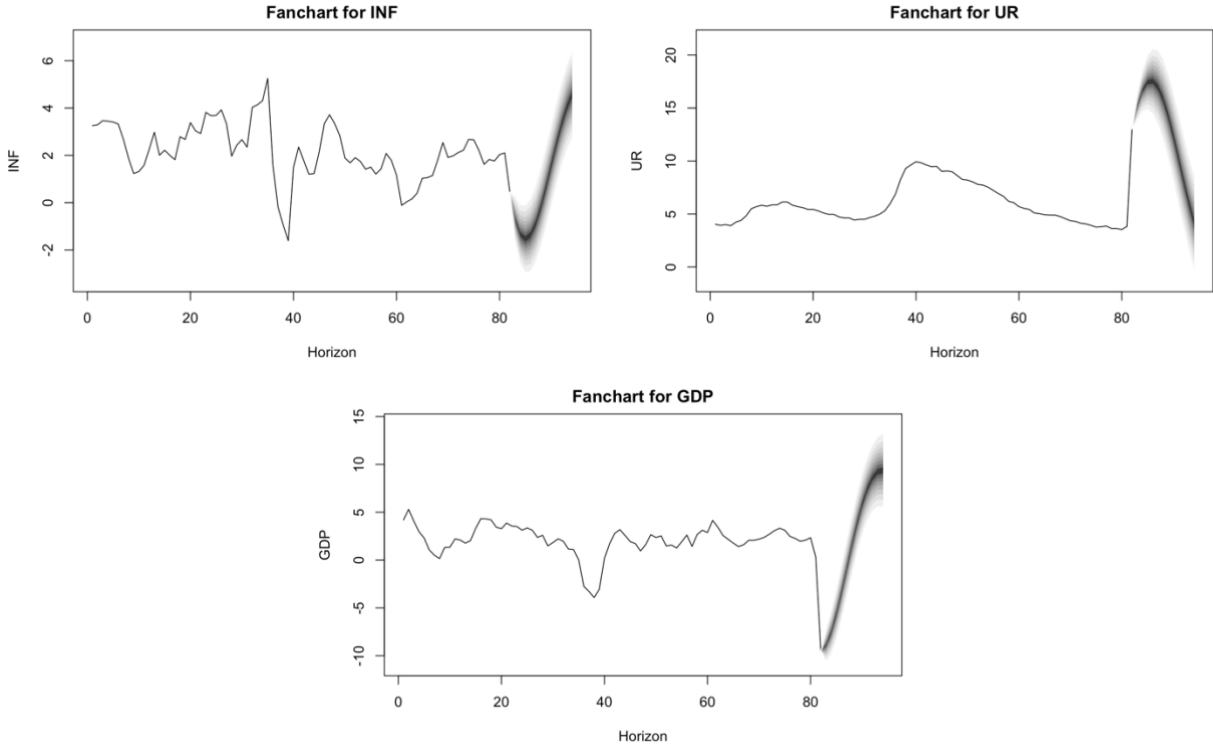
As previously stated, there has been an increase in the Unemployment Rate within the United States due to the stay-at-home orders caused by the coronavirus pandemic. The impulse

response functions that I will explore will be based around a negative shock to the unemployment rate, thus mimicking the current labor market situation. These plots predict the effects of the shock 20 quarters ahead.

95 % Bootstrap CI, 100 runs

Source: Data from FRED

The first impulse response function displays the effect of a positive unemployment rate shock on GDP. Based on these plots, I will be able to determine relationships between the variables. In the first plot, *UR's shock to GDP*, the increase in unemployment decreases overall economic activity. The confidence bands for this impulse response function lie below the x-axis. I can thus conclude that a positive shock to unemployment will have a negative effect on economic output. Ceteris Paribus, United States GDP could see continued decreases up to 5 quarters past the initial shock. The second impulse response function, *UR's shock to UR,* displays the effect of a positive unemployment rate shock on itself. Of course, a positive shock of

one variable on itself is bound to increase the variable. The final impulse response function, *UR's shock to INF,* displays the effect of a positive unemployment shock on inflation. The initial impact of this shock is more ambiguous than the other shocks, the confidence bands don't signal a specific direction until after 5 quarters into the horizon. We cannot conclude with statistical significance that, ceteris paribus, a positive shock to unemployment will increase inflation in the short run. However, the plot does show in the long run the shock will eventually be seen in decreased inflation.

Source: Data from FRED

The fan forecasts above display the predicted paths of each specific variable based on the VAR model described in this research. The first forecast, *Fan chart for INF*, shows that inflation will continue to decrease in the coming quarters until it rebounds. The second forecast, *Fan chart for UR*, shows that the unemployment rate will continue to increase in the coming quarters until

it rebounds as well. These two forecasts mirror each other because these two variables notably impact each other.

The third forecast, Fan chart for GDP, shows that overall economic activity within the United States will rebound from the coronavirus very quickly. This forecast does not take into account continued stay-at-home orders and economic lockdowns within certain areas of the United States. Therefore, this forecast is relatively unreliable. If the economy does not fully reopen, overall economic activity will not recover at the rate within the forecast. The magnitudes of these forecasts are misrepresented. From my data analysis, I know that the most recent values of these variables are outliers within the data. With the lag length of this model being one previous lag, the first forecasts have been contingent on outliers, and then the return to normal levels is more representative of the entire dataset.

7. Conclusions:

Overall, these forecasts are relatively unreliable primarily because of faults within the model: the distribution of the residuals is not considered white noise and the data is not persistent. One improvement that could be made to adjust for the data's lack of persistence is differencing the data. I avoided this method because of the stark change in values due to the negative demand shock. The distribution of the residuals signals that there is an error the model assumptions. Stationarity is one essential model assumption. The most recent economic indicators and the inflation rate associated with the Global Recession of 2008 break up the constant mean and mis specify the model. A more complex model such as a Smooth Transition Autoregressive model could account for the structural break caused by the outlier values.

At best, this research forecasts values based upon previously known relationships between these variables and is very optimistic. The uncertainty within the United States economy

will play a huge factor in the length of the impending recession and recovery. While the research accomplishes the exploration of the relationship between Economic Activity, Inflation, and Unemployment Rate, it does not achieve the goal set upon and is relatively insignificant. My research is unable to produce a statistically significant response to the question of if the United States is headed towards a recession like the Global Recession of 2008. Therefore, there are no noteworthy implications for these findings. Nevertheless, the exploration of these trends and current economic theory has led me to the personal conclusion that the longer stay-at-home orders remain in place, the threat of the coronavirus to the US economic environment will continue to become more concerning.

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