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Research on the Relationship Between Inflation, GDP and Unemployment Rate

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Abstract: Inflation in the United States has continued to rise since the second quarter of 2021, and the Fed's aggressive monetary tightening policy has sparked market concerns. This paper attempts to apply the Vector Autoregression (VAR) model to study the interaction mechanisms between GDP, inflation and unemployment rate between the first quarters of 2012 and 2022 in the United States. Try to disentangle the effects of shocks emanating from each source. As a result, the three macroeconomic factors have a specific causal relationship. GDP and unemployment rate can predict inflation one way, while GDP and unemployment can predict each other. The shocks of GDP and inflation are mainly derived from their own changes, while the shocks of unemployment are mainly derived from changes in GDP.

Keywords: GDP, Unemployment, Inflation, VAR

1. Introduction

The United States' inflation rate has been soaring since March 2021, when it exceeded the acceptable 1-2% per year and peaked at 9.1% in June 2022. The Fed raised interest rates five times in response to high inflation, by 300 basis points in the first three quarters. The Fed's goal is to achieve a soft landing by reducing the red-hot inflation rate that erodes Americans' purchasing power without triggering a recession. However, soft landings are infrequent [1]. Furthermore, it contradicts the accepted economic theory that inflation might drop significantly without a matching rise in labor market slack[2].

The economic theoretical basis of this paper is the Phillips curve and Okun's law. Inflation and unemployment are inversely connected, according the Phillips curve [3]. Okun's law investigates the connection between a nation's GDP and employment levels. It predicts that a 1% drop in employment tends to be accompanied by a 2% drop in GDP and vice versa [4]. Based on these two theories, there is some literature discussing the possible relationship between the three. To examine the connection between China's GDP, inflation, and unemployment, Li and Liu created a VAR model [5]. They also found that, despite the long-term stable equilibrium relationship between these three macroeconomic variables, economic growth is positively connected with unemployment in the short run [5]. In contrast, there is a negative relationship between unemployment and inflation [5]. Using the Autoregressive Distributed Lag (ARDL) Model, Mohseni and Jouzaryan found a significant negative association between inflation, unemployment, and economic growth in Iran from 1996 to 2012 [6]. Sahnoun and Abdennadher implemented a vector error-correction model to

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examine the unidirectional relationship between unemployment, economic growth, and inflation in North African states between 1965 and 2016. [7].

From the past literature, it can be found that GDP, inflation, and unemployment rate have different performance results in different regions, different times, and different detection periods. That is to say, the relationship between these three macroeconomic variables cannot be generalized. As a result, this article uses the VAR model to examine the link between GDP, inflation, and the unemployment rate in the United States during the last decade. This paper reveals the potential relationships and interaction mechanisms of the three macroeconomic variables in the US: GDP, inflation, and unemployment.

2. Methodology

2.1. Data Collection

All three data sets utilized in this essay are from the Federal Reserve Economic Data (FRED). The study spans 41 quarters, from the first quarter of 2012 through the first quarter of 2022. The data for this time is used because, since January 2012, inflation targeting has been the Federal Reserve's primary aim in order to preserve low unemployment and stable prices. Specifically, GDP is the percentage change compared to the previous quarter and the frequency is quarterly. Quarterly inflation rates utilize the Consumer Price Index for All Urban Consumers: All Items in the U.S. City Average (CPIAUCSL). The aggregation method is the three-month average within the quarter. The unit of Unemployment Rate (UNRATE) is a percentage, the frequency is a quarter, and the aggregation method is also an average. These variables' descriptive statistics and correlation matrix are shown below.

Table 1: Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
Inflation	41	2.175399	1.894675	-0.11289	8.58063
GDP	41	1.130771	2.136796	-8.82764	8.78811
UNRATE	41	5.55122	1.914232	3.6	12.96667

Table 2: Correlation matrix.

	Inflation	GDP	UNRATE
Inflation	1		
GDP	0.2717	1	
UNRATE	-0.3399	-0.3153	1

2.2. The Vector Autoregression (VAR) Model

The most current observations of one variable are connected to the history data for that variable as well as other variables by use of a multivariate time series model that is known as a vector autoregressive (VAR) model. It is utilized to illustrate the relationship between a number of different quantities as they change over a period of time. Each variable in the VAR model is a linear combination of its historical values and those of the other variables. This three-equation system investigates three interdependent time series. They are one for the inflation rate, one for GDP, and one for unemployment. The vector autoregressive model of order 1, called VAR(1), is assumed to be as follows:

$$\text{Inflation}_t = \alpha_1 + \beta_{11}\text{Inflation}_{t-1} + \beta_{12}\text{GDP}_{t-1} + \beta_{13}\text{UNRATE}_{t-1} + \varepsilon_{\text{Inflation}} \quad (1)$$
$$\text{GDP}_t = \alpha_2 + \beta_{21}\text{Inflation}_{t-1} + \beta_{22}\text{GDP}_{t-1} + \beta_{23}\text{UNRATE}_{t-1} + \varepsilon_{\text{GDPt}} \quad (2)$$
$$\text{UNRATE}_t = \alpha_3 + \beta_{31}\text{Inflation}_{t-1} + \beta_{32}\text{GDP}_{t-1} + \beta_{33}\text{UNRATE}_{t-1} + \varepsilon_{\text{UNRATEt}} \quad (3)$$

Where Inflation is CPI
GDPt is Gross Domestic Product growth rate
UNRATEt is unemployment rate
Steps performs an VAR,
1. Assess data stationarity
2. Establishment of lag length
3. Estimation of VAR
4. Test Inverse Roots of VAR Characteristic Polynomial
5. Test Autoregression
6. Test the granger causality
7. Variance decomposition
8. Forecasting

3. Findings

3.1. Stationarity Test

This study employed the Dickey-Fuller and Phillips–Perron tests to determine if inflation, GDP, and unemployment rate have unit roots. The null hypothesis says that time series with unit roots are not stationary. Alternative hypothesis is series is stationary. Below is a table containing the test outcomes. The P-values of the Dickey-Fuller and Phillips–Perron inflation tests are more significant than 5%, indicating that the inflation time series is nonstationary.

Table 3: Unit roots test of original series.

P-Values	Inflation	GDP	Unemployment
Dickey-Fuller test	0.9971	0.0000	0.0000
Phillips–Perron test	0.9912	0.0000	0.0000

Therefore, the unit root test on the difference among the three series is required. The results are shown in Table 2. The three-time series in the first difference is stationary since all P-values are less than 0.05.

Table 4: Unit roots test of 1-st difference series.

P-Values	dInflation	dGDP	dUnemployment
Dickey-Fuller test	0.0001	0.0000	0.0000
Phillips–Perron test	0.0000	0.0000	0.0000

3.2. Lag Length Criteria

Final prediction error (FPE), Akaike's information criteria (AIC), Schwarz's Bayesian information criterion (SBIC), and Hannan and Quinn information criterion (HQIC) suggest a 3-lag length for the VAR model of dinflation, dGDP, and dUnemployment.

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Table 5: Lag-order selection criteria.

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-196.085				12.7648	11.0603	11.1063	11.1922
1	-136.59	118.99	9	0.000	0.774244	8.255	8.43923	8.78284*
2	-126.529	20.122	9	0.017	0.738952	8.19606	8.51847	9.11978
3	-110.957	31.144*	9	0.000	.528493*	7.83094*	8.29151*	9.15054
4	-108.098	5.717	9	0.768	0.787268	8.17213	8.77088	9.88761
* Optimal lag								
Endogenous: dGDP dInflation dUNRATE								
Exogenous: _cons								

3.3. Inverse Roots of VAR Characteristic Polynomial

After estimating the VAR model using the difference between first-quarter inflation, GDP, and unemployment, the system's eigenvalue stability requirement is examined. The outcomes are displayed in the table below. The estimations meet the eigenvalue stability condition since each eigenvalue has a modulus of less than 1. This means that the VAR model consisting of dInflation, dGDP, and dUnemployment satisfies the stability condition.

Table 6: Eigenvalue stability condition.

Eigenvalue			Modulus
-0.3963469	+	.6941659i	0.799348
-0.3963469	-	.6941659i	0.799348
0.2582114	+	.5080355i	0.569889
0.2582114	-	.5080355i	0.569889
-0.4382183	+	.2205673i	0.490597
-0.4382183	-	.2205673i	490597
0.4252468	+	0.1838819i	0.4633
0.4252468	-	0.1838819i	0.4633
-0.3062683			0.306268

Plot the eigenvalues using real on the x-axis and complex on the y-axis to demonstrate the outcome. These eigenvalues are located entirely within the unit circle, as seen graphically in Figure 1.

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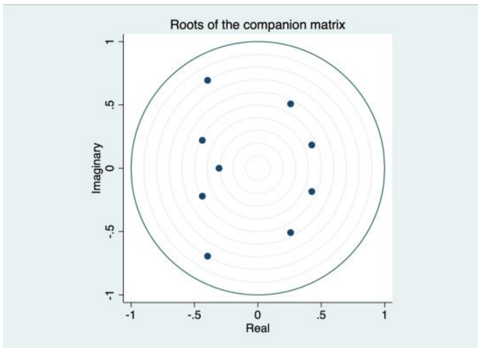

Figure 1: Roots of the companion matrix.

3.4. Granger Causality Test

Granger's causality test tests if one time series predicts another [8]. This study investigates the existence of Granger-causality among dinlfation (difference in inflation), dGDP (difference in GDP) and dunemployment (difference in unemployment). Table 5 displays findings. The results indicate that unemployment may generate Granger growth, whereas inflation cannot. Both GDP and unemployment can Granger cause inflation. GDP Granger causes unemployment, while inflation doesn’t. So, there exists one-way Granger Causality between GDP and inflation, unemployment and inflation. GDP and unemployment exhibit Granger Causality in both directions.

Table 7: Granger causality wald tests.

Equation	Excluded	chi2	df	Prob > chi2
dGDP	dInflation	1.2615	3	0.738
dGDP	dUNRATE	47.412	3	0.000
dGDP	ALL	54.754	6	0.000
dInflation	dGDP	25.248	3	0.000
dInflation	dUNRATE	10.202	3	0.017
dInflation	ALL	29.486	6	0.000
dUNRATE	dGDP	14.458	3	0.002
dUNRATE	dInflation	1.9468	3	0.584
dUNRATE	ALL	15.277	6	0.018

3.5. Impulse Response Function (IRF)

An impulse-response function illustrates the variable's development after a shock. It describes how the variable responds over time to exogenous impulses called "shocks”. Impulse response function graph in Figure 2.

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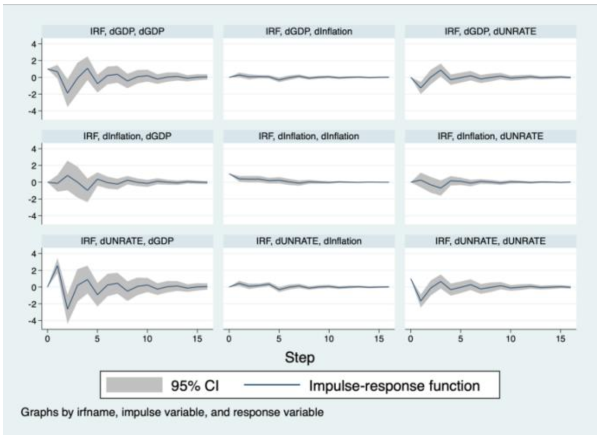

Figure 2: Impulse response function.

The first is the analysis of the impact of unemployment and inflation shocks on GDP, respectively. When inflation increases, GDP increases for the first two quarters, then decreases and stabilizes after the fifth quarter. The second is the response of GDP to the shock of the unemployment rate. When unemployment rises, GDP would fall sharply after a brief increase in the first quarter. Then GDP will rebound in the third quarter and stabilize gradually after that. These two points can be summed up as the increase in inflation or unemployment having a slight short-term positive effect on GDP growth, but the negative effect is close behind.

The second component is an individual investigation of how changes in GDP and unemployment rates influence price increases. When GDP grows, inflation increases slightly in the first quarter with no apparent response and then stabilizes. The same situation occurs in the effect of the unemployment rate shock on inflation, which also has a slight positive effect at first and then stabilizes. That is to say, GDP and unemployment rates have no obvious effect on inflation.

The third is the analysis of the unemployment rate by shocks of GDP and inflation rate respectively. When GDP grows, unemployment decreases in the first quarter, increases significantly in the second and third quarters, and then stabilizes. The influence of an inflation shock on the unemployment rate is the opposite to that of a GDP shock. When inflation increases, unemployment also increases slightly in the first quarter, then decreases in the second and third quarters, and then stabilizes.

3.6. Forecast Error Variance Decomposition (FEVD)

The forecast error variance decomposition, often known as FEVD, is a component of the VAR model analysis that breaks down the variance of the prediction error into the contributions made by various exogenous shocks. FEVD may show how a shock affects the model's variables over time [9]. The next three tables will show the performance of the three variables for specific exogenous shocks after 16 periods.

Table 8: Variance decomposition of dGDP.

period	dGDP	dInflation	dUNRATE
1	1	0	0
2	0.8495	0.001292	0.149207
3	0.734762	0.015331	0.249907
4	738033	0.0151	0.246867

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Table 8: (continued).

5	0.716982	0.030874	0.252144
6	0.704933	0.033002	0.262065
7	0.704194	0.033027	0.262779
8	0.701256	0.033794	0.264949
9	0.697615	0.034679	0.267706
10	0.697541	0.034679	0.26778
11	0.696611	0.034991	0.268397
12	0.695764	0.035173	0.269063
13	0.695742	0.035172	0.269085
14	0.695507	0.035246	0.269247
15	0.695278	0.035296	0.269425
16	0.695274	0.035296	0.26943

First of all, without considering the contribution of GDP itself, the inflation shock to GDP rate will gradually increase and reach a maximum value of about 3.5% in the 16th period, while the contribution of the unemployment rate will reach about 26.9%.

Table 9: Variance decomposition of dInflation.

period	dInflation	dGDP	dUNRATE
1	0.671542	0.328458	0
2	0.622166	0.265686	0.112149
3	0.628674	0.265646	0.10568
4	0.640653	0.245944	0.113403
5	0.509872	0.355609	0.134519
6	0.502259	0.337	0.160741
7	0.501473	0.338203	0.160324
8	0.500321	0.334522	0.165157
9	0.497833	0.333059	0.169108
10	0.497778	0.333034	0.169188
11	0.497025	0.332501	0.170473
12	0.496441	0.331919	0.17164
13	0.496434	0.331923	0.171643
14	0.496262	0.331736	0.172002
15	0.496113	0.331609	0.172278
16	0.496112	0.331609	0.172279

The above table shows the proportion of GDP and unemployment shocks to inflation. Except inflation shocks to itself, the contribution to inflation of GDP shocks will gradually increase and stabilize at around 33.2% after the sixteenth period, while the contribution to unemployment shocks will reach 17.2%.

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Table 10: Variance decomposition of dUNRATE.

period	dUNRATE	dGDP	dInflation
1	0.110753	0.88906	0.000187
2	0.310086	0.681667	0.008247
3	0.307443	0.677577	0.014979
4	0.309659	0.64133	0.049011
5	0.313736	0.635559	0.050705
6	0.313532	0.635056	0.051412
7	0.31636	0.631863	0.051777
8	0.318577	0.629225	0.052198
9	0.318563	0.629218	0.052219
10	319636	0.627675	0.052689
11	0.320097	0.627107	0.052796
12	0.320099	0.627078	0.052824
13	0.320352	0.626729	0.052919
14	0.32048	0.626575	0.052945
15	0.320481	0.62657	0.052949
16	0.32055	0.626473	0.052977

The above table shows the proportion of GDP and inflation rate shocks to unemployment. Excluding the effect of unemployment on itself, the contribution of GDP shocks will reach 62.6%, while the contribution of inflation shocks will gradually increase to 5.3%.

After doing the above series of analyses, GDP, inflation, and the unemployment rate for the next four quarters are forecasted, from Q2 2022 to Q1 2023. The outcomes are displayed in the table below. The first row shows the difference between 2021 and 2022. Between Q2 2022 and Q1 2023, changes are expected. According to the forecast, GDP will drop by about 0.32% in the second quarter of 2022, inflation will increase by about 0.53%, and the unemployment rate will increase by about 0.16%.

Table 11: Forecast.

Date	dGDP_f	dInflation_f	dUNRATE_f
2022q1	.44602	.58024	-.2
2022q2	-.31885948	.52869061	.15815958
2022q3	.71575251	.30166778	-.92500831
2022q4	-1.5356199	.15738523	.47405046
2023q1	1.0646783	.25279951	-.03398041

4. Conclusion

This study looks into the correlation between GDP, inflation, and the unemployment rate in the United States. To begin, evidence from the Granger Causality test. The GDP and inflation, as well as unemployment and inflation, are all linked in a unidirectional Granger causation. Specifically, GDP can Granger cause inflation, and the unemployment rate can also Granger cause inflation, but the inflation rate cannot Granger cause GDP or unemployment. That is to say, GDP and unemployment time series are helpful in the prediction of inflation time series, but not vice versa. There is a Granger causation in both directions between GDP and unemployment. That is, the GDP and unemployment time series are mutually predictive.

From the impulse response function, the effects of inflation and unemployment shocks on GDP tend to be the opposite. The impact of GDP and unemployment shocks on inflation is relatively muted and has the same trend. The shocks of GDP and inflation have the opposite impacts on unemployment. According to forecast error variance decomposition (FEVD), GDP and inflation shocks are mostly driven by their own changes, whereas unemployment shocks are primarily caused by GDP. There are certain limitations to using the VAR model, such as when there are other larger factors in society that impact the model, the prediction will be inaccurate.

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