Examining the Dynamic Relationship between GDP, CPI and M2 in the United States Using VAR Modeling

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Abstract. The article examines the dynamics between GDP, CPI and M2 in the U.S. A vector autoregression (VAR) model is used to analyze the relationship between these variables. It is found that positive shocks to GDP have a short-run negative effect on M2, but this effect diminishes and tends to zero in the long-run. The Fisher equation and the quantity theory of money, which postulate that economic output and money supply eventually rebalance, can be used to explain this occurrence. In the short term, an increase in output suppresses the money supply. Furthermore, it was shown that the CPI's fluctuations had little effect on GDP. This finding is in line with neoclassical economic theory, which maintains that variations in the level of prices have little bearing on actual economic output. On the contrary, an increase in M2 has a positive cumulative effect on both CPI and GDP, which suggests that an increase in the money supply leads to an increase in the price level and economic output, which is consistent with Keynesian economic theory. Overall, this paper analyzes the dynamic relationship between key variables in the U.S. economy through a VAR model, providing important insights into monetary policy and economic fluctuations, which are important for understanding and predicting the direction of the U.S. economy, as well as for formulating effective macroeconomic policies.

Keywords: GDP, CPI, M2, VAR Model, Dynamic Relationships.

1 Introduction

In recent years, the complexity and diversity of the U.S. economy has made the study of the dynamics among its key economic variables - GDP, CPI, and M2 - particularly important. GDP (Gross Domestic Product) as a composite measure of economic activity, the interaction between GDP (Gross Domestic Product) as a composite measure of economic activity, CPI (Consumer Price Index) as a measure of inflation, and M2 (Broad Money Supply) as a proxy for liquidity and money supply is important in understanding and forecasting the direction of the U.S. economy.

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1.1 Contexts

The United States economy has undergone a number of major shifts over the past few decades, including the deepening of globalization, the information technology revolution and the policy adjustments that followed the financial crisis. These modifications have not only had an impact on inflation and economic growth, but they have also changed how the money supply and economic activity are related. For example, the financial crisis of 2008 and the subsequent implementation of quantitative easing policies have significantly affected the growth and distribution of M2. At the same time, the volatility of inflation in recent years reflects the complex interaction between CPI and economic policy. Therefore, it is important to study the dynamic relationship among GDP, CPI, and M2 to understand the effects of macroeconomic policies and their transmission mechanisms in the current economic environment. In 2023, U.S. economic activity was strong, with a notable 4.9 percent annual growth rate in the third quarter. However, GDP growth forecasts for 2024 indicate a slowdown in growth to about 0.7%, influenced by the cumulative effects of the previous monetary tightening and a gradual reduction in consumer spending growth [1]. Inflation, after peaking at 9.1% in June 2022, has shown signs of easing. As of October 2023, the Consumer Price Index (CPI) fell to 3.2% year-on-year. Nonetheless, core inflation excluding volatile food and energy prices remains above the Fed's 2% target, indicating that underlying price pressures remain [2].

1.2 Literature Review

A substantial amount of research has been done on the connection between GDP, CPI, and M2. Friedman first proposed—and empirical evidence later supported—that shifts in the money supply had a substantial impact on economic growth and inflation [3]. Further investigating the way that monetary policy affects economic activity, Bernanke and Mishkin noted that adjustments to the money supply can affect the GDP and CPI through the credit channel [4].

In recent years, several studies have focused on the specific case of the United States. For example, Stock and Watson analyzed the dynamic relationship between economic variables in the U.S. through a vector autoregressive (VAR) model and found that money supply has a significant effect on GDP and CPI [5]. On the other hand, Cecchetti et al. used a single-indicator model to forecast inflation, showing that simple time series models can provide accurate forecasts in some cases [6].

However, depending on the time period and economic climate, monetary policy may have varying consequences. For example, Taylor proposed that the central bank should adjust interest rates in line with the Taylor rule in order to stabilize the economy [7]. But Clarida et al. discovered that monetary policy's effects varied significantly between economic cycles [8]. Kim and Roubini looked at how monetary policy affected the Asian financial crisis and discovered that monetary policy had quite different effects during times of crisis than it does during normal periods [9].

Furthermore, monetary policy's long-term consequences on the economy have drawn a lot of attention. Barro developed the Ricardian equivalence theory which

states that the government's financing of fiscal deficits through the issuance of bonds does not have a long-term effect on the overall economy because rational consumers will increase their savings in anticipation of future increases in taxes [10]. However, Mankiw and Romer noted that through influencing investment and technological advancement, long-term economic growth may be impacted by monetary policy [11]. The relationship between the money supply and the US economy, inflation, interest rates, and unemployment was studied by Andre Amaral, Taysir E. Dyhoum et al. empirical evidence was provided to confirm the major impact of monetary policy on inflation and economic growth through the construction of a vector autoregressive (VAR) model. Policymakers can use the findings as a reference to better understand and anticipate the short- and long-term implications of monetary policy [12].

A series of harsh monetary policy actions have been adopted by the Federal Reserve since 2020 in reaction to the global New Crown outbreak, which caused an economic shock. These actions primarily consist of the following:

(1) Reduced interest rates: To cut borrowing costs and promote investment and consumption, the Federal Reserve cut the federal funds rate to around zero in March 2020.

(2) Quantitative easing: In order to preserve the stability of the financial markets and stimulate economic growth, the Federal Reserve has resumed and greatly increased its program of quantitative easing. Through the purchase of Treasury bonds and mortgage-backed securities (MBS), the Fed has injected a substantial amount of liquidity into the market.

(3) Tools for emergency lending: To support the financing needs of different kinds of businesses and local governments, the Federal Reserve established a number of emergencies lending tools, including the Commercial Paper Financing Facility (CPFF), the Main Street Loan Program (MSLP), and the Municipal Liquidity Facility (MLF).

(4) Forward-looking guidance: the Federal Reserve made it clear that it would extend the duration of low interest rates, and promised not to raise rates until it achieved its inflation target and full employment. This forward guidance helps to stabilize market expectations and enhance the confidence of economic agents.

(5) Modifying the monetary policy framework: In August 2020, the Federal Reserve announced the implementation of average inflation targeting (AIT), which permits inflation to temporarily surpass the 2% target in order to compensate for previous inflation shortfalls and promote job creation and economic recovery.

During the epidemic, these aggressive monetary policy actions were crucial in stabilizing financial markets and promoting economic recovery. However, over time, these measures have also brought new challenges, such as the risk of asset price bubbles, rising debt levels and increasing inflationary pressures.

In summary, different methodologies and models yield different results, even though a lot of study has been done on the relationship between GDP, CPI, and M2. Therefore, further research on the dynamic relationship between these variables, especially when considering the latest economic data and policy context, remains important.

2 Research Design

2.1 Data Sources

The Bureau of Economic Analysis provides the U.S. Gross Domestic Product (GDP), which is based on data from the first quarter of 1959 to the first quarter of 2024. The Federal Reserve Board's Money Supply (M2) and the U.S. Bureau of Labor Statistics' Consumer Price Index (CPI) also contain data from the same period. The Consumer Price Index (CPI), which is based on data from the first quarter of 1959 to the first quarter of 2024, is provided by the U.S. Bureau of Labor Statistics.

Studying the dynamics of GDP, CPI, and M2 in the US using quarterly data spanning from the first quarter of 1959 to the first quarter of 2024 presents a number of noteworthy benefits:

(1) Long time horizons: capturing long-term trends: Longer time horizons better capture long-term trends and structural changes in economic variables. This is important for understanding the dynamics between economic variables.

(2) Identifying cyclical fluctuations: Longer time series can cover multiple economic cycles, including periods of recession and boom, helping to analyze the behavior of economic variables at different stages of the cycle.

(3) Increase sample size: Improve statistical significance: more data points can improve statistical significance and make the model estimates more reliable and robust.

(4) Rich dynamic information: Longer time series provide rich dynamic information that better captures the interrelationships between variables and feedback mechanisms.

(5) Coverage of important economic events: Economic policy changes: The time period covers a number of important monetary and fiscal policy changes, such as the end of the Bretton Woods system, the oil crises of the 1970s, the period of hyperinflation in the 1980s, the global financial crisis of 2008, and the New Crown epidemic of 2020. These events have important implications for the dynamics of GDP, CPI and M2.

(6) Technological and structural changes: The period also includes technological advances, the development of financial markets and the deepening of globalization, all of which may affect the relationship between economic variables.

(7) Advantages of quarterly data: balancing data volume and detail: quarterly data provide a higher temporal resolution than annual data, capturing changes in economic variables in greater detail, yet are not as susceptible to short-term noise as monthly data.

(8) Timely response to policy effects: Quarterly data can reflect the effects of policy changes and external shocks in a timelier manner, making them suitable for dynamic analysis and policy evaluation.

(9) Suitable for time series analysis: VAR models and time series analysis: VAR models and other time series analysis methods require longer historical data for reliable estimation and testing. Longer time series data can better fulfill the needs of these methods.

Consequently, studying the dynamic relationships between GDP, CPI, and M2 in the United States using quarterly data spanning from the first quarter of 1959 to the first quarter of 2024 offers a wealth of long- and short-term information, covers several economic cycles and significant events, and enhances the significance and reliability of model estimates. The moderate temporal resolution of quarterly data facilitates dynamic analysis and policy evaluation and is ideal for conducting research on the dynamic relationships of economic variables.

2.2 VAR Model Setup

An extensively used statistical model in multivariate time series research is the Vector Autoregression (VAR) model. The VAR model extends the concept of univariate autoregressive models (AR models) by providing a systematic way of capturing the dynamic relationships between variables by allowing for interdependence and interactions across multiple time series. The VAR(p) The form of the model is as follows:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \epsilon_t \tag{1}$$

Y_t is a k-dimensional vector representing the values of all variables at time t.

A_i is k × k the matrix of coefficients representing the interrelationship between each variable at lag i.

ϵ_t is a k-dimensional error vector representing the shock term or random error at time t. It is usually assumed to have zero mean and constant variance covariance matrix.

The system matrix form is as follows:

$$\begin{pmatrix} A_1 & A_2 & \cdots & A_{p-1} & A_p \\ I_k & 0 & \cdots & 0 & 0 \\ 0 & I_k & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & I_k & 0 \end{pmatrix} \tag{2}$$

Among other things, the I_k is the unit matrix of k × k the unit matrix of and 0 is thek × k the zero matrix of

Characterization of the VAR model:

(1) Multivariate analysis: the VAR model considers multiple time series variables simultaneously, capturing the dynamic relationship between them.

(2) Simplicity and Flexibility: the VAR model has a simple structure and is flexible as it only requires the estimation of the coefficient matrices of the linear equations, with no structural constraints.

(3) No structural constraints: the VAR model does not presuppose any causal relationship between variables, but rather captures the interactions between variables through a data-driven approach.

Advantages of using VAR models to analyze the dynamic relationship between GDP, CPI, and M2:

(1) Capturing the interactions between variables: the VAR model enables each variable to be explained by the past values of other variables in the system in addition to its own past values. As a result, complex relationships and dynamics between GDP, CPI, and M2 can be adequately captured by VAR models. A VAR model, for instance, can show how adjustments to the M2 money supply impact GDP and CPI and vice versa.

(2) No need to presuppose causality: VAR models do not need to presuppose causality between variables. All variables are treated as endogenous, and this data-driven approach allows the model to automatically capture interactions between variables based on the data. This is very useful in economic analysis, where the relationships between economic variables are often complex and variable.

(3) Multivariate systematic analysis: VAR models are able to handle multiple time series simultaneously, providing a systematic view to analyze the interactions between economic variables. For example, by analyzing GDP, CPI, and M2 simultaneously, VAR models can help identify and understand the overall dynamics among the three, rather than relying solely on the analysis of individual variables.

(4) Structured Analysis: A VAR model's Impulse Response Function (IRF) allows for further investigation of the dynamic interactions between variables. For example, the long-term impact of shocks to one variable on other variables can be shown using the IRF.

(5) Dealing with Complex Economic Phenomena: Economic phenomena are often complex and intertwined, and VAR models are able to deal with this complexity by considering the interactions of multiple variables to provide a more comprehensive economic analysis. For instance, a VAR model can concurrently consider the links between GDP growth, inflation (CPI), and money supply (M2) while analyzing the effects of monetary policy.

2.3 Smoothness Test for GDP, CPI, M2 Data

Smooth data is crucial for building VAR models as it ensures the validity, reliability and interpretability of the model. By appropriately processing non-smooth data (e.g., differencing), the time series data can be made to satisfy the smoothness requirement, resulting in the construction of a more accurate and meaningful VAR model.

In order to construct an effective VAR model, this paper conducts smoothness tests on the GDP, CPI, and M2 data of the U.S. The test results are as follows:

Table 1. Stationary test, raw

Variables	Test statistic	P-value
Raw		
GDP	-3.159	0.0929
CPI	-2.984	0.1366
M2	-3.339	0,0601

It's clear from Table 1 that the GDP raw data's smoothing test p-value is 0.0929, which is considerably higher than 0.05 and does not rule out the first hypothesis—a hint that the GDP raw data is not smooth. The smoothing test's p-value for the CPI's raw data is 0.1366, which is clearly greater than 0.05 and does not allow the initial hypothesis to be rejected, suggesting that the CPI's raw data is not smooth. The smoothness test's p-value for the raw M2 data is 0.0601, which is higher than 0.05 and does not allow the original hypothesis to be rejected, suggesting that the raw M2 data is not smooth.

Since the original data for the GDP, CPI, and M2 are not smooth, this study will separate the data to satisfy the smoothness requirements of the VAR model. The differentiated data's smoothness test yielded the following findings:

Table 2. Stationary test, Growth rate

Variables	Test statistic	P-value
Growth rate		
GDP	-11.404	0.0000
CPI	-11.354	0.0000
M2	-11.187	0.0000

Table 2 clearly shows that the VAR model can be created and that the differentiated GDP, CPI, and M2 data are all smooth time series data. The differentiated data's smoothness test has a p-value of 0.0000.

2.4 Selecting the Optimal Lag Order of the VAR Model

Determining the lag order is a critical step when building a VAR (Vector Autoregression) model because the choice of lag order directly affects the performance and explanatory power of the model. Choosing the right lag order ensures that the model captures the dynamic structure of the data without overfitting or underfitting. Information Criteria are a class of statistics used to select the lag order of a model. Common Information Criteria include:

AIC (Akaike Information Criterion):

$$\mathrm{AIC} = -2\ln(\mathrm{L}) + 2\mathrm{k} \tag{3}$$

where k is the number of parameters in the model and L is the highest likelihood estimate. AIC tends to choose a larger number of lag orders, biased against underfitting.

BIC (Bayesian Information Criterion):

$$\mathrm{BIC} = -2\ln(\mathrm{L}) + \mathrm{k}\ln(\mathrm{n}) \tag{4}$$

where n is the sample size. the BIC prefers to choose fewer lag orders, biased against overfitting.

HQIC (Hannan-Quinn Information Criterion):

$$\mathrm{HQIC} = -2\ln(\mathrm{L}) + 2\mathrm{k}\ln(\ln(\mathrm{n})) \tag{5}$$

where n is the sample size, k is the number of parameters in the model, and L is the likelihood function value under maximum likelihood estimation. Larger samples typically yield better results using HQIC since it prevents overfitting more successfully.

SBIC (Schwarz Bayesian Information Criterion):

$$\mathrm{SBIC} = -2\ln(\mathrm{L}) + \mathrm{k}\ln(\mathrm{n}) \tag{6}$$

where n is the sample size, k is the number of parameters in the model, and L is the likelihood function value under maximum likelihood estimation. Large sample sizes are advantageous for SBIC performance as it effectively prevents overfitting. Underfitting may occur when SBIC favors the simple model excessively when the sample size is small.

The ideal lag order is determined by looking at Table 3, which displays the outcomes of the lag order selection criterion depending on the given lag order:

Table 3. Selection-order

Lag	FPE	AIC	HQIC	SBIC
0	1.7e-07	-7.06749	-7.05038	-7.02499
1	1.2e-07	-7.43436	-7.36593	-7.26436
2	1.1e-07	-7.51241	-7.39264	-7.2149
3	1.1e-07	-7.5029	-7.33181	-7.07789
4	6.8e-08*	-7.99134*	-7.76892*	-7.43883*
5	6.9e-08	-7.97432	-7.70057	-7.2943
6	7.1e-08	-7.94274	-7.61766	-7.13522
7	7.3e-08	-7.92135	-7.54494	-6.98632
8	7.5e-08	-7.89983	-7.4721	-6.8373
9	7.6e-08	-7.87983	-7.40077	-6.68979
10	7.9e-08	-7.84683	-7.31644	-6.5293
11	7.8e-08	-7.85676	-7.27504	-6.41172
12	7.4e-08	-7.9144	-7.28136	-6.34186

In terms of the lag order selection criteria:

FPE: minimum at lag 4. AIC: minimum at lag 4. HQIC: minimum at lag 4. SBIC: minimum at lag 4. These information criterion agreement results show that lag 4 is the best choice for all the criteria.

Therefore, this paper builds a VAR (4) model based on lag order 4.

3 Empirical Findings

3.1 Model Stability

The unit circle is mostly utilized in the construction of vector autoregressive (VAR) models in order to verify the model's stability. Specifically, the stability of a VAR model is determined by checking whether the mode of the model's characteristic root is within the unit circle. This is because the characteristic roots of a VAR model re-

flect the effects of the individual lagged terms in the model, and if these effects are too large (i.e., the mode of the characteristic root is greater than one), the model may diverge, leading to unstable forecasts. The figure below shows the unit circle test:

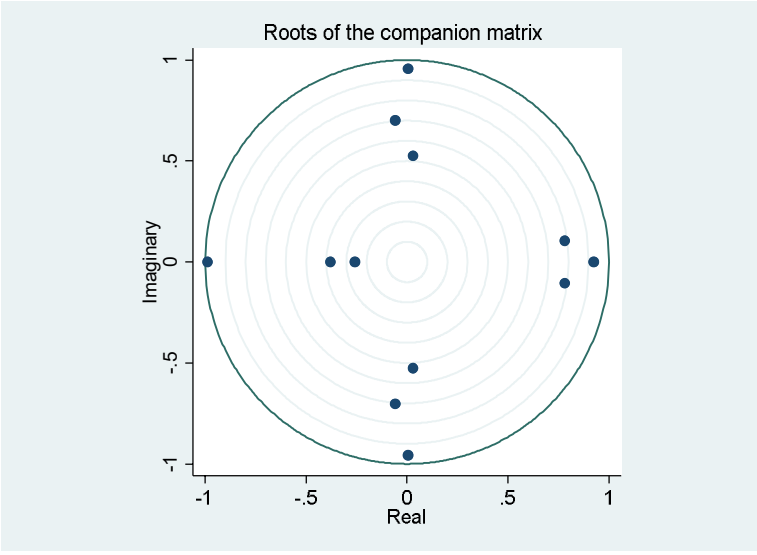

Fig. 1. Model Stability.
Photo credit: Original

The findings of the unit root test for the VAR(4) model are displayed in Figure 1. Since every root is either inside or on the unit circle, the VAR model is smooth and may be constructed with a lag order of 4.

3.2 Impulse Response Analysis

Figure 2 illustrates two cumulative orthogonalized shock response functions showing the cumulative impact of a GDP-facing shock on CPI and M2, respectively. The horizontal axis shows the time step (STEP), which represents the time since the shock occurred. The vertical axis is the size of the cumulative impact. The blue line indicates the cumulative impact of the shock on CPI or M2. The gray area is the 95% confidence interval.

The graph on the left shows the cumulative impact of GDP on the CPI:

Steps 1-5: Within the first few steps, the cumulative impact of the shock on the CPI is small and almost zero.

Steps 5-10: The cumulative impact of GDP shocks on the CPI increases gradually over time, reaching a more pronounced upward trend at about step ten.

Steps 10-30: After the tenth step, the cumulative impact of the shock on the CPI continues to increase with progressively wider confidence intervals, indicating increased uncertainty, and after the 30th step, the impact levels off.

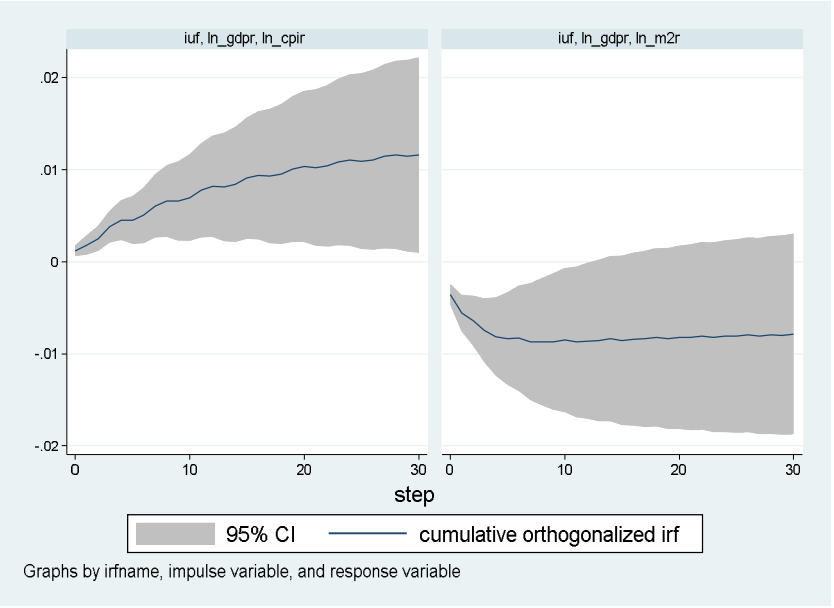

Fig. 2. Impulse (GDP) and response.
Photo credit: Original

CONCLUSION: Positive GDP shocks have a cumulative positive influence on the CPI that is noticeable at first and gradually diminishes. This phenomenon could be explained by either the monetarist quantity theory of money, as advocated by Friedman, which states that if economic growth is accompanied by an increase in the money supply and this growth outpaces the growth of the economy, inflation will result, which is an increase in the price level, or by Keynesian economic theory, which holds that an increase in demand during an economic expansion leads to an increase in the price level.

The graph on the right shows the cumulative impact of GDP on M2

Steps 1-5: Within the first few steps, the cumulative effect of the shock on M2 is negative, suggesting that a positive shock to GDP may lead to a reduction in M2.

Steps 5-10: the negative effects diminish over time, reaching a nadir at about step 10.

Steps 10-30: The cumulative effect decreases to zero after step 10, suggesting that GDP shocks have a minor and stabilizing long-term effect on M2. Step 30 results in virtually no shock impact on M2.

CONCLUSION: Positive GDP shocks have a negative short-term impact on M2, but over time, this impact progressively lessens and eventually approaches zero. This phenomenon may be in line with the Keynesian theory that in the short run, when the economy grows (positive GDP shocks), the demand for money increases, consumers and firms are more willing to hold money for transactions and investment, and the supply of money in the banking system may decrease, leading to a decrease in M2. This phenomenon is particularly pronounced during periods of rapid economic

growth, as money is used more for consumption and investment rather than being deposited in banks. The money supply and demand will eventually find a new equilibrium as a result of economic growth's boost in productivity and return on investment, and the change in M2 will stabilize. This aligns with the distinct Keynesian evaluations of both short- and long-term economic trends.

This phenomenon might be explained by Friedman's quantity theory of money. According to the quantity theory of money, there is a relationship between the money supply (M2), price level, and economic output. GDP growth may, in the near term, increase the demand for money, which would reduce bank reserves, tighten the money supply, and decrease M2. Eventually, though, the money supply does catch up with economic expansion. To encourage economic expansion, the central bank may raise the money supply, which would lessen and eventually eliminate the detrimental effects of M2. This long-run equilibrium link is also emphasized by Friedman's theory of monetarism.

The quantity theory of money stresses the equilibrium of money supply and demand over the long term, whereas Keynesianism stresses short-term variations in the need for money.

Figure 3 illustrates two cumulative orthogonalized shock response functions showing the cumulative impact of a CPI-facing shock on GDP and M2, respectively. The horizontal axis shows the time step (STEP), which represents the time since the shock occurred. The vertical axis is the magnitude of the cumulative impact. The blue line indicates the cumulative impact of the shock on GDP or M2. The gray area is the 95% confidence interval.

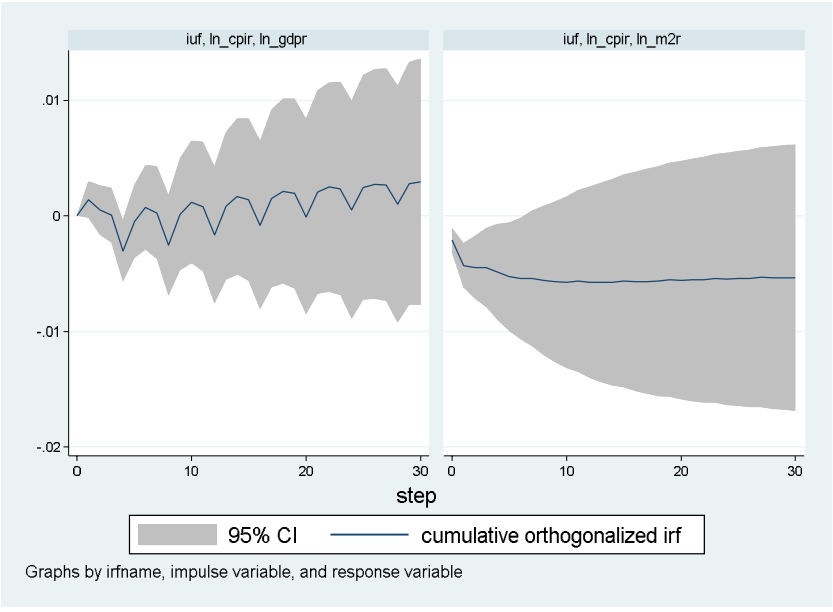

Fig. 3. Impulse (CPI) and response.
Photo credit: Original

The graph on the left shows the cumulative impact of the CPI on GDP:

Steps 1-5: Within the first few steps, the cumulative impact of CPI shocks on GDP is small and close to zero.

Steps 5-10: over time, the cumulative impact of the CPI on GDP is characterized by cyclical fluctuations.

Steps 10-30: The cumulative impact of the CPI on GDP does not significantly deviate from zero over the entire period of analysis, suggesting that the cumulative impact of the CPI on GDP over time is small. The fluctuating confidence intervals indicate that uncertainty is increasing over time, but the overall impact remains small.

Conclusion: Overall, the cumulative impact of the CPI on GDP is small, and although there are fluctuations in the medium term, the cumulative impact tends to be close to zero in the long term. This suggests that changes in the CPI have a limited impact on GDP. This phenomenon may be consistent with the Fisher effect and price stickiness theory. According to the Fisher effect, real interest rates stay constant while nominal interest rates fluctuate in response to fluctuations in inflation. As a result, a rise in the nominal interest rate (which offsets the impacts of inflation and has no bearing on real economic activity) is also caused by an increase in the Consumer Price Index (CPI). (GDP). In this instance, the market will absorb the change in CPI by adjusting the nominal interest rate, and real GDP will only be slightly impacted. On the other hand, the sticky pricing theory contends that wages and prices move slowly and do not quickly change in the short term, even as inflation increases. As a result, the short-term effect of CPI changes on GDP is reduced. Prices and wages are sticky, so businesses' and consumers' behavior won't change right once, and the GDP won't respond as quickly.

Further explanations that are particular to the US economy could be the relative independence of supply and demand as well as the moderating effect of monetary policy. There may be some degree of relative independence between supply and demand in a big, diverse economy like the US. changes in the CPI primarily reflect changes in the price level, while GDP reflects total output and economic activity. Or because the Federal Reserve (Fed) regulates economic activity through monetary policy. If the CPI rises, the Federal Reserve may curb inflation by raising interest rates, thereby stabilizing economic growth. Monetary policy adjustments can mitigate the direct impact of CPI changes on GDP to some extent. This mechanism makes the impact of inflation on GDP indirect and limited.

The graph on the right shows the cumulative effect of the CPI on M2

Steps 1-5: Within the first few steps, there is a rapid negative cumulative effect of the CPI shock on M2, followed by a rapid leveling off.

Steps 5-10: The negative cumulative effect of the CPI on M2 minimizes at about 10 steps.

Steps 10-30: The cumulative impact of shocks tends to zero over time. Confidence intervals are initially narrow and then gradually widen, indicating increased uncertainty in the long run.

CONCLUSION: The CPI initially has a large negative influence on M2, but this effect quickly vanishes and, over time, the cumulative effect tends to be very close to zero. This might indicate a temporary decrease in the money supply (M2) as a result

of the CPI increase, but it won't have much of an effect over time. These phenomena could align with Friedman's quantity theory of money, which postulates a long-term relationship between the money supply (M2), the price index (CPI), and GDP (gross domestic product). An increase in the CPI may lead to a short-term tightening of monetary policy, such as an increase in interest rates or a reduction in the money supply to fight inflation. M2 may momentarily decrease as a result of such restrictive regulations. However, after time, the money supply and price level return to a new equilibrium, thus eliminating any long-term effects. The US economy's current situation may also be attributed to the central bank's monetary policy reaction function. Central banks, like the Federal Reserve, typically implement tight monetary policies (such as increasing interest rates and decreasing bank reserves) in response to increases in the CPI, which in the short term causes M2 to decline. This is so that inflation can be controlled, which is the aim of the central bank's lowering of the money supply. Eventually, though, the central bank's policy adjusts to changes in the status of the economy. Monetary policy may be loosened and the growth rate of M2 returns to normal when inflation is under control and the economy stabilizes, eliminating the long-term impact.

Figure 4 presents two cumulative orthogonalized shock response functions showing the cumulative impact of M2 facing shocks on GDP and CPI, respectively. The horizontal axis shows the time step (STEP), which represents the time since the shock occurred. The vertical axis is the size of the cumulative impact. The blue line indicates the cumulative impact of the shock on CPI or GDP. The gray area is the 95% confidence interval.

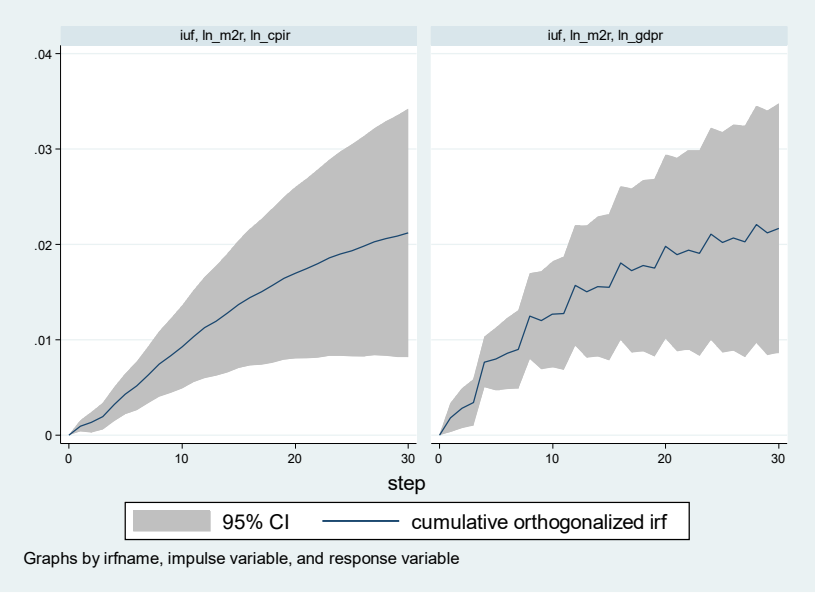

Fig. 4. Impulse (M2) and response.
Photo credit: Original

The chart on the left shows the cumulative impact of M2 on the CPI:

Steps 1-5: Within the first few steps, the cumulative impact of the M2 shock on the CPI is small, but shows a steady upward trend.

Steps 5-10: The cumulative impact of M2 on the CPI increases gradually over time and becomes significant after about 10 steps.

Steps 10-30: After 30 steps, the cumulative impact of M2 shocks on CPI continues to increase and the confidence intervals become progressively wider, indicating increasing uncertainty. Overall, an increase in M2 has a positive cumulative effect on CPI.

CONCLUSION: A rise in M2 has a cumulatively beneficial effect on the CPI that is observable gradually and gets stronger with time. This implies that an increase in M2, or the money supply, could cause the price level (CPI) to rise. The monetarist and quantum theories of money are most in line with this phenomena. These ideas describe how an increase in the economy's aggregate demand leads to a progressive expansion of the money supply, which in turn boosts the level of prices.

The graph on the right shows the cumulative impact of M2 on GDP

Steps 1-5: Within the first few steps, the cumulative impact of M2 shocks on GDP is small and growth is relatively flat within the first 10 steps.

Steps 5-10: After about 10 steps, the cumulative impact of M2 on GDP begins to increase significantly and maintains an upward trend.

Steps 10-30: After step 30, the cumulative impact of M2 shocks on GDP continues to increase and the confidence intervals become progressively wider, suggesting an increase in long-run uncertainty. Overall, an increase in M2 has a positive cumulative effect on GDP.

CONCLUSION: The GDP benefits cumulatively from an increase in M2, and this effect becomes increasingly pronounced over the medium and long terms. This suggests that an increase in money supply (increase in M2) contributes to economic growth (rise in GDP). This phenomenon is consistent with Keynesian economic theory. Keynesian theory explains how an increase in the money supply drives economic growth by lowering interest rates, increasing consumption and investment, and creating a multiplier effect.

4 Conclusion

4.1 Policy Recommendations

The findings have important policy implications for monetary policymakers. First, the Fed needs to balance the relationship between short-run economic growth and long-run inflation when setting monetary policy. In the short term, expansionary monetary policy works well, but over time, increasing the money supply could raise inflation. As a result, the Federal Reserve should exercise caution while implementing monetary expansionary policy and consider its long-term effects.

Second, the findings of this paper suggest that monetary policy should be coordinated with other economic policies. For example, monetary policy expansion should be appropriately combined with fiscal policy (e.g., fiscal surpluses) to avoid the risk

of long-run inflation. Regarding the relationship between monetary and fiscal policy, this argument backs up Mankiw and Romer's theory.

Finally, the findings suggest that the Federal Reserve, in responding to economic crises, should flexibly utilize a variety of monetary policy tools and adjust the strength and direction of its policies according to the specific economic environment. For example, during a recession, the Fed can stimulate the economy by increasing M2, but when the economy is overheating, it should prevent inflation by reducing M2.

4.2 Research Limitations and Future Research Directions

There are still several limits even if the research presented in this publication offers numerous insightful observations. First, the VAR model was the only one utilized in this article. To further evaluate the robustness of the findings, future research could make use of more advanced econometric techniques like the structural vector autoregressive (SVAR) model or the Bayesian vector autoregressive (BVAR) model. Second, as the data in this paper only relate to the United States, future research can be broadened to other countries or regions in order to compare the effects of monetary policy in different economies. Furthermore, the analysis in this paper solely focuses on the effects of M2 on GDP and CPI; future studies can consider additional macroeconomic variables such as the interest rate, exchange rate, and unemployment rate to obtain a more comprehensive knowledge of the dynamic effects of monetary policy on the economy.

4.3 Summary

This study uses vector autoregressive (VAR) modeling and impulse response function (IRF) to examine the dynamic relationship between the money supply (M2), GDP, and the consumer price index (CPI) in the United States. The findings show that, although expansionary monetary policy has a significant beneficial short-term influence on inflation and economic growth, it may eventually result in permanent inflation.

Several policy recommendations are made in this report based on the study's findings. When deciding on monetary policy, the Fed must first weigh the importance of both long-term inflation and short-term economic growth. Second, monetary policy should be coordinated with other economic policies to avoid the risk of long-term inflation. Finally, the Federal Reserve should flexibly utilize various monetary policy tools and adjust the policy strength and direction according to the specific economic environment.

Future studies could adopt more sophisticated econometric methods and expand to other countries or regions to further validate the robustness and generalizability of the results. Further research could take into account additional macroeconomic factors in order to completely comprehend the dynamic influence of monetary policy on the economy.

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