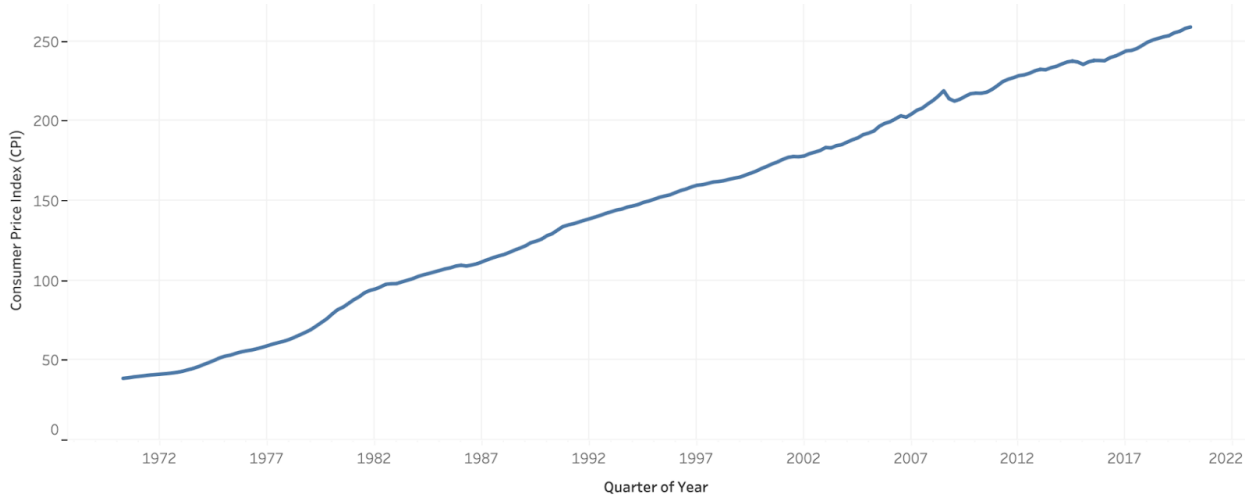
Introduction

The work focuses on two crucial macroeconomic variables M2 and Consumer Price Index (CPI) of the United States of America. M2 is a monetary aggregate used in macroeconomics to represent the broad money supply within an economy. It encompasses several components of money, serving as an indicator of the total amount of money accessible to individuals and businesses for transactions and store of value purposes. On the other hand, CPI is a measure that quantifies the average change over time in the prices paid by average consumers for a predefined basket of goods and services. It serves as a prominent indicator of inflation and is widely employed for assessing changes in the cost of living.

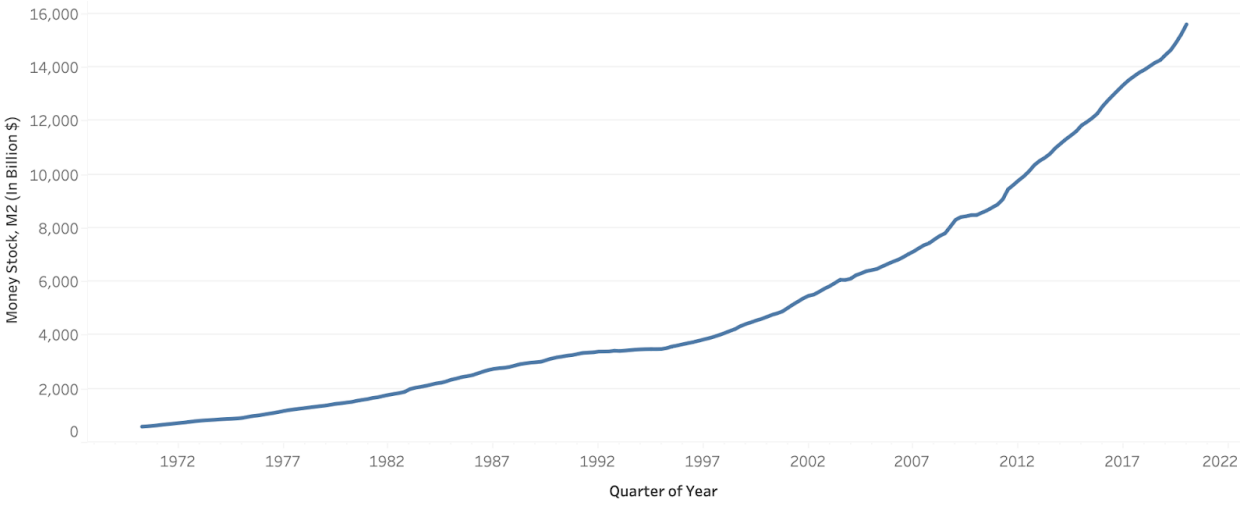
The data is taken from the Federal Reserve Bank of St. Louis from 1970 to 2020. The both variables' data is quarterly ranging from the second quarter of 1970 to first quarter of 2020. Only the variable CPI is seasonality adjusted.

For statistical analysis Stata has been used and for most time series visualisations Tableau has been used because of its simplicity of usage.

Graphical Representation and Properties of M2 and CPI

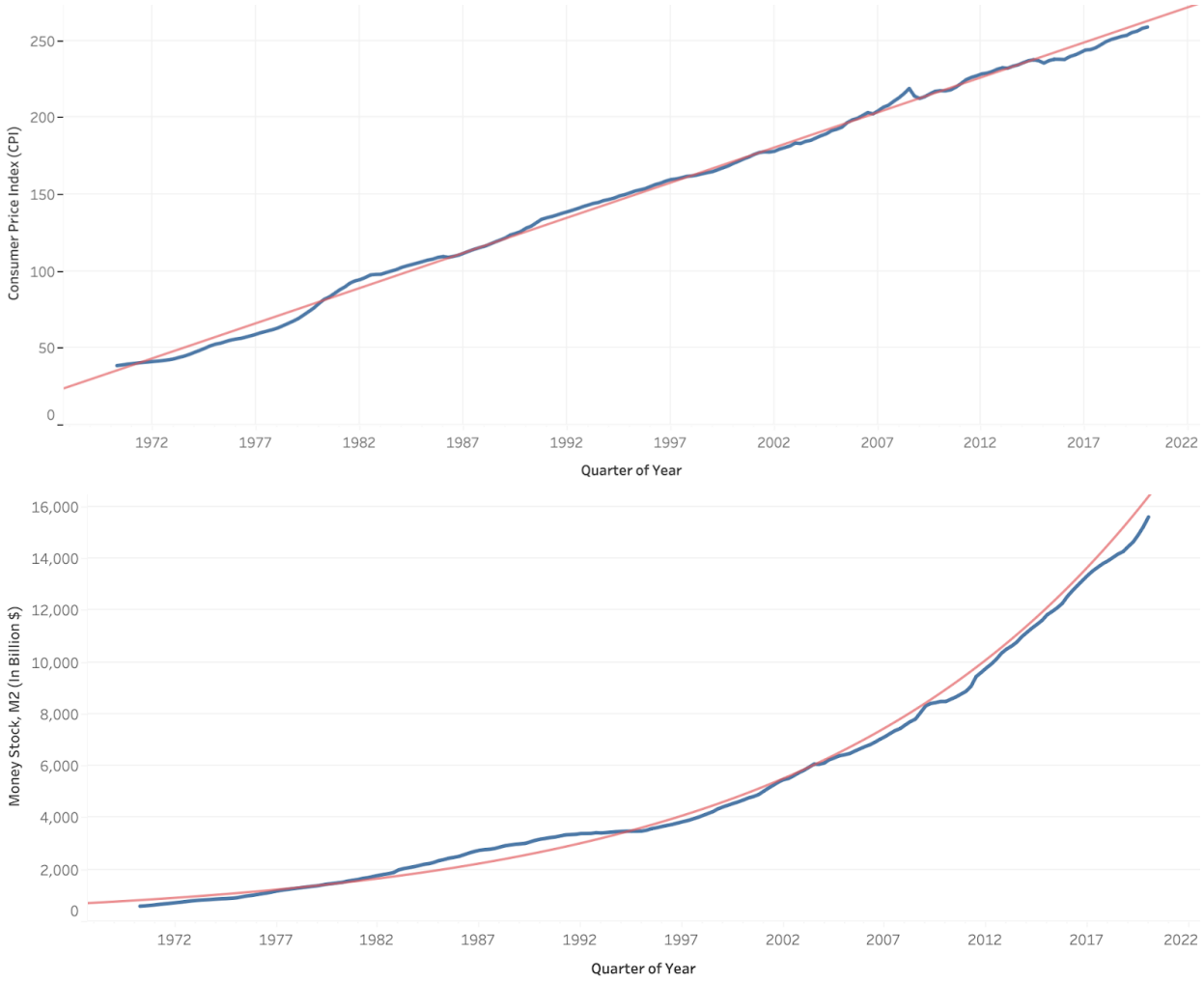


Graph -1: Time Series plot of CPI



Graph- 2: Time Series Plot of M2

From graphical representation, it is observable that there is an upward trend in both M2 and CPI. Which means both variables are not stationary over time.



Graph- 3: Time Series Plot CPI of M2 with Trendline

The above graph confirms that CPI shows a linear trend over time whereas M2 shows an exponential trend over time. The trend is shown with the red line.

Now for further analysis this trend needs to be removed to achieve stationarity in the time series data. To achieve that First Difference of both variables can be used. To see whether the first difference is stationary Augmented Dickey-Fuller Test needs to be performed on both variables. This test tests for the presence of unit root in a time series, in other words it checks for stationarity of a time series dataset. The results of Augmented Dickey-Fuller Test with 0 lag has been shown below for both variables:

Dickey-Fuller test for unit root — Number of obs = **198**

	Test Statistic	Interpolated Dickey-Fuller: 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	**-10.086**	**-3.477**	**-2.883**	**-2.573**

MacKinnon approximate p-value for Z(t) = **0.0000**

Table- 1: Augmented Dickey-Fuller Test of CPI

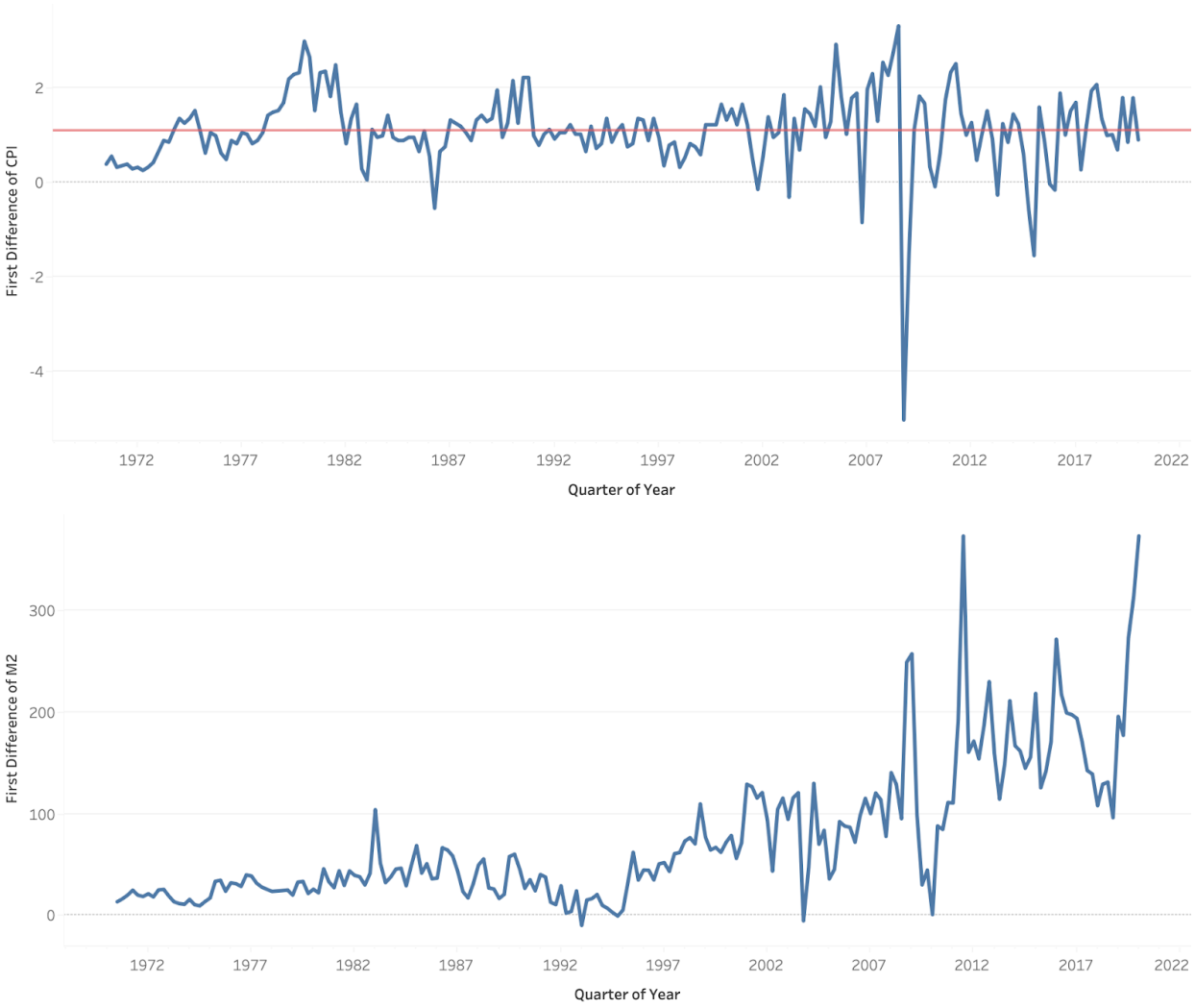
Dickey-Fuller test for unit root — Number of obs = **198**

	Test Statistic	Interpolated Dickey-Fuller: 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	**-3.036**	**-3.477**	**-2.883**	**-2.573**

MacKinnon approximate p-value for Z(t) = **0.0317**

Table- 2: Augmented Dickey-Fuller Test of M2

Both the test statistic are within the acceptance range of the null hypothesis. Which means the above test results show that both variables' first differences are stationary over time.



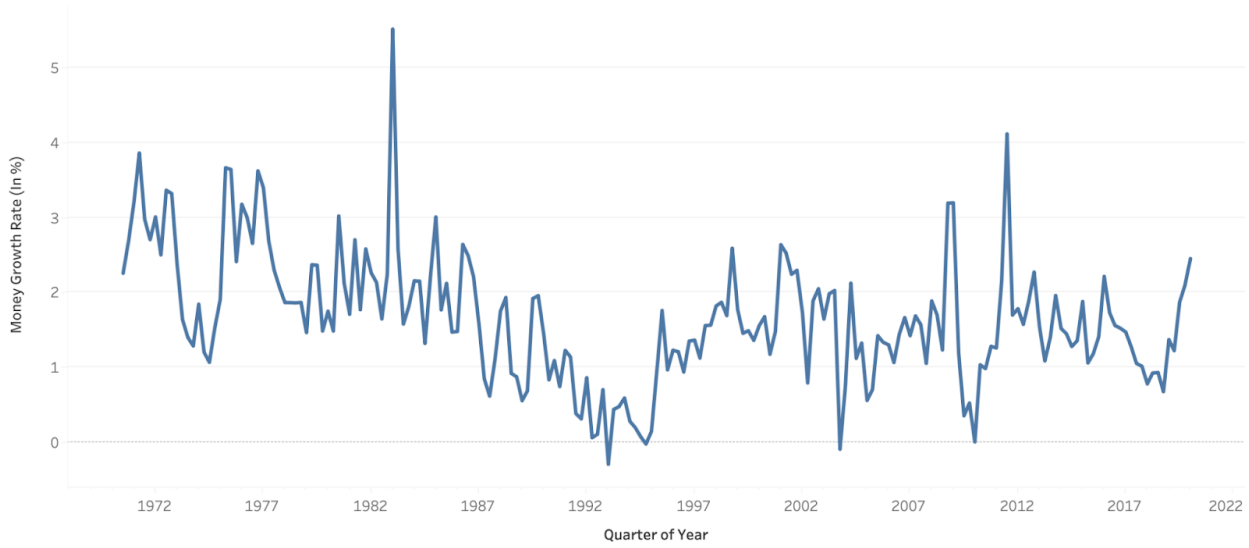
Graph- 4: Time Series Plot of First Difference of CPI & M2

From graphical representation it is also observable that both the first differenced variables are stationary over time. Which solves for the presence of trend in the original time series data of CPI and M2.

Money Growth Rate and Inflation

The money growth rate refers to the percentage change in the money supply(M2 in this case) within an economy over a year. It indicates how quickly the amount of money circulating in the economy is increasing. The money growth rate can be found from the following formula:

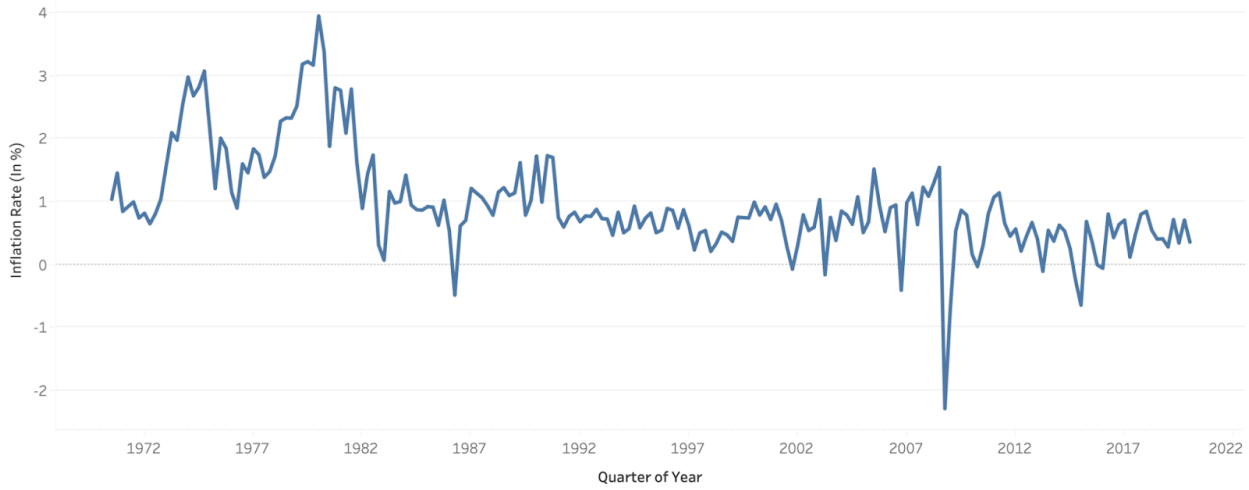
Money Growth Rate = $(M2_t - M2_{t-1})*100/M2_{t-1}$



Graph- 5: Money Growth Rate (%)

Inflation is the general increase in the prices of goods and services over time, leading to a decrease in the purchasing power of money. In the words of Milton Friedman, "Inflation is caused by too much money chasing after too few goods". CPI serves as a benchmark for measuring inflation, and changes in this index provide insights into how the cost of living is changing over time. The inflation rate can be found from the following formula:

Inflation Rate = $(CPI_t - CPI_{t-1})*100/CPI_{t-1}$



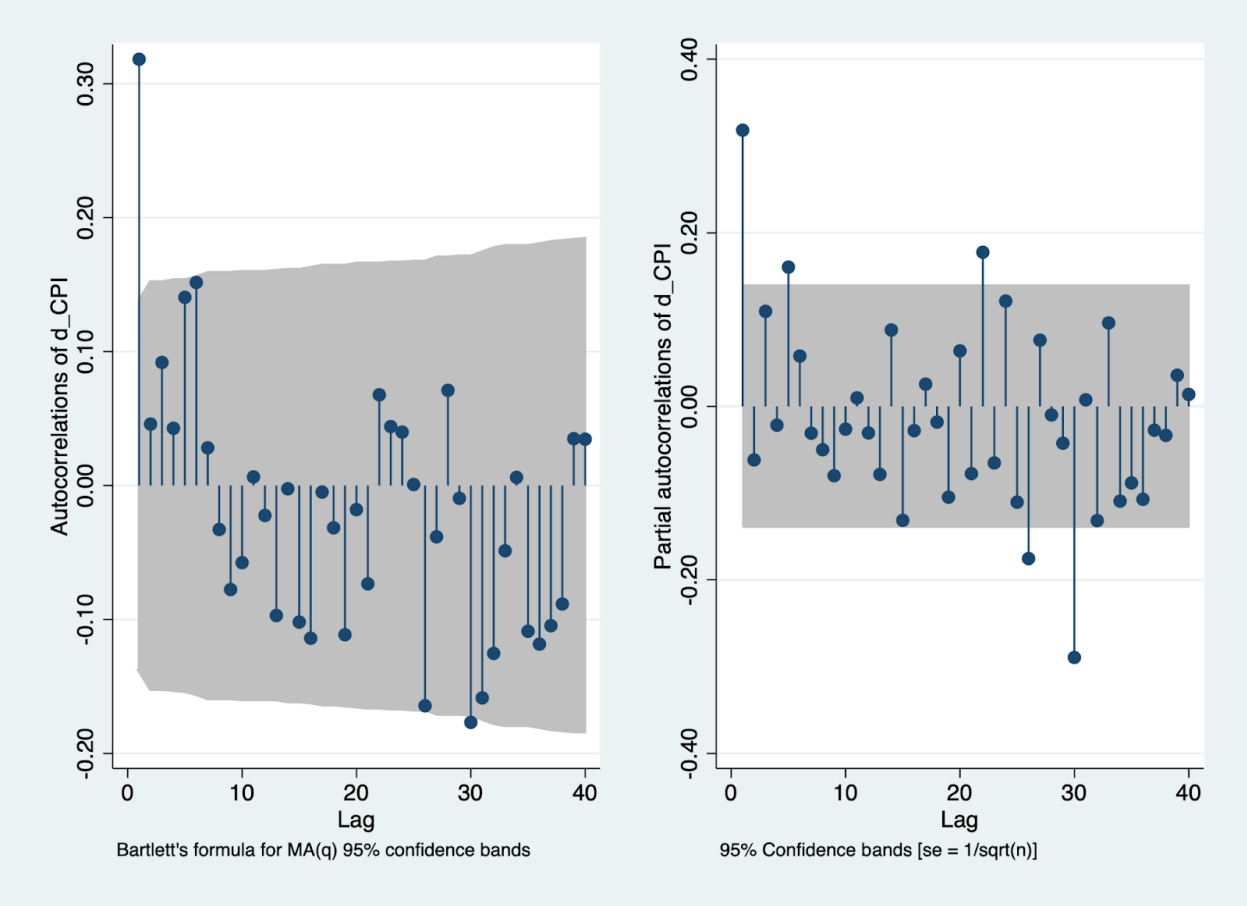
Graph- 6: Inflation Rate (%)

Time Series Model For Each Univariate Variable:

An ARMA(p,q) model refers to a time series model which has both moving average and autoregressive components. In the model p refers to the autoregressive term and q refers to moving average term. ARMA model can be stated with the following equation:

$$X_t = \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}.$$

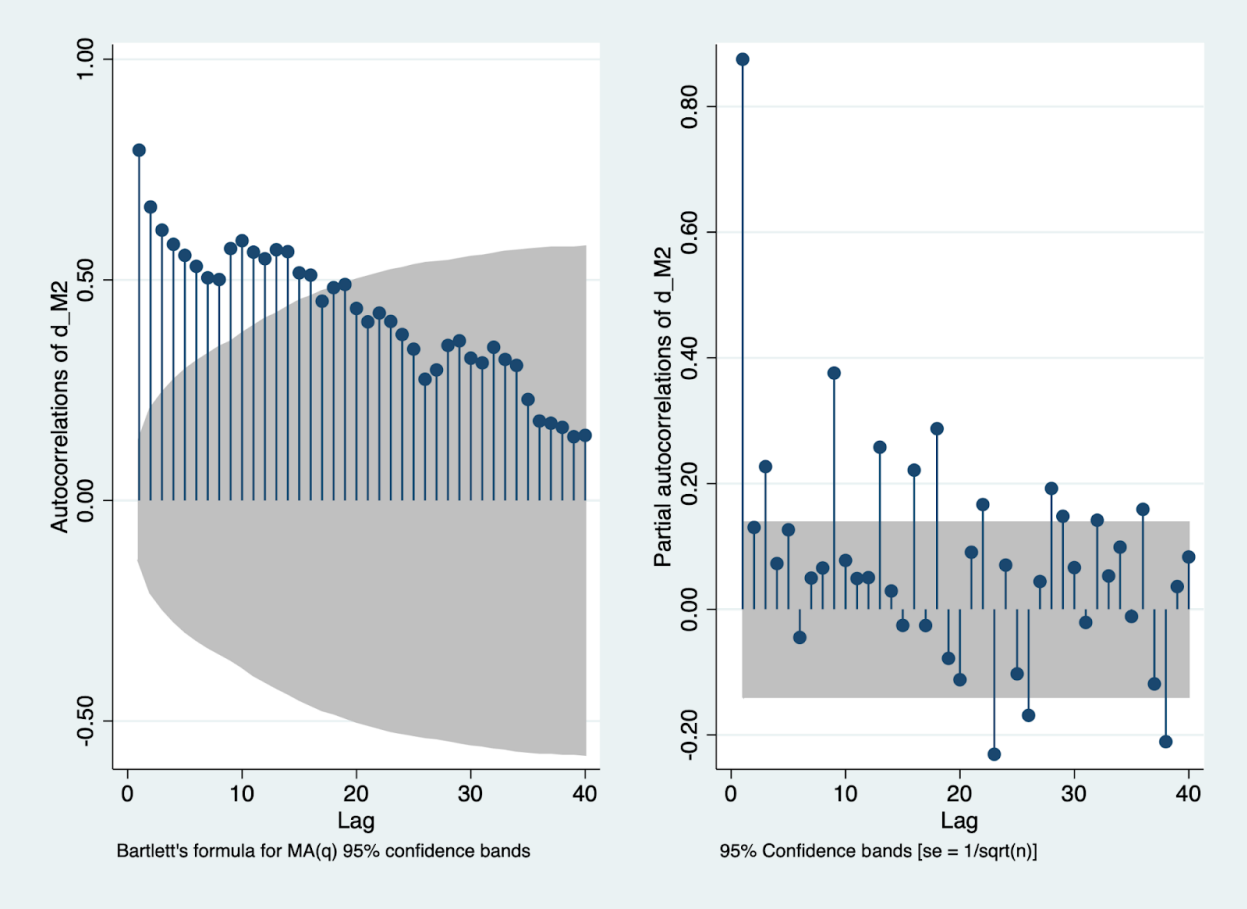
To know the values of "p" and "q" in an ARMA model we need to perform Autocorrelation and Partial Autocorrelation analysis. The Autocorrelation Function (ACF) will provide us with the value of "q" and Partial Autocorrelation Function (PACF) lets us know about the value of the "p" component of an ARMA model.



Graph- 7: ACF & PACF Graph of First Difference of CPI with Confidence Interval

In the above graph, it is observed that there is only one significant spike in ACF of First Difference of CPI which translates to the "q" term of the ARMA model for First Difference of CPI is 1. After lag 1 the decreases and dips below the confidence interval. Same case can be observed for the PACF graph where there is only one significant spike after which the spikes

start to die down. Which means the "p" term for the ARMA model is 1 as well. So the model appropriate for the First Difference of CPI is ARMA(1,1).



Graph- 8: ACF & PACF Graph of First Difference of M2 with Confidence Interval

In the above graph, it is observed that there is only one significant spike in ACF of First Difference of M2 which translates to the "q" term of the ARMA model for First Difference of M2 is 1. After lag 1 the spikes start to die down. Same case can be observed for the PACF graph where there is only one significant spike after which the spikes start to die down. Which means the "p" term for the ARMA model is 1 as well. So the model appropriate for the First Difference of M2 is ARMA(1,1).

Vector Autoregressive Model & The Impact of Shock

A Vector Autoregressive (VAR) model is an econometric time series model used for analysing the dynamic relationships among multiple time series variables. It is an extension of the autoregressive model, which deals with a single time series, to a multivariate setting where

several time series variables are analysed simultaneously usually in a matrix formation. To select the lag order of the VAR model we need Akaike Information Criterion (AIC) and Schwarz's Bayesian Criteria (SBC).

Selection-order criteria
Sample: 1971q1 - 2020q1 Number of obs = 197

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1358.3				3409.74	13.8101	13.8236	13.8435
1	-1222.2	272.21	4	0.000	891.795	12.469	12.5095	12.569*
2	-1215.2	13.997*	4	0.007	865.07*	12.4385*	12.506*	12.6052

Endogenous: fd_M2 fd_CPI
Exogenous: _cons

Table- 3: AIC and SBC of VAR Model

From the above table we can see that AIC says appropriate lag order of 2 whereas SBC indicates appropriate lag order of 1. As SBC is asymptotically consistent for a large number of observations, we take the SBC's inference and take lag order of 1 for the VAR model.

Vector autoregression

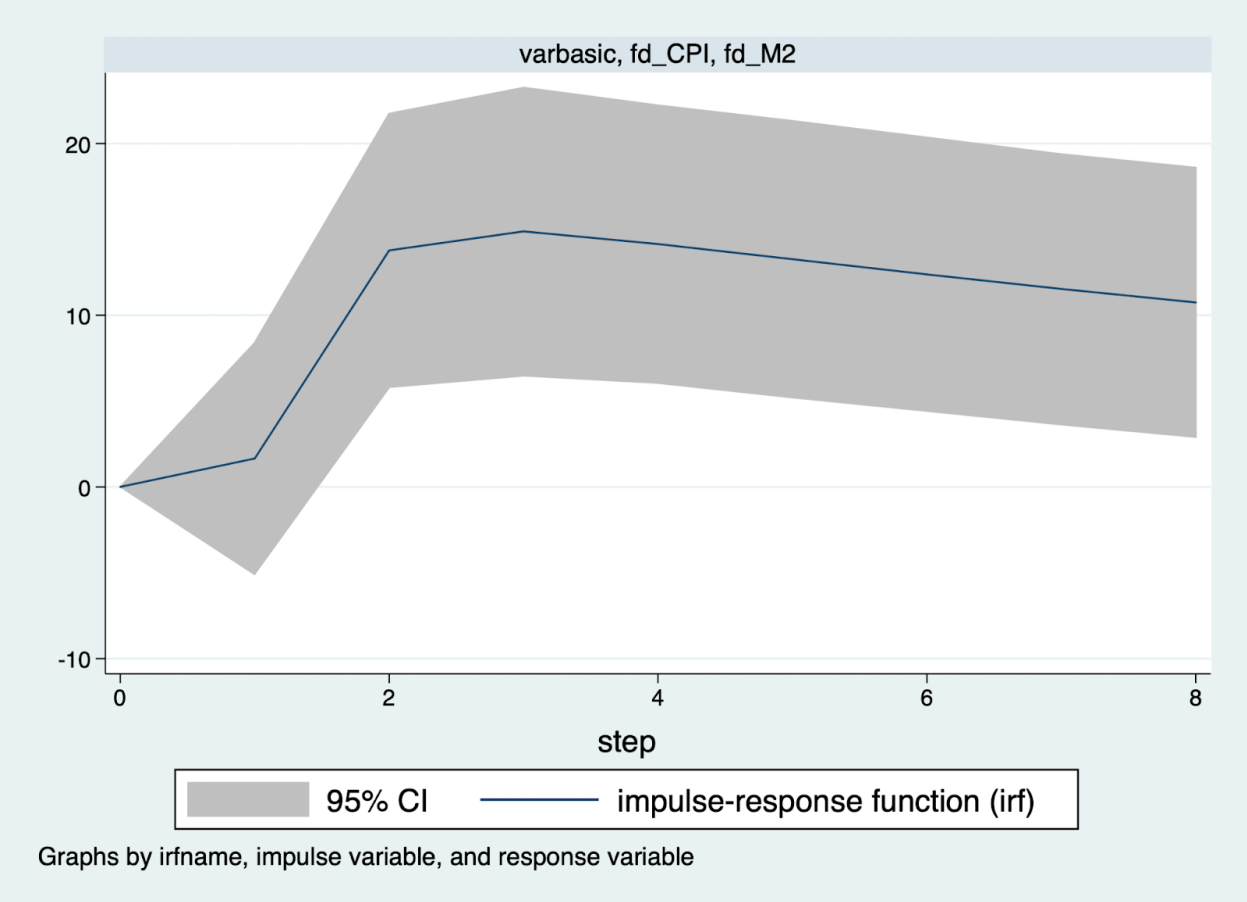
Sample:	1970q4 - 2020q1	Number of obs	= 198
Log likelihood	= -1227.485	AIC	= 12.45945
FPE	= 883.3287	HQIC	= 12.49978
Det(Sigma_ml)	= 831.3798	SBIC	= 12.55909

Equation	Parms	RMSE	R-sq	chi2	P>chi2
fd_M2	3	38.223	0.7044	471.7881	0.0000
fd_CPI	3	.800417	0.1017	22.41844	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
fd_M2						
fd_M2						
L1.	.8887355	.0409989	21.68	0.000	.8083791	.969092
fd_CPI						
L1.	6.783134	3.252463	2.09	0.037	.4084233	13.15785
_cons	2.537368	5.736026	0.44	0.658	-8.705036	13.77977
fd_CPI						
fd_M2						
L1.	.0000889	.0008585	0.10	0.918	-.0015938	.0017716
fd_CPI						
L1.	.3194307	.068109	4.69	0.000	.1859396	.4529218
_cons	.7496527	.1201166	6.24	0.000	.5142285	.9850769

Table- 4: VAR Summary Table

From the above VAR summary table, it is observed that lag 1 values of First Difference of M2 have a significant impact on both First Difference of M2 and First Difference of CPI, while lag 1 values of First Difference of CPI have a significant impact only on First Difference of CPI and no statistically significant impact on First Difference of M2. Also both the variables are significantly affected by its previous values.



Graph- 9: IRF to a shock in First Difference of M2 on First Difference of CPI

The above graph represents the Impulse Response Function (IRF) to a shock in First Difference of M2 on First Difference of CPI. It is observed that a unit shock in the money supply M2 (Change in Money Supply) at the initial time period results in a pretty high impact on CPI (Inflation Rate) in the first 2 periods. But the impact dampens gradually after that. It can be deduced that a shock (Increase) in money supply can increase the CPI and increase in CPI means increase in inflation. This serves as the proof of the classical macroeconomic theory that increased money supply creates inflation.