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UDK: 338.23:336.74(73)
DOI: 10.2478/jcbtp-2022-0024

Journal of Central Banking Theory and Practice, 2022, 3, pp. 79-98
Received: 11 November 2021; accepted: 29 December 2021

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Quantitative Easing and Macroeconomic Performance in the United States

Abstract: This scientific paper examines the relationship between macroeconomic variables whose performance is measured under the implementation of Quantitative Easing in the US, by estimating vector autoregression (VAR) and Impulse Response Function with monthly data from US Federal Reserve, observed during the period January 1994-January 2022. Variables include: Consumer Price Index (CPIAUCSL); Industrial Production (INDPRO); Unemployment Rate (UNRATE); Interest Rates, Government Securities, Government Bonds (INTGSBUSM193N); Volatility Index (VIXCLS), Real Broad Effective Exchange Rate (RBUSBIS), Federal Surplus or Deficit (MTSDS133FMS), Money Supply M1 (WM1NS), M2 (WMNS), M3 (MABMM301USM189S). An evidence on macroeconomic variables of Consumer Price Index and Industrial Production when evaluating the effectiveness of QE is provided.

Keywords: Quantitative Easing, US Federal Reserve, VAR, Impulse Response Function.

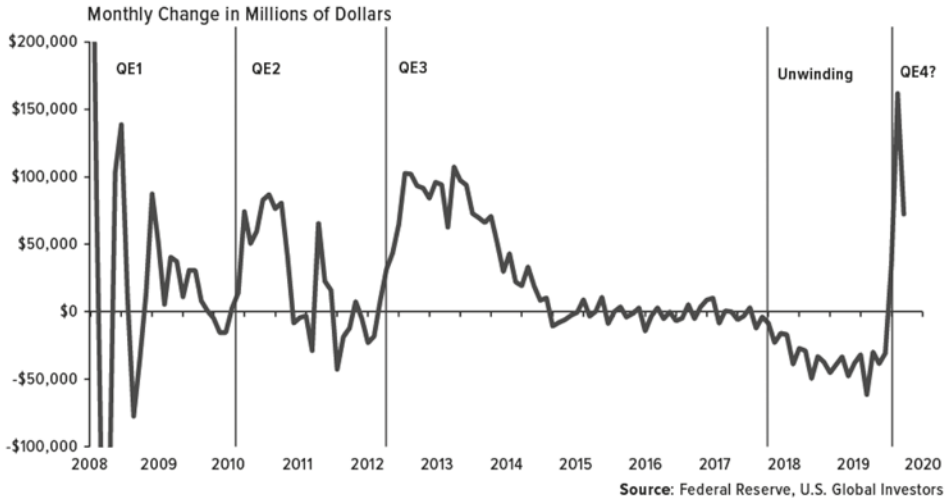
JEL Classification: E52, F00, E65.

1. Introduction

Quantitative easing (QE) represents a type of unconventional monetary policy, according to which a national central bank (Federal Reserve in the United States) tries to improve national economic performance by purchasing a large number of long-term securities in the open market.

Purchasing a large number of long-term securities is done with an objective of increasing the money supply and encouraging lending and investment. Quantitative easing in the United States has been executed in four waves, starting from January 2009, and it is still active. The Federal Reserve still purchases securities to make their way onto its balance sheet. Before the 2007-2008 global financial crisis, the Fed implemented monetary policy by doing small daily open-market operations to ensure that the federal funds rate traded near its target level; however, because of the fact that those operations were small and often temporary, they led US economy into the new set of measures, known as Quantitative Easing (QE). The monetary tool Fed used earlier to lower the short-term interest rate became dysfunctional, which caused a great need to find another economy-boosting method - it was Quantitative Easing. Quantitative Easing is influencing longer-term yields, and the size of QE operations is much greater. The central bank purchases Assets, which mostly consist of long-term Treasury bonds and agency mortgage-backed securities (MBS). Under the scope of Quantitative Easing, economic changes should take place in accordance with the following chain of powerful events: the Fed creates credit, buys assets, demand increases, new money (credit) enters the economy, interest rates go down and the economy grows. The 2007-2008 global financial crisis was caused by the bursting of the housing bubble, a temporary period of few years of low supply, high demand, and inflated prices, which are above fundamentals, which brought a new incertitude to the Federal Reserve: conducting expansionary monetary policy, at the zero lower bound. In years prior to 2008, the Federal Reserve had tried to revive the economy and stimulate economic growth by lowering the federal funds rate (FFR), which led interest rates to reach the zero lower bound. The Fed`s zero lower bound period went from December 16, 2008 to December 17, 2014. Consequently, the monetary tool this central bank used earlier to lower the short-term interest rate became dysfunctional. There was a great need to find another method that would boost the economy. Then, in the Fed's arrangement, quantitative easing (QE) enters the scene, including large-scale purchases of assets with longer maturities, such as mortgage-backed securities (MBS's) and 10-year Treasuries. Quantitative easing in the United States has been executed in four waves. The Federal Reserve still purchases securities to make their way onto its balance sheet. Quantitative easing in the US has been executed in four phases. Figure 1 presents a historical overview of these four phases:

Figure 1: Federal Reserve Expanding its Balance Sheet at Fastest Rate since Financial Crisis

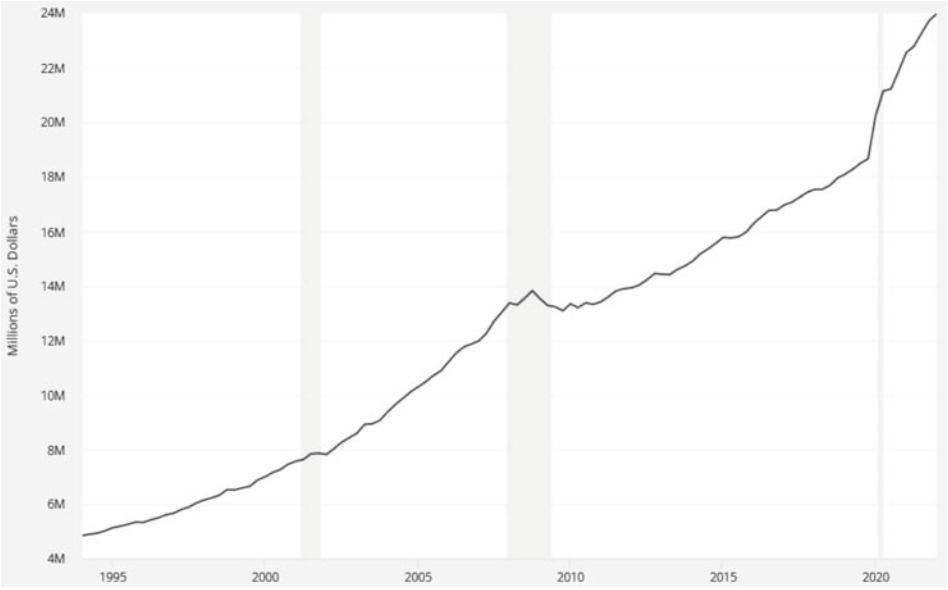


Source: USGI, 2019

2. Institutional Background: The Federal Reserve Balance Sheet

The Fed uses different programs and initiatives to realize their goals, with the result leading to a change in the composition of the Fed's balance sheet. By increasing or decreasing the amount and scope of assets or liabilities on its balance sheet, the Fed increases or decreases the money supply. While their assets include different Treasuries and mortgage-backed securities bought in the open market, as well as loans made to banks, liabilities involve currency in circulation and bank reserves held at commercial banks. Before 2008, the Federal Reserve had tried to stimulate economic growth by lowering the federal funds rate (FFR), which led interest rates to reach the zero lower bound. The goal of zero lower bound policy (ZIRP) was to initiate economic expansion and to boost inflation by discouraging the hoarding of cash, and instead encouraging lending, spending, and investment. In December 2014, ZIRP was substituted with NIRP (Negative Interest Rates Policy). NIRP became the main policy tool for many of major central banks, including the Fed, as they were battling falling inflation, rising currencies and economic weakness. In 2018, the Federal Reserve started unwinding its balance sheet by not replacing maturing securities. The trend ended in 2019 because of a crisis in repo markets. Figure 2 exhibits Fed's balance sheet, for the period 1994 Q1 - 2021 Q4:

Figure 2: Fed's Balance Sheet: Total Assets



Source: FRED Economic Data. (2021)

3. Related Literature

QE and Consumer Price Index /Inflation: As stated by Fabo, Jančoková, Kempf and Pástor (2021) from the ECB, there is substantial heterogeneity in the effectiveness of QE across different countries. Focusing on standardized effects, which are easier to compare across countries due to differences in QE program sizes, QE is most effective at raising output in the U.S., followed by the EA and the UK. For inflation, QE is again the most effective in the U.S. (European Central Bank, 2021). According to Coenen and Wieland (2003) and Peersman (2011) and their analysis of coordinated monetary policy, quantitative easing causes an upshift in inflation. As confirmed by Krušković (2022), central bank intervention in inflation targeting is utilized as a tool which secures the necessary liquidity in the foreign exchange market, prevents the exchange rate cycle, prevents the currency crisis and, therefore, precludes the extreme fluctuation of the interest rate, everything with the goal of achieving a defined inflation target or the specific inflation target range.

QE and Industrial Production: Sadahiro (2005) executed Vector Error Correction Model analysis, in which the impulse responses of the inflation rate and industrial production to an increase in the monetary base resulted in a fact that industrial production does increase, albeit the magnitude is minimal, while the inflation rate decreases. In their analysis, Schenkelberg and Watzka (2013) found a negative effect of QE on industrial production for the first 15 months. In order to identify the QE policy shock, Carrera, Perez Forero and Ramirez-Rondan (2015) estimated a structural vector autoregressive (SVAR) model with block exogeneity, finding that in the US, a QE policy shock produces a positive and significant effect in the industrial production (IPUS) and prices (CPIUS) in the medium-term.

QE and Unemployment Rate: According to the study by the President of the San Francisco Federal Reserve, John Williams, asset purchases had reduced the US unemployment rate by 1.5 percentage points by late 2012 and helped the economy avoid deflation (Voxeu, 2015). The counterfactual analysis by Liu (2021) discovered that unemployment would have been 70 BP higher and inflation would have been 100 BP lower if the Federal Reserve had not conducted QE. As reported by Fawley and Neely (2013), a change in short-term real interest rates potentially influences the level of output and employment. According to Walker (2020), the cumulative effect of QE on the unemployment rate, over the 60-month horizon, shows a decrease of 79 BP, what is significantly smaller than the estimate provided by Chung, Laforte, Reifschneider and Williams (2012).

QE and Interest Rates, Government Securities, Government Bonds: As found by Walker (2020), after the initial shock and over a 60-month horizon, rates on 30-year mortgages fell by a peak value of 5 BP. The same is confirmed by Krishnamurthy and Vissing-Jorgensen (2011), who state that the main channel in lowering MBS rates is a portfolio balance effect via the MBS purchases during a time of market stress. Fuster and Willen (2010) show that the large reductions on agency MBS rates in 2008 were followed by reductions in mortgage rates offered by mortgage lenders to households. As Williamson (2017) states, large-scale purchases of assets by central banks were a cause of a large increase in the Federal Reserve's balance sheet during the global financial crisis (2007-2008).

QE and Volatility Index (VIX): The VIX is perceived as a prime measure for financial market risk aversion and a general warrant for economic risk, financial turmoil, and uncertainty (Gambacorta, Hofmann and Peersman, 2014). The focus of research of Poutachidou and Papadamou (2021) were popular stock market indicators Nasdaq, S&P 500, Dow Jones, and VIX. According to their research, published in the paper "The Effect of Quantitative Easing through Google Metrics on US Stock Indices Stock", market volatility is calmed when investor atten-

tion on quantitative easing increases. Poutachidou and Papadamou (2021) also find that in the days leading up to the federal announcement of the QE program, there was a decline in the VIX index.

QE and Exchange Rate: Quantitative easing has large and constant effects on the exchange rate. If the domestic currency depreciates, it reduces country's wages and production costs relative to those of the foreign counterpart. Exchange rates could impact both the total amount of foreign direct investment and the allocation of the investment spending across a range of countries (Goldberg, 2009) A typical Federal Reserve or ECB expansionary QE shock raised the relative balance sheet by 20% and depreciated the exchange rate by 7%, in the sample analyzed by Dedola, Georgiadis, Gräb & Mehl (2021). According to Onour and Sergi (2021), a necessary condition in order to stabilize the exchange rate system is that the return on investment should not be less than the depreciation rate of domestic currency in the formal foreign exchange market.

QE and Fiscal Deficit (Total Public Debt): The composition of the central bank's balance sheet changes the composition of the privately-held and public debt which, in turn, affects the sensitivity of inflation to fiscal shocks. Combination of public debt and quantitative easing is hypothesized to have a profound effect on inflation. QE has shown positive effects only when it has been implemented together with decisive fiscal stimulus, since it has counteracted interest rate rises, that deficit and debt growth would have otherwise caused (Bossone, 2014). Bossone argues that QE must be accompanied by fiscal expansion for the policy action to be successful in stimulating aggregate demand and raising inflation.

QE and Money Supply (M1, M2, M3): M1 money supply includes very liquid funds such as cash, checkable deposits, traveler's checks. M2 money supply is less liquid and involves M1 money supply, plus savings and time deposits, certificates of deposits, money market funds. M3 represents a collection of the money supply, involving M2 money, large time deposits, short-term repurchase agreements, institutional money market funds, and larger liquid funds. Walsh (2010) states that central banks do not directly control money supply, inflation (Consumer Price Index), or long-term interest rates, which are likely to be most relevant for aggregate spending, but they can have a close control over narrow reserve aggregates as the monetary base or a short-term interest rate. QE episode in the US was characterized by a sharp increase in the size of the balance sheet of the Fed, together with an increase in money aggregates, a decrease in the long versus short interest rates spread, and a short-term interest rate unchanged and close to zero (Carrera, Perez Forero and Ramirez-Rondan, 2014).

Data and Methodology

Methodology of this scientific paper is based upon previous scientific research of extensive functioning of the transmission mechanism of unconventional monetary policy, including fundamental Vector Autoregression models whose aim is to distinguish the various channels through which unconventional monetary policies affect the real economy. Some of these fundamental models can be found in scientific papers created by Boehl, Goy and Stroebel (2021), Walker (2020), Gambacorta et al. (2014); Peersman (2011), among which few of them use zero and sign restrictions on the response of macroeconomic variables, in order to identify unconventional monetary policy shocks. As stated by Iddrisu and Alagidede (2020), large volumes of empirical works have relied on the vector auto-regression (VAR) and its variants in the transmission exposition, with ordering of variables in the system informed by theory. The productiveness of quantitative easing measures on the economy of the United States is investigated thoroughly using a vector auto-regression (VAR) model. Vector Autoregression (VAR) represents a forecasting algorithm which could be utilized when two or more time-series have an impact on each other, meaning that the relationship among the time series included is bi-directional. The basic requirements for VAR usage are having at least two time-series (variables), influencing each other. A model is autoregressive because every variable (time series) is modelled as a function of the past values, meaning that predictors are nothing but the lags (time delayed value) of the series. A typical auto-regression AR(p) model equation is following:

$$Yt = \alpha + \beta 1Yt\text{-}1 + \beta 2Yt\text{-}2 + \ldots + \beta pYt\text{-}p + \varepsilon t$$

In this equation, α represents the intercept, a constant, and β1, β2 to βp represent the coefficients of the lags of Y to order p, while εt represents the error, considered as white noise. In the Vector Autoregression (VAR) model, every variable is modelled as a linear combination of past values of itself, combined with the past values of other variables in the system. For the purposes of this research, QE's effect on long-term rates are measured, and it is checked whether they passed through to increased real economic activity, proxied by real Industrial Production. Sustainability of QE as a monetary policy is dependent upon analysis results robustly showing that long-term rates fell, which passed into the macroeconomy in increased production and inflation. Thus, the final VAR analysis focuses primarily on industrial production and inflation when evaluating the effectiveness of quantitative easing. The error terms in these regressions represent the "surprise" movements in the variables after taking its past values into account. If the different variables are correlated with each other, as they usually are in

macroeconomic applications, the error terms in the reduced form VAR model is also correlated across equations. All the required diagnostics tests are performed, including tests for the optimal number of lags (LR, FPE AIC, SC, HQ); stability condition test (roots of characteristic polynomials); test for Autocorrelation; test for heteroscedasticity (VAR residual heteroscedasticity test). Data used for VAR analysis is obtained from Federal Reserve Economic Data (FRED). The sampling frame includes ten variables observed monthly during the period January 1994 - January 2022. Variables used in the research are:

- Consumer Price Index for All Urban Consumers: All Items in U.S. City Average (CPIAUCSL); Units: Index 1982-1984=100, Seasonally Adjusted
- Industrial Production: Total Index (INDPRO); Units: Index 2017=100, Seasonally Adjusted
- Unemployment Rate (UNRATE); Units: Percent, Seasonally Adjusted
- Interest Rates, Government Securities, Government Bonds for United States (INTGSBUSM193N); Units: Percent per Annum, Not Seasonally Adjusted
- CBOE Volatility Index: VIX, (VIXCLS); Units: Index, Not Seasonally Adjusted
- Real Broad Effective Exchange Rate for United States (RBUSBIS); Units: Index 2010=100, Not Seasonally Adjusted
- Federal Surplus or Deficit [-] (MTSDS133FMS); Units: Millions of Dollars, Not Seasonally Adjusted
- M1 (WM1NS); Units: Billions of Dollars, Not Seasonally Adjusted
- M2 (WM2NS); Units: Billions of Dollars, Not Seasonally Adjusted
- M3 for the United States (MABMM301USM189S); Units: National Currency, Seasonally Adjusted

VAR modelling in software EViews is meant as a step by step procedure, in which every task is related to a special panel. When a model has been estimated, the diagnostic tests and the stability analysis and the structural analysis use the results obtained from the estimation. When VAR model has been estimated, it is followed by an Impulse Response Analysis, whose goal is to describe the evolution of a model's variables in reaction to a shock in one or more variables, can be used (Lütkepohl, Krätzig and Boreiko, 2006). Reduced-form emphasizes each endogenous (dependent) variable singularly as a function of predetermined variables:

$$Yt = c + A(L)Yt\text{-}1 + ut$$

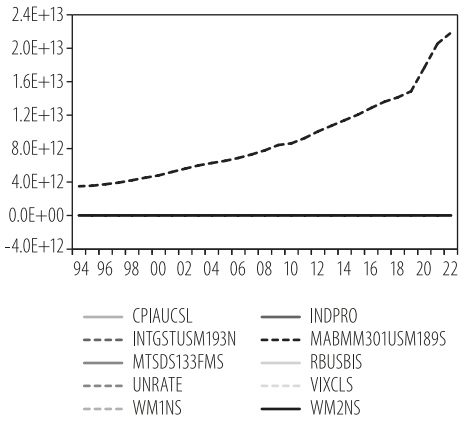
In the given equation, Yt represents a vector of dependent variables, c represents a vector of intercepts, A(L) represents a matrix of autoregressive coefficients of lagged Yt values, while ut represents a vector of residuals. Variables achieve stationarity when they are differenced. When it comes to macroeconomic indicators used for the benchmark regression, they are expressed by the following equation:

$$Yt = \{CPIt, IRt, IPt, VIXt, ERt, M1t, M2t, M3t, URt, FSoDt\}$$

5. Results and Discussion

Constructing graphs from data is an important part of the process of data analysis and presentation. Results displayed in graphs are generally more concise and often more illuminating; one may be able to detect patterns and relationships in data that are not readily apparent from examining tables of summary statistics (Eviews Help, 2021). Observing the data graph for period from 01/01/1994 to 01/01/2022, it is noticeable that variables generally move together, with their general tendency matched, and they are close to zero, excluding the variable MABMM301USM189S, which is M3 for the United States, and has general upward tendency during the entire series, shown in the Figure 3:

Figure 3: Graphical display of data



Source: Author, EViews Software

To estimate simple Vector Autoregressive Model (VAR), we use the first difference of all variables. VAR Residual Serial Correlation LM Test belongs to the class of asymptotic (large sample) tests known as the Lagrange multiplier (LM) tests. The null hypothesis of the LM test is that there is no serial correlation up to lag order p, where p is a pre-specified integer. In order to test residual autocorrelation, Autocorrelation LM Test is executed, using two lags, as shown in Table 1:

Table 1: VAR Residual Serial Correlation LM Tests

VAR Residual Serial Correlation LM Tests
Date: 05/09/22 Time: 21:31
Sample: 1994M01 2022M01
Included observations: 335

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	528.0566	100	0.0000	5.823467	(100, 2195.6)	0.0000
2	431.2484	100	0.0000	4.650823	(100, 2195.6)	0.0000

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	528.0566	100	0.0000	5.823467	(100, 2195.6)	0.0000
2	891.8955	200	0.0000	5.072320	(200, 2674.1)	0.0000

* Edgeworth expansion corrected likelihood ratio statistic.

Source: Author, EViews Software

Observing the Autocorrelation LM Test results, it is noticeable that all autocorrelations are significant, with p-values at zero, making VAR model insufficient to capture all the dynamics, which leads us to determine what number of lags should be used, by estimating Lag Length Criteria. Table 2 illustrates VAR Lag Order Selection Criteria:

Table 2: VAR Lag Order Selection Criteria

VAR Lag Order Selection Criteria
Endogenous variables: D(CPIAUCSL) D(INDPRO) D(INTGSTUSM193N) D(MABMM301USM189S) D(MTSDS133FMS) D(RBUSBIS) D(UNRATE) D(VIXCLS) D(WM1NS) D(WM2NS)
Exogenous variables: C
Date: 05/09/22 Time: 21:43
Sample: 1994M01 2022M01
Included observations: 332

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-19726.16	NA	2.04e+39	118.8926	119.0072	118.9383
1	-18697.92	1988.353	7.61e+36	113.3007	114.5615	113.8035
2	-18402.05	554.3037	2.34e+36	112.1208	114.5277*	113.0807
3	-18211.87	344.8500	1.36e+36	111.5775	115.1305	112.9945*
4	-18065.01	257.4465*	1.04e+36*	111.2952*	115.9944	113.1692

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Author, EViews Software

In order to determine lag-length criteria, we observe the results of Akaike, Schwartz and Hannan-Quinn length decision. SIC (Schwartz, 1997) and HQIC (Hannan and Quinn, 1979) are stricter in penalizing loss of degree of freedom than AIC (Akaike, 1974). Since the aim is to find the model with the lowest value of the selected information criterion, which is, in this case, the Akaike Information Criterion (AIC) with the criteria value 111.2952*, the number of lags used for the purposes of this research is 4. The AIC tends to produce the most accurate structural and semi-structural impulse response estimates for realistic sample sizes (Ivanov and Kilian, 2005). Stability of the VAR system implies Stationarity Conditions. If all inverse roots of characteristic AR polynomial have modulus less than one and lie inside the unit circle, the estimate VAR is stable. If the VAR is not stable, diverse tests conducted on VAR model may be invalid. AR Roots Table, or Roots of Characteristic Polynomial, with no roots lying outside the unit circle shown in Table 3 is generated:

Table 3: Roots of Characteristic Polynomial

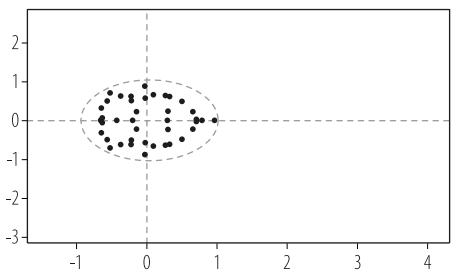
Roots of Characteristic Polynomial
Endogenous variables: D(CPIAUCSL) D(INDPRO) D(INTGSTUSM193N) D(MABMM301USM189S) D(MTSDS133FMS) D(RBUSBIS) D(UNRATE) D(VIXCLS) D(WM1NS) D(WM2NS)
Exogenous variables: C
Lag specification: 1 4
Date: 05/09/22 Time: 21:45

Root	Modulus
0.973912	0.973912
-0.018449 + 0.880335i	0.880528
-0.018449 - 0.880335i	0.880528
-0.515275 + 0.708072i	0.875714
-0.515275 - 0.708072i	0.875714
0.794640	0.794640
-0.555596 - 0.498197i	0.746249
-0.555596 + 0.498197i	0.746249
-0.362883 + 0.623834i	0.721701
-0.362883 - 0.623834i	0.721701
0.714953 - 0.027970i	0.715500
0.714953 + 0.027970i	0.715500
-0.638757 - 0.318607i	0.713807
-0.638757 + 0.318607i	0.713807
0.510802 + 0.486352i	0.705306
0.510802 - 0.486352i	0.705306

0.665824 + 0.223411i	0.702306
0.665824 - 0.223411i	0.702306
0.336532 + 0.613296i	0.699561
0.336532 - 0.613296i	0.699561
0.274202 - 0.638092i	0.694513
0.274202 + 0.638092i	0.694513
0.104801 - 0.660160i	0.668427
0.104801 + 0.660160i	0.668427
-0.216828 - 0.619964i	0.656788
-0.216828 + 0.619964i	0.656788
-0.648051	0.648051
-0.624423 + 0.061490i	0.627443
-0.624423 - 0.061490i	0.627443
-0.012575 - 0.573432i	0.573570
-0.012575 + 0.573432i	0.573570
-0.209364 - 0.507664i	0.549141
-0.209364 + 0.507664i	0.549141
-0.418474	0.418474
0.312851 + 0.233759i	0.390537
0.312851 - 0.233759i	0.390537
0.303541	0.303541
-0.137251 + 0.223951i	0.262664
-0.137251 - 0.223951i	0.262664
-0.192463	0.192463
No root lies outside the unit circle.	
VAR satisfies the stability condition.	

Source: Author, EViews Software

Figure 4: Inverse Roots of AR Characteristic Polynomial



Source: Author, EViews Software

Since each modulus is lower than 1, the system is stationary, which is confirmed in AR Roots Graph, or Inverse Roots of AR Characteristic Polynomial, shown in Figure 4, with no roots lying outside the unit circle:

An additional Autocorrelation LM Test is executed using four lags, showing that VAR model is sufficient to capture all the dynamics, illustrated in Table 4:

Table 4: Autocorrelation LM Test

VAR Residual Serial Correlation LM Tests Date: 05/09/22 Time: 21:46 Sample: 1994M01 2022M01 Included observations: 332						
Null hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	176.7081	100	0.0000	1.802085	(100, 1959.3)	0.0000
2	185.5462	100	0.0000	1.896449	(100, 1959.3)	0.0000
3	257.4035	100	0.0000	2.679265	(100, 1959.3)	0.0000
4	220.5612	100	0.0000	2.274406	(100, 1959.3)	0.0000

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	176.7081	100	0.0000	1.802085	(100, 1959.3)	0.0000
2	383.8851	200	0.0000	1.993191	(200, 2377.4)	0.0000
3	741.9909	300	0.0000	2.700850	(300, 2423.6)	0.0000
4	932.1522	400	0.0000	2.590541	(400, 2380.5)	0.0000

* Edgeworth expansion corrected likelihood ratio statistic.

Null hypothesis: No serial correlation at lags 1 to h

Source: Author, EViews Software

VAR model should be free from heteroscedasticity, with the variables having similar dispersion. Heteroscedasticity means unequal scatter. In terms of regression analysis, heteroscedasticity is presented in the context of the residuals or error term. More precisely, heteroscedasticity represents a systematic change in the spread of the residuals over the range of measured values. Heteroscedasticity is a problem because ordinary least squares (OLS) regression assumes that all residuals are drawn from a population that has a constant variance (homoscedasticity). Thus, in order to satisfy the regression assumptions and to get reliable results, the residuals should have a constant variance. According to the Breusch-Pagan-Godfrey heteroscedasticity test, observing probability of the Chi-Square test whose value is higher than 0.05, the data has no heteroscedasticity. The dataset has homoscedasticity and it is acceptable for regression. As illustrated in Table 5, Prob. Chi-Square(9) value is 0.0641:

Table 5: Heteroskedasticity Test: Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.827203	Prob. F(9,326)	0.0625
Obs*R-squared	16.13533	Prob. Chi-Square(9)	0.0641
Scaled explained SS	76.05547	Prob. Chi-Square(9)	0.0000

Source: Author, EViews Software

An impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. If the innovations are contemporaneously uncorrelated, interpretation of the impulse response is straightforward. Impulse response analysis represents an important step in econometric analyses, which use vector autoregressive models. Their main purpose is description of the evolution of a model's variables in reaction to a shock in one or more variables (EViews Help, 2020). With None Response Standard Errors, using Cholesky dof adjusted Decomposition Method, we estimate the model with ordering:

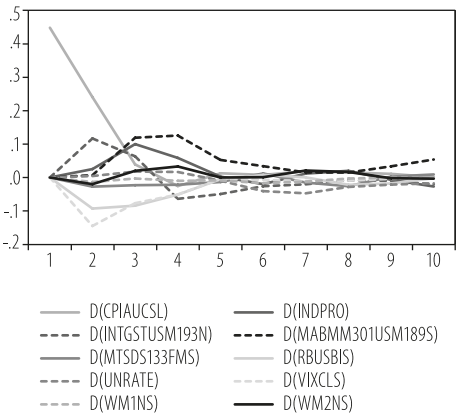
Yt = {CPIt, IRt, IPt, VIXt, ERt, M1t, M2t, M3t, URt, FSoDt}

Impulse Response Function Analysis is based upon the following criteria:

- Magnitude of the Shock: One Standard Deviation
- X axis represents the periods, while Y axis shows the percentage variation.

To make it clear for interpretation, responses of Consumer Price Index/Inflation D(CPIAUCSL) and Industrial Production D(INDPRO) are presented individually. Figure 5 exhibits response of D(CPIAUCSL) to Innovations:

Figure 5: Response of D(CPIAUCSL) to Innovations



Source: Author, EViews Software

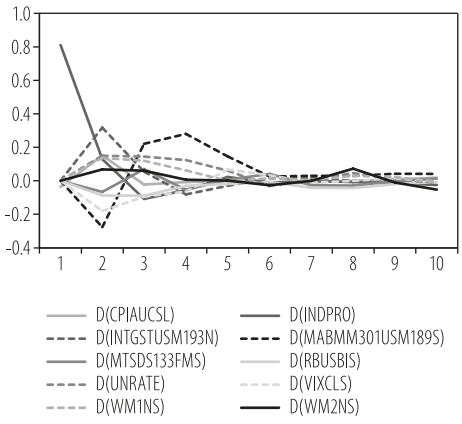
An abrupt fall in Consumer Price Index/Inflation (CPIAUCSL) is one standard deviation shock which causes:

- Industrial Production (INDPRO) to slightly increase directly after the shock
- Unemployment Rate (UNRATE) to stay constant
- Interest Rates, Government Securities, Government Bonds (INTGSBUSM193N) to rise and fall during the decline of CPIAUCSL
- Volatility Index: VIX (VIXCLS) to move from negative territory to positive territory over time

- Real Broad Effective Exchange Rate (RBUSBIS) to move from negative territory to positive territory over time
- Federal Surplus or Deficit (MTSDS133FMS) to stay constant almost throughout the entire period, with slight changes
- M1 (WM1NS) to stay constant
- M2 (WM2NS) to stay constant almost throughout the entire period, with slight changes
- M3 (MABMM301USM189S) to slightly increase directly after the shock

According to the same principle as the previous one, Figure 6 exhibits response of D(INDPRO) to Innovations:

Figure 6: Response of D(INDPRO) to Innovations



Source: Author, EViews Software

An abrupt fall in Industrial Production (INDPRO) is one standard deviation shock which causes:

- Consumer Price Index/Inflation (CPIAUCSL) to slightly increase directly after the shock
- Unemployment Rate (UNRATE) to slightly increase directly after the shock
- Interest Rates, Government Securities, Government Bonds (INTGSBUSM193N) to rise and fall during the decline of CPIAUCSL
- Volatility Index: VIX (VIXCLS) to move from negative territory to positive territory over time
- Real Broad Effective Exchange Rate (RBUSBIS) to move from negative territory to positive territory over time
- Federal Surplus or Deficit (MTSDS133FMS) to move from negative territory to positive territory over time
- M1 (WM1NS) to slightly lower its positive trend
- M2 (WM2NS) to stay constant almost throughout the entire period, with slight changes
- M3 (MABMM301USM189S) to experience great turbulence from negative to positive territory

6. Conclusion

The large volumes of empirical works have relied on the vector auto-regression (VAR), Impulse Response Function, which is more acceptable to interpret, and its variants in the transmission exposition, with ordering of variables in the system informed by theory. Some of these fundamental models can be found in scientific papers created by Boehl (2021), Walker (2020), Baumeister and Benati (2013), Gambacorta et al. (2014), and Peersman (2011), among which few of them use zero and sign restrictions on the response of macroeconomic variables, in order to identify unconventional monetary policy shocks. In this scientific paper, the effectiveness of quantitative easing measures on the economy of the United States is investigated thoroughly using a vector auto-regression (VAR) model. Summarizing academic views on the effect of QE, and the results of this research, it is concluded that Quantitative Easing is an effective tool in stabilizing financial markets, when they would otherwise be dysfunctional. Quantitative easing causes an upshift in inflation, including the immediate negative influence on the federal funds rate, at the point of time when reserves increase. At the same time, considering the main variables of interest that reveal the impact of QE on the macroeconomics, industrial production, mortgage rates and yields are unrestricted. Also, the unemployment rate and the exchange rate are left unrestricted because of a lack of consensus on the effect of QE on these variables. The specificity of this thesis is in investigating the relationship of quantitative easing measures, balance sheet and stated variables prior to and during zero lower bound conditions. Quantitative easing measures (QE) have an impact on Consumer Price Index/Inflation, Industrial Production, Unemployment rate, VIX (volatility index), and Exchange Rate in the United States. Lowering interest rates (Interest rates, Government securities, Government bonds) results in an increase in real economic activity. There is a different impact of Quantitative Easing measures (QE) on the macroeconomic indicators during and outside the period of expansionary fiscal policy. There is a different impact of Quantitative Easing measures (QE) on the macroeconomic indicators during and outside the zero-lower bound period. There are different macroeconomic outcomes caused by Quantitative Easing measures (QE) when applied in combination with expansionary fiscal policy. Purchases of government securities by the Fed have emphasized market-based discipline of federal spending. Quantitative Easing is perceived to blur the difference between fiscal and monetary policy. Theoretically, QE functions by reducing long-term interest rates through reducing expectations of future central bank policy rate rises and by directly raising financial market asset prices, what is also confirmed by this research. Condemning only one institution (Fed) for the performance of the entire economy is not the most acceptable approach because

it consists of several financial institutions who have their specific roles. While there are current limitations on the Fed's ability to act, historic evidence shows that past barriers have been neither permanent nor immutable. As a member of the Financial Stability Oversight Council (FSOC), the Federal Reserve was given the authority to identify large financial institutions which have an ability to pose threats to financial system stability and expose them to more rigid regulatory standards (Schellhorn, 2020).

References

1. Akaike, H. (1974). A new look at the statistical model identification. IEEE Trans. Automat. Control. vAC-19. 716-723.
2. Baumeister, C., Benati, L. (2011). Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound. *International Journal of Central Banking*. https://www.ijcb.org/journal/ijcb13q2a9.pdf
3. Boehl, G, Goy, G. and Strobel,F. (2021). A structural investigation of quantitative easing. Discussion Paper; *Deutsche Bundesbank;* No 01/2021.
4. Bossone, B. (2014). "Secular stagnation", *Economics Discussion Paper* No 2014-47, November 19.
5. Fabo, B., Jančoková, M., Kempf, E., Pástor. L. (2021). Fifty shades of QE: comparing findings of central bankers and academics. *ECB*. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2584~004629c8e7.en.pdf
6. Carrera, C., Perez Forero, F. Ramirez-Rondan, N. (2015). Effects of U.S. Quantitative Easing on Latin American Economies. *PERUVIAN ECONOMIC ASSOCIATION*; Working Paper No. 35. http://rcuela.net/ape/wp-content/uploads/2014/01/WP-35.pdf
7. Carrera, C., Pérez Forero, F., Ramírez-Rondán, N. (2014). Effects of the U.S. Quantitative Easing on a Small Open Economy. *Working Paper Series, Banco Central de Reserva Del Perú*. https://www.bcrp.gob.pe/docs/Publicaciones/Documentos-de-Trabajo/2014/documento-de-trabajo-17-2014.pdf
8. Chung, H., Laforte, J.P., Reifschneider, D., Williams, J. C. (2012). "Have We Underestimated the Likelihood and Severity of Zero Lower Bound Events?" *Journal of Money, Credit, and Banking*, Vol. 44, pg 47-82.
9. Coenen, G. and Wieland, V. (2003). "The Zero-Interest Rate Bound and the Role of the Exchange Rate for Monetary Policy in Japan." *European Central Bank Working Paper Series*, No. 218,.
10. D'Amico, S. (2013, January 4). The Fed - The Federal Reserve's Large-Scale Asset Purchase Programs: Rationale and Effects. Board of Governors of the Federal Reserve System.
11. Dedola, L., Georgiadis, G., Gräb, J., & Mehl, A. (2021). Does a big bazooka matter? Quantitative easing policies and exchange rates. *Journal of Monetary Economics*, 117, 489–506. https://doi.org/10.1016/j.jmoneco.2020.03.002
12. European Central Bank. (2021, November 2). Asset purchase programmes. https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html
13. EViews Help. (2020). EViews. http://www.eviews.com/help/helpintro.html#page/content/VAR-Vector_Autoregressions_(VARs).html

14. Fawley, W.; Neely, J. (2013). *Federal Reserve Bank of St. Louis Review* January/February 2013 51 Four Stories of Quantitative Easing. Federal Reserve Bank of St. Louis Review, January/February 2013, 95(1), 51–58. https://files.stlouisfed.org/files/htdocs/publications/review/13/01/Fawley.pdf
15. FRED Economic Data. (2021). Federal Reserve Economic Data. https://fred.stlouisfed.org/#
16. Fuster, A., & Willen, P. (2010). $1.25 Trillion is Still Real Money: Some Facts About the Effects of the Federal Reserve's Mortgage Market Investments. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1692760
17. Gambacorta, L., Hofmann, B. and Peersman, G. (2014). "The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis," *Journal of Money, Credit and Banking*, 46 (4), 615–642.
18. Goldberg, L.S. (2009), Exchange rates and foreign direct investment. *Princeton Encyclopedia of the World Economy*, Vol. 1: 393-396
19. Hannan, E.J. and Quin, G.G. (1979). The determination of the order of an autoregression. *J.R. Statistic*. Soc. B, 41, 190-195.
20. Lütkepohl, H., Krätzig, M. & Boreiko, D . (2006). VAR Analysis in JMulTi. JMulTi. http://www.jmulti.de/
21. Iddrisu, A. A. and Alagidede, I. P. (2020). Revisiting interest rate and lending channels of monetary policy transmission in the light of theoretical prescriptions. *Central Bank Review*. https://doi.org/10.1016/j.cbrev.2020.09.002
22. Ivanov, V., & Kilian, L. (2005). A Practitioner's Guide to Lag Order Selection For VAR Impulse Response Analysis. *Studies in Nonlinear Dynamics & Econometrics*, 9(1). https://doi.org/10.2202/1558-3708.1219
23. Krishnamurthy, A. and Vissing-Jorgensen, A (2011). "The Effects of Quantitative Easing on Interest Rates." *FRBSF Economic Policy Review*.
24. Krušković, B. D. (2022). Central Bank Intervention in the Inflation Targeting. *Journal of Central Banking Theory and Practice*, 11(1), 67–85. https://doi.org/10.2478/jcbtp-2022-0003
25. Liu, P., Theodoridis, K.,"Changing Macroeconomic Dynamics at the Zero Lower Bound." *Journal of Business and Economic Statistics*, Vol. 40, 2018.
26. Lu, M. (2021). The Fed's Balance Sheet: The Other Exponential Curve. Visual Capitalist. https://www.visualcapitalist.com/the-feds-balance-sheet-the-other-exponential-curve/
27. Onour, I. A., & Sergi, B. S. (2021). The impact of a political shock on foreign exchange markets in a small and open economy: A dynamic modelling approach. *Journal of Central Banking Theory and Practice*, 10(3), 137–152. https://doi.org/10.2478/jcbtp-2021-0028

28. Peersman, G. (2011). EconStor: Macroeconomic effects of unconventional monetary policy in the euro area. *EconStor.* https://www.econstor.eu/handle/10419/153831
29. Poutachidou, N., & Papadamou, S. (2021). The Effect of Quantitative Easing through Google Metrics on US Stock Indices. *International Journal of Financial Studies*, 9(4), 56. https://doi.org/10.3390/ijfs9040056
30. Sadahiro, A. (2005), Sengo Nihon no Macro Keizai Bunseki, Chapter 9, Toyo Keizai Shimpousha.
31. Schellhorn, C. (2020). Financial System Stability, the Timing of Climate Change Action and the Federal Reserve. *Journal of Central Banking Theory and Practice*, 9(3), 45–59. https://doi.org/10.2478/jcbtp-2020-0035
32. Schenkelberg, H., & Watzka, S. (2013). Real effects of quantitative easing at the zero lower bound: Structural VAR-based evidence from Japan. *Journal of International Money and Finance, 33*, 327–357. https://doi.org/10.1016/j.jimonfin.2012.11.020
33. Schwartz, E.S. (1997). The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging'. *J Finance 52(3) Papers and Proceedings Fifty-Seventh Annual Meeting, American Finance Association*, New Orleans, Louisiana January 4-6, (July 1997), 923-973.
34. USGI. (2019). Is the Fed Gearing Up for a New Round of Quantitative Easing? Here Are the Possible Signs. USFUNDS. https://www.usfunds.com/resource/is-the-fed-gearing-up-for-a-new-round-of-quantitative-easing-here-are-the-possible-signs/
35. Voxeu. (2015), Fifty shades of QE: Central bankers versus academics. *VOX, CEPR Policy Portal*. https://voxeu.org/article/fifty-shades-qe-central-bankers-versus-academics
36. Walker, S. (2020). "Evaluating the effectiveness of quantitative easing: An SVAR approach" *Senior Honors Projects*, 2020-current. 11. https://commons.lib.jmu.edu/honors202029/11
37. Walsh, C. E. (2010). *Monetary Theory and Policy*, Third Edition, Volume 1 of MIT Press Books. The MIT Press.
38. Wang, G. (2019). The Effects of Quantitative Easing Announcements on the Mortgage Market: An Event Study Approach. *International Journal of Financial Studies*, 7(1), 9. https://doi.org/10.3390/ijfs7010009
39. Williamson, S. (2017, August 18). Quantitative Easing: How Well Does This Tool Work? *St. Louis Fed*. https://www.stlouisfed.org/publications/regional-economist/third-quarter-2017/quantitative-easing-how-well-does-this-tool-work