

Assessing the Effect of Quantitative Easing on the US Economy from 2008 to 2015 by a Bayesian-VAR Model

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Abstract. From the huge financial crisis in 2008, central banks began to choose unconventional monetary policies to deal with the persistent economic recession and the most widely-used one is Quantitative Easing (QE). Since QE is a new tool for most countries, many economists try to figure out the macroeconomic effect of QE, which can be used in the policy decision. Most of research on this topic focuses on three indicators, GDP, CPI and the unemployment rate, and find QE has a positive effect on these indicators. However, one gap is that few researchers consider other important economic indicators and they tend to use similar econometric methods. Here my research involves another method, Bayesian VAR (BVAR), to do a counterfactual analysis in two scenarios based on different treatments on the 10-year interest rate for studying the macroeconomic effect of QE on other three variables, Nonfarm Payrolls, Personal Consumption Expenditure, and Industrial Production Index. Compared with the basic scenario with QE, there is no significant positive effect of QE on those three variables. Furthermore, I found the results are very sensitive to the change of the 10-year interest rate. In conclusion, QE is not a panacea as expectations and I strongly recommend that central banks should not continue to rely on QE in the next economic recession and instead come up with a new monetary policy. Since longer forecast horizons usually make the forecasts less informative, it is necessary for further research to find how to effectively isolate the effect of different QE programmes from each other and then do the conditional forecast for each QE period separately to shorten the forecast horizon.

Keywords: Monetary Policy; Quantitative Easing; Bayesian VAR model; Counterfactual Analysis; US Economy.

1. Introduction

Some people attribute the economic revival in the US after 2008 financial crisis to the introduction of QE and argue that in the next economic depression, it may be a sensible decision for the Fed to employ this policy again (Luck and Zimmerman, 2019[22]). This standpoint is consistent with a considerable amount of existing empirical research. However, there are two limitations in previous research. The first one relates to the outcome variables. Most existing articles only consider three variables, namely GDP, CPI and the unemployment rate. Whilst these three variables are the most important indicators to assess the economic performance, they cannot provide a comprehensive description of an economic foundation. The second issue is the robustness of results. Based on different methods, those articles have shown different estimates.

Therefore, it is necessary to use another widely-used method to recheck the robustness of the positive effect of QE programmes on the US economy. In response to these issues, this research considers Personal Consumption Expenditure (PCE) as the outcome variable to represent the performance of the individual consumption. To measure the effect the QE, this study treats the reduction of the 10-year interest rate as the only channel for QE to exert its effect on the US economy. The first reason for doing so is that one of the aims of QE is to affect individuals' consumption decisions by controlling the long-term interest rate. Secondly, other articles have provided the interlink between the long-term interest rate and economic variables (Dewachter et al., 2006[6]; Bauer et al., 2016[3]). In addition, unlike most analysts in the US who prefer using DSGE models to study the US economy (Chen et al., 2011[4]; Gertler et al., 2013[11]), this study undertakes a counterfactual analysis by using a BVAR model to conduct conditional forecasts in two scenarios. In the policy scenario, this dissertation uses the 10-year interest rate based on its actual observation values. In the no-policy scenario, the 10-year interest rate is increased by different basis points (bps) to create its

counterfactual values at some possible levels when there is no QE. These counterfactual values are based on previous research regarding the effect of QE on the 10-year interest rate, such as Ehlers (2012) [9]; Kuttner (2018[20]).

Finally, the results relating to PCE illustrate that although the QE programmes introduced by the Fed have stabilised the US economy after the financial crisis, they failed to provide a persistent momentum to economic recovery. Furthermore, after a short-term positive effect on the growth rate of PCE, QE damaged the two economic indicators. In addition, the effect of QE on the economy is very sensitive to the treatment of the 10-year interest rate, meaning that the Fed has to be careful about the number of basis points by which the QE operations reduce the 10-year interest rate. Otherwise, such an unconventional monetary policy would offer a negative effect on the economy.

2. Literature Review

A common opinion is that QE has affected the macroeconomy through its influence on the long-term interest rate (Lenza et al., 2010[21]). Consequently, before looking at the effect of QE programmes on the US economy, it is necessary to understand how this policy has changed the interest rate in the financial market. Unlike conventional tools, QE aims to control the spending decisions of consumers and the aggregate demand by influencing long-term interest rates. In particular, Federal Open Market Committee (FOMC) members have emphasised that this policy was designed to affect the 10-year interest rate. Based on this background, some economists have made efforts to calculate the influence of QE programs on the 10-year interest rate. Their estimates are summarised in the Table 1 as follows:

Table 1. Empirical Results about the Effect of QEs on 10-year Interest Rate

<i>Study</i>	<i>QE1 Basis points</i>	<i>QE2 Basis points</i>	<i>QE3 Basis points</i>	<i>Total Basis points</i>
Gagnon et al. (2011)	-91***			
Krishnamurthy and Vissing-Jorgenson (2011)	-107*	-30***		
Ehlers (2012)		-40***		
Bauer and Neely (2014)	-123**	-23	-14*	
Kuttner (2018)	-100***	-30**	Smaller than 30	
Carlo (2012)				150 to 190

Another essential aspect of this field is the macroeconomic effect of QE in the US, which is also the main issue in this research, given the ultimate target of QE programs is to deal with a persistent economic recession. Almost all researchers in this field attempt to figure out whether QE programmes have a positive effect on GDP, CPI and unemployment rate, and their studies imply that those LSAPs have indeed mostly prevented deflation and economic depression, although by using different methods, they obtain different estimates of the exact magnitude. Most studies of the US economy tend to use the DSGE model and its expansion forms, such as Chen, Cúrdia, Vasco, and Ferraro (2011) [4], Gertler and Karadi (2013) [11]. A few researchers choose different methods, like Chung et al. (2012) [5] and Hesse et al. (2018) [14]. The unemployment rate is another popular factor in previous studies (Ihrig, Klee, Li, Schulte, and Wei, 2012[15]; Wu and Xia, 2016[30]), despite its lower frequency. However, only a few other important economic indicators in the US have appeared in such existing research. Therefore, it is necessary to consider other important economic indicators within the model in order to conduct a comprehensive analysis of the effect of QE on the entire economy.

Table 2. Empirical Results about the effect of QE on the US economy

<i>Study</i>	<i>Method</i>	<i>GDP</i>	<i>CPI</i>	<i>Unemployment Rate</i>	<i>Other Factors</i>
Chen, Cúrdia, Vasco, and Ferraro (2011)	DSGE	QE3: 0.4%			
Chung et al. (2012)	Probability Distribution	QE1: 3% QE2: 1%			No effect on Core PCE
Ihrig, Klee, Li, Schulte, and Wei (2012)	FRB/US model			-1.2%	
Gertler and Karadi (2013)	DSGE with financial friction	QE1: 3.5% QE2: 1%			
Wu and Xia (2016)	FAVAR			-0.4% to -1.8%	
Hesse et al. (2018)	small-scale VARs	0.1%	0.1%		Stock Market: 1.5%

3. Variables and Econometric Methodology

3.1 Introduction of Variables

This study relies on a large data set to include 20 economic variables that form the foundation of the US economy. Since the basic activity in an economy is production and consumption activities (Romer, 2004[27]), the study uses the Industrial Production Index, Manufacturing Production and Consumption Goods Production to represent production and introduces nominal Personal Consumption Expenditure, Wholesale Sales and Retail Sales to represent consumption. For the employment situation, aside from the unemployment rate, Nonfarm Payrolls and Initial Jobless Claims are contained in the data set. In addition, other indicators, such as the Small Business Optimism Index and the Michigan Consumer Sentiment Index, reflect the US economy from a micro perspective.

This study uses Personal Consumption Expenditure (PCE) as the main research object. PCE measures the goods and services targeted towards individuals and consumed by individuals and is considered to be a more accurate representation of individuals' consumption decisions (Kenton, 2019[16]). More importantly, from 17 February 2000, the FOMC began to change its primary measure of inflation from the CPI to the chain-type price index for PCE (Greenspan, 2000[12]). Consequently, the change pattern of PCE can provide a better prediction for the decisions of the Federal Reserve on its future monetary policies.

Besides, this study assumes that QE exerts its influence on the economy mainly through the reduction of the 10-year interest rate and thus treats this interest rate variable as the intermediary of QE's effect. This assumption comes from the purpose of QE. According to the claims of FOMC members, the main aim of QE is to affect the 10-year interest rate and a significant body of research has shown that QE has indeed reduced the 10-year interest rate. The link between long-term interest rates and macroeconomic variables has been identified in some theoretical or empirical studies.

3.2 Bayesian VAR (BVAR)

Vector autoregression (VAR) models have been widely used in macroeconomic analysis and forecasting (Hausken and Ncube, 2013[13]). However, they also possess a risk of over-parameterisation when applied in large dimensions. Accordingly, in most macroeconomic cases which involve a large number of variables with long lags, one popular way of solving the over-parameterisation problem is to involve the Bayesian statistical inference in the framework of VAR models. The aim of this method is to restrict the parameter space by introducing a prior distribution. Specifically speaking, according to Bayes' Rule, researchers can assume that coefficients to be estimated in VAR models have a certain prior distribution, meaning they can combine the prior distribution with the likelihood function to obtain a posterior distribution of those parameters (Armero and Conesa, 2004[1]), reducing the range of coefficients and the loss of the degree of freedom to increase the accuracy of forecasts.

BVAR has been a frequently used tool for forecasting analysis, particularly for a large information set. Dua and Ray (1995) [8] use a BVAR model to predict the employment rate in Connecticut, which finds that the prediction accuracy is higher than that of VAR and ARIMA models. Kenny et al. (1998) [18] adopt BVAR to study the inflation problem in Ireland and point out that BVAR provides a better prediction than non-Bayesian methods. Edge et al. (2006) compare forecast performances using different methods, such as a random walk model, a DSGE model and BVAR, and conclude that the forecast result of BVAR is the most robust. Banbura et al. (2010) [2] show that medium or large Bayesian VAR outperforms FAVARs and smaller VARs in terms of forecasting accuracy. Subsequently, the empirical exercise of Koop (2013) [19] also arrives at the same result.

Overall, BVAR is a useful method for the macroeconomic forecast, especially when working with dozens or hundreds of variables (Koop, 2013) [19]. Therefore, the use of BVAR model in this research is desirable both for theoretical and pragmatic grounds.

3.3 Prior Choice

Because estimates of a BVAR model rely on the prior distribution of coefficients, the next step is to choose a suitable prior. However, there is no single prior that always leads to the best forecast, nor is there a theoretical reason for asserting that one prior must be better than another (Koop, 2013[19]). As a result, it is not possible to use a universal standard to point out only one prior from all candidates that may be the most appropriate choice for this model.

Since many applied macroeconomists have reflected that there are usually cointegration relationships among macroeconomic variables, we need a prior to fit this belief (Sim and Zha, 1998[29]). One prior, subsequently introduced by Sims (1993) [28], is the dummy initial observation prior, which has been found to improve forecasts with economic time series (Sim and Zha, 1998) [29]. There is some empirical research, such as Robertson et al. (1999) [25] and Giannone et al. (2010) [10], that has shown that when it comes to models in medium or large scales, forecasts under the dummy initial observation prior can outperform those under the Minnesota prior at all the horizons. The basic idea of this prior is that although there is some doubt about the accuracy of naive random walk forecasts and the exactitude of prior means, coefficient by coefficient, it is highly possible that if some coefficients deviate from their prior means, other coefficients will deviate in an offsetting way and therefore the no-change forecasts will be reasonably accurate (Sims, 1993) [28]. In short, this prior includes non-zero terms off the diagonal of the covariance matrix commonly by adding a set of dummy observations into the data set, rather than directly specifying the prior covariance structure. Furthermore, the magnitude of the weight attached to each dummy observation is introduced to control the tightness of the prior restriction (Robertson et al., 1999) [25].

4. Counterfactual Analysis

4.1 Conditional Forecast

A common method of testing policy effectiveness is to construct a counterfactual analysis in the absence of the policy intervention and analyse the difference between the actual result and the counterfactual one (M. Hashem and Ron, 2014[23]). Generally, conditional forecasts constitute a great tool for counterfactual analysis. They are forecasts that are conditional on a subset of variables which have been constrained the path to take specific values determined by users over the forecast horizon. Hence, this technique is very suitable for such situation where researchers create a scenario for some given variables and obtain the outcome for other variables, or analyse the comparison among outcomes in different scenarios to do a counterfactual analysis (Dieppe et al. 2015[7]).

There are different methods for conditional forecasts. This research uses the tilting method, also known as the relative entropy approach, which is specified by Robertson et al. (2005) [26]. Compared with the classical conditional forecast methodology, the tilting approach has two main advantages. Firstly, the traditional conditional forecast methodology developed by Waggoner and Zha (1999) [31] is a hard forecast which means that the values for condition variables are always set exactly by users. However, rather than an exact value, it is more realistic to allow some variability in this value, given researchers may not be entirely confident about the accuracy of this value. In this study, this issue occurs because there is not an exact number to represent by how many basis points QE has decreased the 10-year interest rate, instead it is a range of possible numbers. In contrast, the tilting methodology is a soft forecast which allows the user to do conditional forecasts on any points associated with the distribution around the mean value for condition variables. Secondly, another difference between the tilting methodology and the traditional approach is that this technique is using the condition to predict a new distribution which can also resemble the unconditional forecast distribution. Hence, conditional forecasts under the tilting method are more compliant with the initial distribution (Dieppe et al., 2015[7]).

4.2 Analysis Scenarios

The counterfactual analysis in this article relies on empirical findings in previous research regarding the effect of QE on 10-year interest rates. Based on different methods, certain articles conclude that QE may have depressed the 10-year interest rate by different amounts, ranging from 100 bps to 130 bps for QE1, 20 bps to 40 bps for QE2 and approximately 20 bps for QE3. According to Kuttner (2018) [20], the entire effect of QE would range from 150 bps to 190 bps. This impact is employed in this research by increasing the actual 10-year interest rate by different bps during each QE period to arrive at the potential original level without this QE program and completing conditional forecasts on the changed 10-year interest rate to obtain the resulting counterfactual simulations.

There are two scenarios in this research: a policy scenario and a no policy scenario. The policy scenario has been set as the baseline model prediction and in this scenario a conditional forecast will be generated based on the actual observations of the 10-year interest rate from November 2008 to the end of the forecast horizon, December 2015. The study does not take the real value for each observation of NFP, PEC and IPI as its baseline, because the actual changes in these variables may also arise from shocks in other factors that are not captured in the model (Kapetanios et. al, 2012[17]). In this way, the change in these three variables is identified only as the impact of QE and the counterfactual analysis is isolated from potential shocks of other factors. Consequently, the conditional result of the baseline model may be lower than the actual value, as such shocks, that are not included in the model, may also push up the recovery of the economy.

In the no policy scenario, the study supposes a median counterfactual case named as 170-basis-points where the 10-year interest rate would have been 115 basis points higher over the QE1 period from November 2008 to October 2010. For the QE2 period which is from November 2010 to August 2012, the study increases the changed 10-year interest rate after QE1 by an additional 35 points. During the rest forecast horizon, the 10-year interest rate is increased by another 20 points. To conduct sensitivity analysis to cover the range of all potential effect of QE on the 10-year interest rate, the

study also sets two more sub-scenarios. The lower-bound case is called the 150-basis-points case with a 100-basis-point for QE1, a 30-basis-point for QE2 and a 20-basis-point for QE3. The upper-bound case is marked as the 190-basis-points equipped with a 130-basis-point for QE1, a 40-basis-point for QE2 and a 20-basis-point for QE3, which is summarised in Table 3 below.

Table 3. Counterfactual Analysis Treatment for Different Scenario

	<i>Scenario</i>	<i>Treatment</i>		
		QE1	QE2	QE3
No-policy Scenario (Counterfactual Model)	Median 170 Basis-Points Case	+115 bps	+35 bps	+20 bps
	Lower 150 Basis-Points Case	+100 bps	+30 bps	+20 bps
	Upper 190 Basis-Points Case	+130 bps	+40 bps	+20 bps
Policy Scenario (Baseline Model)		Actual Values of Each Observation		

5. Empirical Results

5.1 Results from the BVAR Model

The empirical results are largely based on a counterfactual analysis comparing a policy scenario and a no-policy scenario. This article uses the tilting methodology to complete conditional forecasts of data from November 2008 to December 2015 to build the counterfactual analysis. For the conditional forecast, it is also assumed that in the no policy scenario, the increase treatment for the 10-year interest rate occurs in the initial month in each QE period, after which it remains at the same level over the whole period until the next QE programme. One reason for this assumption is to make the estimation process simple. The other reason is that the large-scale purchase operation usually caused an immediate significant decrease in the interest rate (Maggio, Kermani and Palmer, 2016[24]) and therefore it is reasonable to assume that the reduction in the interest rate happened at the beginning of each QE period when the Fed implemented its purchase programmes.

Altogether, most results below are extracted from three comparisons among different conditional forecasts. The first comparison focuses on the difference between the actual value line and the basic model prediction line. If the baseline prediction is lower than the actual observation value, it means that even if we predict the growth rate of each variable based on the real 10-year interest rate in the policy scenario, the forecast is still lower than actual observation value of each outcome variable. The effect of QEs on the economy mainly comes from the second comparison between the conditional forecasts in the no-policy scenario and the basic model prediction. If the conditional forecasts in the no-policy scenario are lower than the baseline prediction, it means that without QEs the growth rate of those three variables would have been lower than the case with QE and implies that QE has a positive effect. The third comparison among the conditional forecasts under three sub-scenarios in the no policy scenario aims at checking if the result is sensitive to different increase treatments on the 10-year interest rate, since there is no such an exact number accepted by all economists that can represent by how many basis points QE has decreased the 10-year interest rate.

5.2 Estimate of Nominal Personal Consumption Expenditure

According to the Interest Rate Endogenous case in the Figure 1, there are four remarkable findings that require analysis.

For the first two findings, in more than half of the whole forecast horizon, the basic model prediction line is under the actual value line, especially for observations in the QE1 and QE3 periods. Therefore, some shocks, which have not been included in my model, may have increased the personal consumption, such as fiscal shocks from policies implemented by the Department of the Treasury. Another resemblance is that the no-policy scenario is more likely to involve considerable fluctuations than the baseline model and thus the QE policy has the function of stabilisation of the economy.

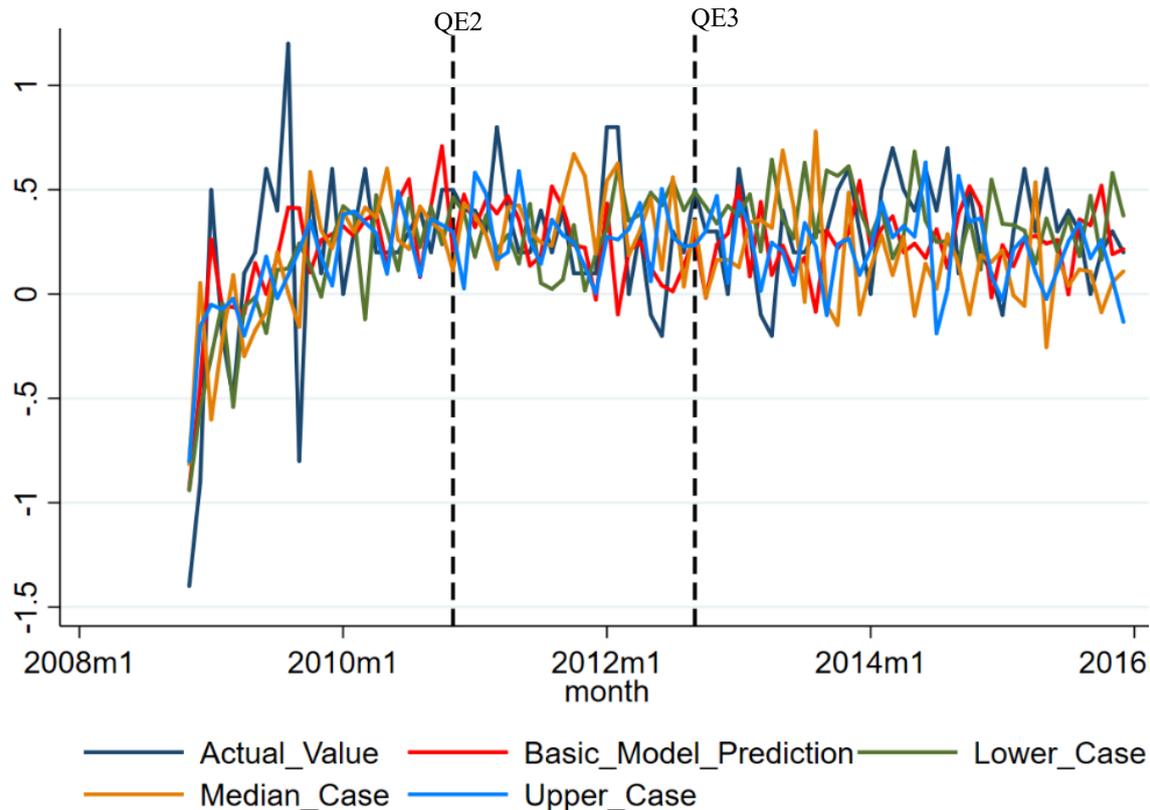


Figure 1. Conditional Forecast for Nominal Personal Consumption Expenditure

The third point is that the results of the counterfactual analysis for PCE may heavily depend on the different treatment of the 10-year interest rate. For instance, the conditional forecast in the lower case is higher than the basic model prediction during almost all months after January 2012. That is, if the three QEs decreased the 10-year interest rate by 100 bps, 30 bps and 20 bps respectively, the growth rate of PCE would have been smaller by a maximum value of approximately 1%, which is a significant effect, given the average value for the real observations of PCE is only approximately 0.25%. However, the conditional forecast in the median or upper case does not show the same character. On the contrary, the forecast line for the upper case crosses the baseline prediction regularly and the counterfactual forecast for the median forecast becomes consistently lower than that for the policy scenario from the end of 2013, meaning that the QEs have a beneficial effect.

Another discovery stems from the comparison of the baseline model prediction result and the conditional forecast under median 170 basis-points case in a no-policy scenario. At the beginning of each QE operation, the baseline prediction is usually above the conditional forecast in the median case. However, after several months, the median treatment forecast will conversely exceed the basic model prediction, implying that this policy may have improved the consumption situation only in the short-term and subsequently it would begin to inversely reduce the personal consumption of most Americans.

6. Conclusion

This article provides new findings on the potential macroeconomic effects of the QE programme implemented by the Fed during November 2008 to December 2015. To overcome some shortcomings in previous research, this study involves a new economic indicators as the outcome variable rather other GDP, CPI and unemployment rate. To measure the effect of QEs, this research treats the reduction of the 10-year interest rate as the only channel for QE to exert its effect on the wider US economy. Unlike other researchers, who frequently use the DSGE model and its expansion form, this

study applies a counterfactual analysis by using a BVAR model to conduct conditional forecasts in two scenarios, the policy scenario, and the no-policy scenario.

The results of this study show that although such unconventional monetary policy has played a significant role in stabilising the economy after the collapse of Lehman Brothers, it has been insufficient to avoid a significant fall in economic activities. As a result, I hesitate to favour the statement that the QE as an unconventional monetary policy is a very useful tool to overcome a persistent economic recession, although it may have increased the GDP growth and prevented deflation. Instead, I support the conclusion in the article by Lenza et al. (2010) [21] that the QE program is not a panacea. This is because I suspect that the three QE programs introduced by the Fed from November 2008 did not ameliorate the economic foundation in the United States, but only achieved temporary economic recovery and surface prosperity by pushing up asset market prices such as the stock market. If we re-examine the US economy from the perspective of PCE, the QE program fails to have a persistent positive effect on real production and consumption activities, but show a negative influence during a longer period.

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