Evaluation and Comparison of the Quantitative Easing Programs of the US and UK: Macroeconomic and Currency Market Effects

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Abstract

This paper analyses the unconventional monetary policy response to the 2008 financial crisis by the Federal Reserve and Bank of England. Specifically, this paper discusses the design, implementation, goals, along with the macroeconomic and currency market effects of Quantitative Easing (QE) employed by these central banks from 2008 to 2013. Using established results of QE on financial variables, namely the compression of the long-term bond yield spread, we employ a Vector Autoregression, and conduct a counterfactual estimation to quantify the macroeconomic and currency market impact of QE insofar as it has been transmitted via this specific channel. The results suggest that for the macroeconomic impact, the US program found more success in the long run, while the UK program experienced slightly more desirable results in the short run. For the currency market impact, our results suggest that the relationship between the exchange rates and the bond spread strengthened during the financial crisis, and that QE appreciated the dollar index in the US and depreciated the UK Sterling index. Finally, the effects in the US were much less clear cut compared to the UK, as the US financial system is more complex and susceptible to speculation.

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1. Introduction

Quantitative Easing (QE) is an Unconventional Monetary Policy (UMP) that was first widely used by central banks around the world during the 2008 financial crisis. Through different transmission mechanisms, such as decreased term premiums and creating liquidity in the financial market, it raises aggregate demand and stimulates the economy back to the desired state. As the effects of the financial crisis come to end, there has been little research done analyzing the effectiveness of this program on the economy

and its full effects using more recent data. In this research paper, we analyze the effectiveness of such a policy in the United States (US) and United Kingdom (UK) by studying its effects on various macroeconomic variables and the currency markets, utilizing theory and empirical analysis.

1.1 The Great Recession

There are many hypotheses for what caused the global economic deterioration of 2007-2008. Many critics blamed central banks in advanced economies for keeping interest rates too low for too long, while others blamed the large quantity of foreign reserve holdings in emerging markets. Regardless of the origin, the financial markets saw excess liquidity, the creation of complex financial instruments such as collateralized debt obligations of sub-prime mortgages, and bubbling asset prices, which ultimately led to the crash of the financial markets (Baily and Taylor 2014).

The first signs surfaced in mid-2007, as banks around the world began to show losses from the subprime real estate market in the US. Financial markets dried up and became illiquid in the following months. In December 2007, the Federal Reserve (FED), Bank of England (BOE), European Central Bank (ECB) and Bank of Canada (BOC) announced a coordinated effort to bring about new liquidity-enhancing measures. With a few major commercial banks already on default, central banks cut interest rates and introduced a number of new liquidity facilities. By September 2008, the FED had to inject billions of dollars into the economy to prevent a systematic breakdown, while several European banks collapsed and had to be bailed out or nationalized (Annunziata 2011). This is often regarded the beginning of the recession.

1.2 Monetary Policy and Central Banks

Prior to this, conventional monetary policy was secure in its application and logic. The goal of this type of monetary policy was to target an inflation rate of 2 percent annually,[1] with the FED having a dual mandate which also included keeping employment at full capacity. These goals were met by either buying or selling securities to affect the overnight rate for banks, which in turn affected short-term interest rates. After the recession, the FED and BOE were forced to apply UMPs, as interest rates reached their effective lower bounds. QE involves a central bank creating new reserves (currency) in order to purchase financial assets, such as mortgage-backed securities (MBS), government bonds and so forth. The ultimate goal of QE was to increase spending and meet the central bank's target inflation rate. By 2015, the US and UK had wrapped up their respective QE programs.

There have been numerous economic papers that have discussed the effects of QE, but these focus largely on the effects on financial variables. There has been little research done into the effects of QE on currency markets in these countries.

[1] The FOMC uses PCE inflation measure whereas Bank of England focuses on CPI inflation.

1.3 Summary of Research

The goal of this paper is to find the effect of QE in the US and UK on macroeconomic variables and currency markets, namely their respective currency indices. This is done by estimating a Vector Autoregression (VAR), and running a counterfactual simulation to evaluate what would have happened had the central banks not proceeded with these UMPs. The theory suggests that as QE decreases the term premium, the currency index in the country will decrease, and that the relationship between bond spread and currency indices becomes stronger following the implementation of QE.

Our empirical results suggest that the use of QE strengthens the relationship between the bond spread and currency indices, while appreciating the US currency and depreciating currency in the UK. For the macroeconomic effects, the main way in which QE impacted the economy was through increasing the prices of risky assets, which made individuals wealthier. Therefore, an increase in GDP and a decrease in inflation would be expected after QE is applied. Since QE has only recently been applied in practice, there is little historical evidence on which to compare these programs. We found that for macroeconomic variables in the long run, the US program outperformed that of the UK, while in the short run, the UK program had more desirable effects on inflation. This paper hopes to provide information of the wider currency market effects these UMPs had, which has not been covered in any previous literature to the extent of our knowledge, and determine if this type of monetary policy is an effective substitute to previous conventional monetary policies.

2. Policy and Theory of QE

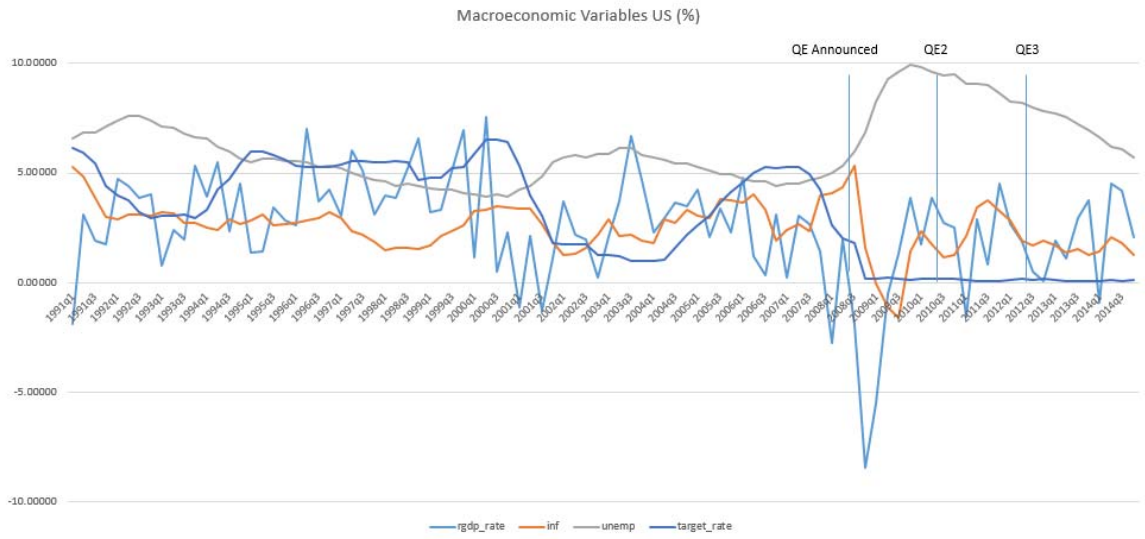
2.1 Details of QE Policy

US Financial Markets and Federal Reserve's QE Policies

Shortly after the failure of Lehman Brothers on September 15th, 2008, the FED began to initiate the large-scale asset purchase (LSAP) program of QE (Federal Reserve 2012). It was around this time the Federal Open Market Committee (FOMC) lowered the overnight rate to between 0 and 0.25 percent, effectively its lower bound. There was a need for further monetary policy intervention in order to meet their dual mandate. In order to do so, the FOMC announced they would be purchasing large amounts of housing agency debt and mortgage-backed securities (MBS). According to the FED, the ultimate goal of their QE program was to "reduce the cost and increase the availability of credit for the purchase of houses, which in turn should support housing markets and foster improved conditions in financial markets more generally" (Federal Reserve 2008). The first round of purchases, QE1, occurred in November 2008. In QE1, the FED purchased $100 billion in government-sponsored enterprise (GSE) debt, as well as $500 billion in MBS. In March 2009, QE1 was extended to purchase an additional $750 billion in MBS and GSE, as well as $300 billion in Treasury securities. In November 2010, the second phase, QE2, began, in which the FED purchased another $600 billion in longer-dated

treasuries, at a rate of $75 billion per month. QE2 ended in June 2011. The final phase, QE3, began in September 2012, and involved the purchase of $40 billion in MBS per month, which was later increased to $85 billion. In 2013, the FED announced that they would begin tapering off their LSAP program, and it finally came to an end in October 2014 (Applebaum 2014). Figure 2.1.1 represents a timeline of macroeconomic variables in the US before and during the crisis.

Figure 2.1.1: US Macroeconomic Variables and QE Timeline[1]



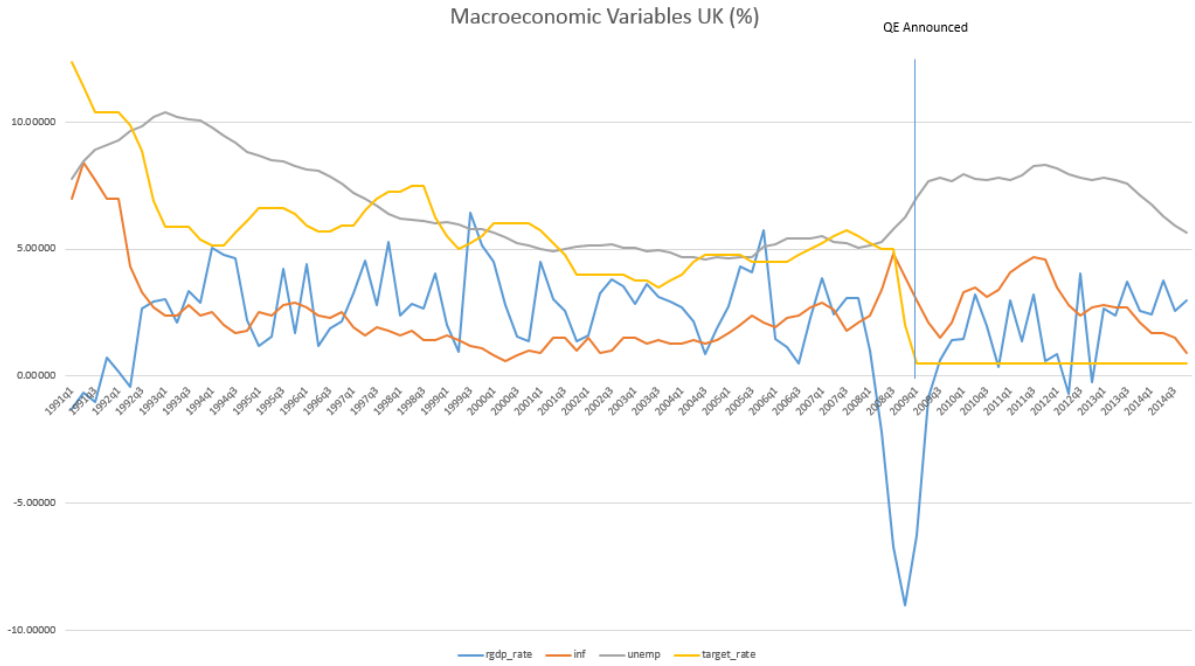
UK Financial Markets and Bank of England's QE Policy

The UK's Monetary Policy Committee (MPC) announced they would begin their LSAP program of UK government gilts (equivalent of US Treasuries) in March 2009. At this point, the MPC had reduced the Bank Rate to its effective lower bound, 0.5 percent. However, the MPC needed additional procedures to meet their inflation goal of 2 percent. To perform QE, the MPC set a target for the stock of asset purchases financed by the creation of reserves, achieved by buying and selling assets through the Asset Purchase Facility (APF).[2] According to the BOE, the goal of QE was to influence inflation enough to reach their 2 percent goal, and by performing QE they hoped to decrease government bond interest rates as well as short-term rates, making it cheaper for businesses to raise capital (Bank of England 2015). The initial purchases totalled £75 billion, but the program was increased to £200 billion by November 2009 (Kapetanios et al. 2012). The final round of purchases brought the total to £375 billion in July 2012. In 2012, the MPC announced that they had decided to keep the bank rate at 0.5 percent and total QE purchases at £375 billion, effectively bringing an end to their QE program (Aldrick,

[1] Data source in Appendix 1.2.
[2] Giudice et al. (2012).

2012). Figure 2.1.2 represents a timeline of macroeconomic variables in the UK before and during the crisis.

Figure 2.1.2: UK Macroeconomic Variables and QE Timeline[1]



2.2 Transmission Channel of QE

Channels Through Which QE Operates

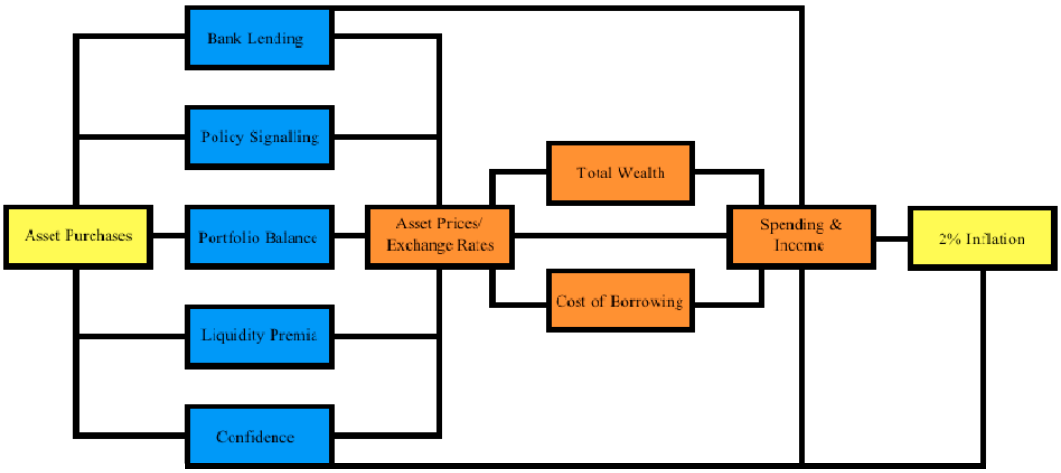
Considering the goal of QE was to stimulate nominal spending in order for inflation to meet the 2 percent target, there are a variety of channels through which QE could work. The first is the policy signalling effect, which includes any information banks or economic agents learn about the central bank plans for monetary policy, including asset purchases and plans to keep target interest low. The second channel is the liquidity premia effect. In this channel, the central bank can improve the functionality of markets by increasing the liquidity of the counterpart of the asset purchases done through QE. However, this channel may only apply while the central bank is performing these purchases. Third, performing QE may increase consumer confidence, as it could be seen by the public that there is an improved future economic outlook. This would also increase willingness to spend now, in turn stimulating the economy and helping the government reach their inflation goal. The fourth channel is the bank lending effect. Since the asset purchases came mainly from banks and other lending institutions, these institutions end up with more reserves on hand. Due to the higher level of liquid assets, banks are

[1] Data source in Appendix 1.2.

encouraged to hand out more loans, which again stimulates the economy (Joyce, Tong, and Woods 2011).

The final channel is the portfolio balance channel. This channel works through the fact that central banks mostly purchase short-term assets held by lending institutions. This pushed up the prices of these assets, and lowered their yields. Since short-term yields decreased, investors were encouraged to look for higher returns elsewhere. They did so by purchasing riskier assets, whose prices had been depressed by the recession. The new demand on these riskier assets drive up their prices. As asset prices increased, individuals become wealthier, increasing aggregate demand (Joyce et al. 2012). Additionally, through this channel, QE reduced the short- and long-term interest rates, lowering the borrowing costs for corporations and making businesses more willing to spend on investments and wages. Again, this worked to increase spending and the income of individuals (Joyce, Tong, and Woods 2011). Most research, including our own, focuses on this channel, as it is considered the most important channel for QE (Kapetanios et al. 2012). It is the most important because QE directly affects asset prices, which is the mechanism for this channel. Figure 2.2.1 is a representation of the transmission mechanisms of QE, and how they affected inflation.

Figure 2.2.1: Transmission Mechanisms of QE, Bank of England (2011)



Hypothesis 1: US and UK

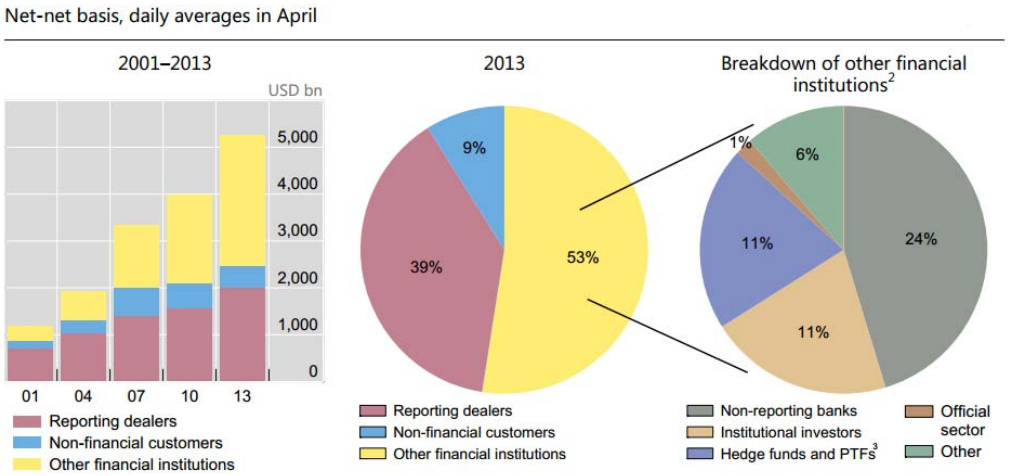
As mentioned above, the goal of these QE programs was to meet the central bank targets for inflation, as well as improve unemployment in the case of the US. In terms of the macroeconomic effects of QE, in the US, we would expect improvements in inflation and increases in real GDP growth, due primarily to the portfolio balance channel mentioned above. Similarly, in the UK we would expect inflation to ameliorate with QE over the no-policy scenario. Additionally, a turnaround in the growth of real GDP, which experienced a large downturn at the beginning of the financial crisis, would be anticipated.

2.3 QE and Exchange Rate Movements

Exchange Rate Movement in US and UK

Exchange rates are important variables to examine during the 2008 financial crisis. They can have significant effects on macro variables in large open economies such as the US and UK. Also, they can be seen as an indicator of the future economic outlook and financial well-being of a nation's economy. Most movement in exchange rates in today's foreign exchange markets is driven by speculation, although the fundamentals of exchange rates are still highly relevant. The Bank of International Settlements (2013) report shows that the foreign exchange market is driven by financial institutions, and shows that turnover is more often driven by speculation rather than trade. The foreign exchange markets are grounded in the theory of interest rate parity. Figure 2.3.1 represents a breakdown of the turnover in foreign exchange markets.

Figure 2.3.1: Foreign Exchange Market by Counterparty (Bank of International Settlements 2013)

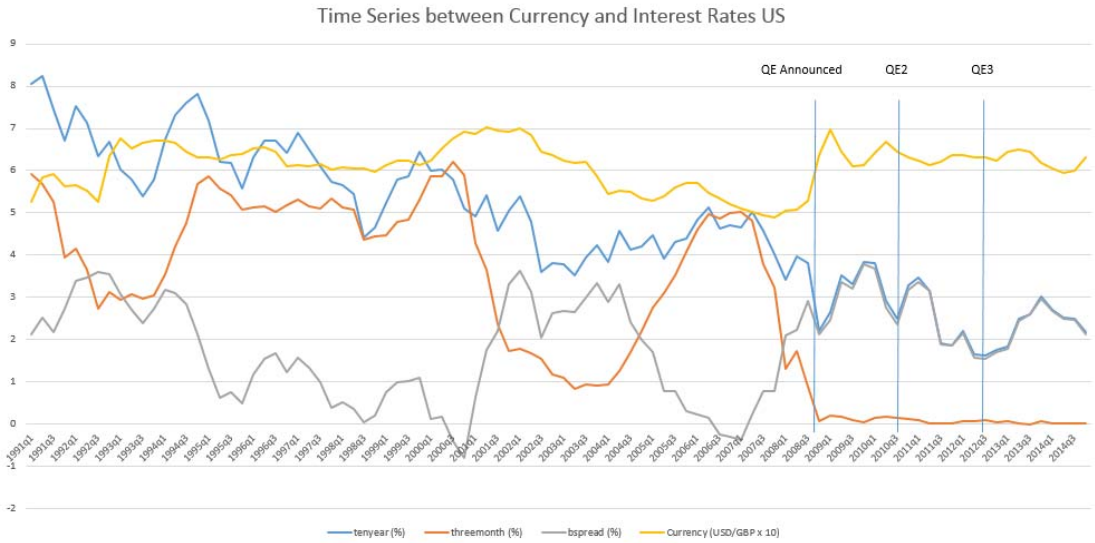


Exchange rate levels moved significantly during the financial crisis. In the US, the DXY began depreciating in 2001,[1] largely as a response to the low interest rate environment of the Treasury and Bond markets. As the financial market crisis unfolded, the index rebounded to a peak in early 2009, but soon began to drop again, following the announcement of QE by the FED in November 2008. The exchange rate index can be seen in Figure 2.3.2.

The ERI (exchange rate index) published by the BOE showed a dramatic depreciation of the sterling. Joyce et al. (2011) found that when QE was first announced, the sterling ERI experienced a 4 percent decrease, but afterwards, from March 4th 2009 to May 31st

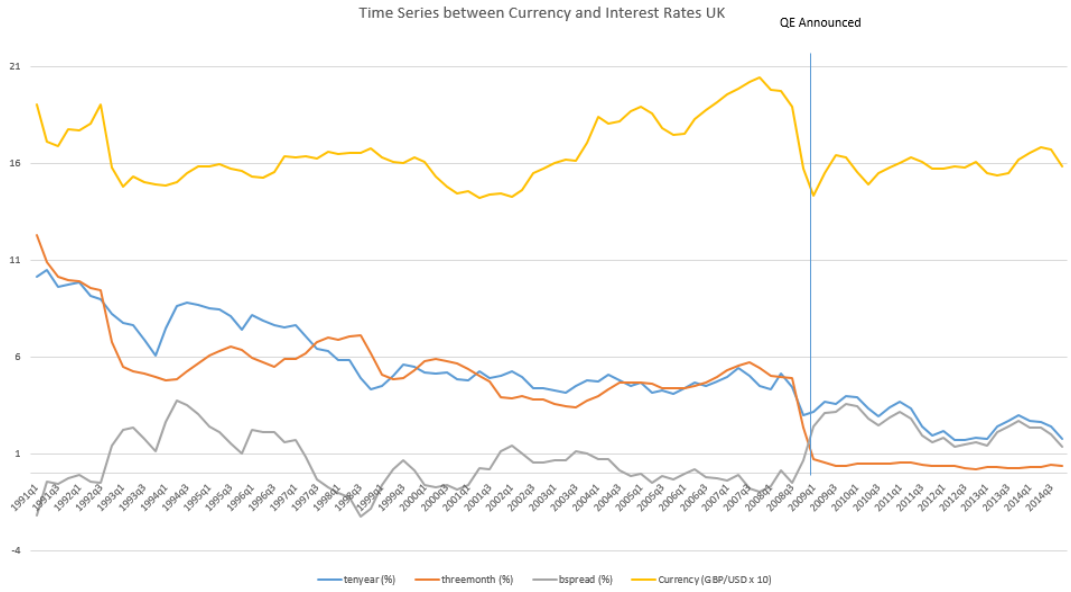
[1] The DXY is a USD dollar index, weighted by a basket of currencies. (Federal Reserve Bank of St. Louis 2016).

Figure 2.3.2: Time Series of Exchange Rate and Interest Rates in US[1]



2010, it saw an increase of 1 percent. Figure 2.3.3 shows a time series of exchange rates and interest rates in the UK.

Figure 2.3.3: Time Series of Exchange Rate and Interest Rates in UK[2]



[1] Data source in Appendix 1.2.
[2] Data source in Appendix 1.2.

2.4 Drivers of Exchange Rate

The Fundamental Theories of Exchange Rates

Understanding what drives exchange rates is a complex task. There are several theories available on the topic. In the traditional open economy model, demand and supply for domestic and foreign currencies are driven by activities such as trade and movement of capital. The law of one price and purchasing power parity (PPP) dictates equilibrium prices, and quantities are driven by prices in domestic and foreign economies. Empirical studies claim that PPP is not a long-term relationship, because real exchange rates tend to resemble a random walk in several studies (Grilli and Kaminsky 1990).

The foreign exchange market and theories on exchange rates have become more complex over the years beyond the traditional open economy model. There are more factors at play, more complex financial instruments and so forth, moving between national borders. Dornbusch (1976) postulates that because of arbitrage opportunities, domestic and foreign securities can be perfect substitutes, assuming there are no frictional costs. Adding in exchange rate expectations, without friction, the authors hypothesize that the relationship investors care about is expected net return on alternative assets, which is interest rates minus anticipated change in interest rate:

$$i=i^*+(e'/e-1),$$

where e' is expected future spot exchange rate, e is the spot exchange rate, or the "permanent rate", i is the domestic interest rate, and i* is the foreign interest rate. Using the Mundell-Fleming model, the authors assert that a monetary expansion gives rise to a depreciation in the exchange rates because of inelastic expectations, with the interest rate and exchange rate expectations playing a critical role in the adjustment process.

Unconventional Policy Effect on Exchange Rates

In their paper, Coenen and Wieland (2003) studied the relationship between interest rate and exchange rate, and they found that a drastic expansion of the monetary base leads to a depreciation of currency during a zero bound interest rate.

The portfolio balancing effects of QE would be expected to put downward pressure on exchange rates. With bond yields low domestically, investors substitute their investments in the country for higher yielding assets elsewhere, thus decreasing demand and increasing supply of domestic currency. There are three main ways through which the lower interest rates caused by QE affect the exchange rate. The first is through what is called the 'money demand effect'. Lower interest rates decrease the demand for assets denominated in domestic currency, which depreciates the currency. The second, the 'output effect', is caused by lower interest rates causing an expansion in domestic output, which appreciates currency. The final channel is the 'fiscal effect'. This channel occurs as the decrease in the interest rate decreases the debt service of the government. This

decreases the inflationary expectations and appreciates the currency (Hnatkovska, Lahiri, and Vegh 2012).

Based on these theories, we hypothesize the relationship between exchange rates and term premiums strengthens during QE. One reason is that with the short-term rate at the lower-bound, speculators would look at the next best indicator for predicting asset yields in each country, the long-term rate and term spread. The second reason is that as people look for investments, they look to the yield curve for future expectations on interest rates. The second hypothesis is that QE depreciates the exchange rate, as it increases supply of domestic currency, and also depreciates bond prices. Through the various channels, QE should depreciate domestic currency.

2.5 Summary of Hypotheses

Hypothesis 1: Macroeconomic variables improved due to QE
Hypothesis 2: Relationship between exchange rate and term premium strengthened during the QE period.
Hypothesis 3: QE depreciates exchange rate

3. Data and Model

3.1 Data

The data used in our model are quarterly macroeconomic data from several national databases, such as the Federal Reserve Economic Database (FRED), OECD, BOE, and the Bureau of Economic Analysis (BEA), with financial data retrieved from Bloomberg. The full list of variables, as well as their description, source and transformation, are available in Appendix 1.1 and 1.2. Summary statistics for all variables are available in Appendix 2. The variable selection for the base VAR models will be explained in Section 3.2.

3.2 Base Empirical Mode

Estimating the effects of QE on macroeconomic variables is a complicated task, as there are many moving pieces. This paper will follow what the majority of research has done in terms of empirical analysis,[1] which utilizes Vector Autoregression (VAR) models in order to analyze the effects of QE on variables of interest. The VAR model used in this paper is a replication of that used by Lenza et al. (2010), who performed their empirical analysis on the macroeconomic effects and rate changes during the financial crisis in the Eurozone area. A similar method was used in Giannone et al. (2012) to analyze monetary policy to economic and loan activities. The base VAR model equation is of the following form:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \beta_3 X_t + \epsilon_t \quad \text{.....(VAR 1)}$$

[1] See Baumeister and Benati (2010) and Lenza et al. (2010).

Here, Y_t is a vector of endogenous variables consisting of the real GDP growth rate (*rgdp_rate*), inflation (*inf*), the overnight rate (*target_rate*) and the term premium (*bspread*). It is also possible to have the variable *bspread* as an exogenous variable, but we have decided to treat *bspread* as an endogenous, as have many other papers (Lenza et al. 2010) and (Baumesiter and Benati 2010). In Section 5.3, we look at the effects of using *bspread* as an endogenous variable and explain our results. Additionally, Y_{t-1} and Y_{t-2} are the first and second lags of Y_t, respectively, X_t is a vector of exogenous variables, listed and described in Appendix 1.1, ϵ_t is the stochastic error term, and the *t* subscript represents the quarterly time period of the observation (*t*=1994Q1,...,2014Q4). Moreover, β_0 is a vector of constants, β_1 and β_2 are matrices describing the relationship between Y_t and its first and second lags, respectively, and β_3 is a matrix describing the relationship between the exogenous variables and the vector of endogenous variables. The variables included in the endogenous vector Y_t were chosen for their macroeconomic importance, as well as their effects on exchange rates.

In order to produce the counterfactual simulation for our paper, we followed several key steps. First, we estimated our base model above (*VAR 1*) for the period of 1994Q1 to 2008Q4. We chose to end our estimation in 2008Q4 because it was after this time that the US and UK programs were put into effect. Doing this allows us to observe the relationship between the variables using about 15 years' worth of data. Once we estimated this VAR, we then conducted our counterfactual simulation. We first take our estimates from the previous *VAR 1* estimation, and forecast out for 8 periods (2 years). We chose 8 periods because we found that for any length of time longer than that, the effect of QE becomes too weak to properly analyze. This estimation was used as our *without-QE* policy scenario. Next, we shocked the variable *bspread* down by 60 basis points. We are working off the results of Gagnon et al. (2010) for the US and Meier (2009) for the UK, which found that QE depressed the long-term maturity premiums on bonds by between 60 and 100 basis points. Section 5.3 describes a sensitivity analysis done to see the effects of changing bond spread by more or less than 60 basis points. We chose to work off the lower-bound estimates in the base model, and this depression in *bspread* was used as a proxy for the effect of QE. With the now-depressed *bspread*, we again forecast out 8 periods from the end of our initial estimation (2008Q4). This estimation was then used as our *with-QE* policy scenario. Similar to Kapetanios et al. (2012), we used this estimation, rather than the actual path of variables, as our estimates for the *with-QE* scenario because the actual path of our endogenous variables is affected not only by QE, but also by several other factors. By doing it this way, the model isolates the direct effects of QE on our variables of interest. Finally, in order to evaluate the magnitude of QE's effects on our variables, we simply compare the results for the *with-* and *without-QE* scenarios by looking at the difference in change in the forecasted inflation and real GDP growth. This should give an indication of the effectiveness of the programs in relation to the situation where QE was not enacted.

In order to test the validity of our model, we followed the above steps for our US data. We then compared our results to those of Baumeister and Benati (2010), who performed a similar empirical analysis of QE's effects on US macroeconomic variables using a more complex VAR model. Our results from this test are seen in Section 4.1.

3.3 Econometric Considerations

(1) Time Varying Parameters

In order for the counterfactual forecast to provide a good estimation for the effects of QE, the relationship between the variables must remain the same before and after QE. While there is reason to believe that there could be changes in the relationship theoretically (Baumeister and Benati 2010), it is important to look at the size of the change and whether it would affect the counterfactual analysis. To look at whether the coefficients have changed before and after QE, the VAR model was used on two different time periods for the US and UK.

First, a comparison between 1991-2008 and 2009-2012 US data was made, and a similar comparison was made for the UK data. The focus of this test is to see if the forecast of the counterfactual on the endogenous variables will hold in the 2009-2012 period. The endogenous variables of interest in this VAR are the real GDP rate and inflation. The results for the US show that the coefficient on the VAR model does indeed change between the pre-crisis and crisis periods. The UK variables also had different coefficients on the VAR. However, the differences are smaller than those from the US. It is important to note however that the R^2 and p-value of the VAR model between 1991-2008 is not very high for the real GDP growth rate. This suggests that the specification of our VAR model can be improved by adding more variables that affect real GDP rate and inflation. Baumeister and Benati (2010) suggest that recent effects of spread compression on macroeconomic variables are strong compared to those from the past two decades, suggesting that using more recent time periods would improve the accuracy of the forecast.

(2) Stationarity Constraints

In order for the VAR results to be correct, the variables need to be stationary. Augmented Dicky Fuller tests were performed on all variables, and a number of variables failed the test and showed a unit root. Most of these variables were translated into log level or log difference to accommodate for the unit root, as seen Appendix 1.1. Both bond spread and target rate were left without manipulation as per industry norm.

(3) Number of Lags for Endogenous Variables

In a VAR model, the number of lags can affect the results. The majority of literature on QE and macroeconomic variables uses two lags in their empirical analysis, as this is seen as the time necessary for the interest rate transmission mechanisms to affect macroeconomic variables. A lag selection function was also used to empirically determine the number of lags most appropriate for the analysis. After observing the results in Figures 3.3.1 and 3.3.2, the conclusion that two lags would be the most effective was reached, for the US and UK.

Figure 3.3.1: US Lag Statistics[1]

Selection-order criteria (lutstats)
Sample: 1994q1 - 2008q4 Number of obs = 60

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-214.817				.088065	-4.19093	-4.19093	-4.19093
1	-145.509	138.62	16	0.000	.01544	-5.96789	-5.74943	-5.40939*
2	-121.035	48.948*	16	0.000	.012358*	-6.25035*	-5.81344*	-5.13337

Endogenous: rgdp_rate inf bspread target_rate
Exogenous: unemp gfcf ca stocks manu savings bus_bankruptcy ind_insolv gov_exp consum housing twusdi _cons

Figure 3.3.2: UK Lag Statistics[2]

Selection-order criteria (lutstats)
Sample: 1991q3 - 2008q4 Number of obs = 70

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-363.282				1.70084	-.972033	-.972033	-.972033
1	-183.464	359.64	16	0.000	.016128	-5.65254	-5.4484	-5.1386*
2	-156.803	53.322*	16	0.000	.012336*	-5.95714*	-5.54886*	-4.92926

Endogenous: rgdp_rate inf bspread target_rate
Exogenous: D.l_unemp gfcf l_ca D.l_stocks manu D.l_savings D.liquidation D.ind_insolv D.l_gov_exp l_consum D.l_housing d_l_seri _cons

4. Empirical Analysis

4.1 Testing Hypothesis 1: QE positively affected Macroeconomic Variables in the US and UK

Previous studies suggest QE would improve GDP and inflation in the US and UK, working through the channels shown in Figure 2.2.1. To test whether QE had a positive impact on these variables, compared to a scenario where it was not enacted, *VAR 1* was estimated to when QE was introduced (2008Q4). Using these results, a counterfactual forecast was conducted. The estimates from this counterfactual were then used to forecast the paths of *rgdp_rate* and *inf* from 2009Q1 onwards. These initial estimates were used as our no-policy estimates (prefix wo_). The *bspread* variable was then decreased by 60 basis points, and the counterfactual was run with these new values. The forecast with the adjusted *bspread* was used as our policy scenario estimates (prefix w_). The difference between the policy and no-policy results were then analyzed to evaluate the impact of QE on *rgdp_rate* and *inf*.

[1] Data source in Appendix 1.2.
[2] Data source in Appendix 1.2.

Results for US: For the US, *VAR 1* was run for the period 1994Q1-2008Q4. The full results of this VAR are in Appendix 3. We see that lag 1 of *bspread* is positive and insignificant, while lag 2 is negative and statistically significant for *rgdp_rate*. For *inf*, lag 1 is negative, lag 2 is positive, but neither are statistically significant. The R^2 for *inf* (R^2 = 0.6196) is much lower than that for *rgdp_rate* (R^2 = 0.8272). Figure 4.1.1 below shows the path of the counterfactual results, along with the actual path of *rgdp_rate* and *inf* (dashed lines).

Figure 4.1.1: Counterfactual Paths (Policy and No-policy) Real GDP Growth and Inflation in US[1]

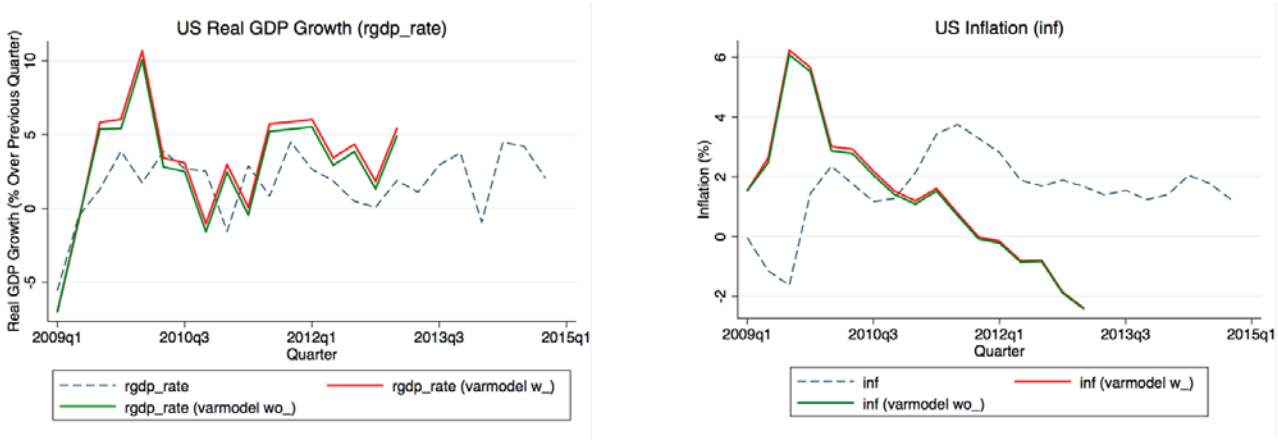
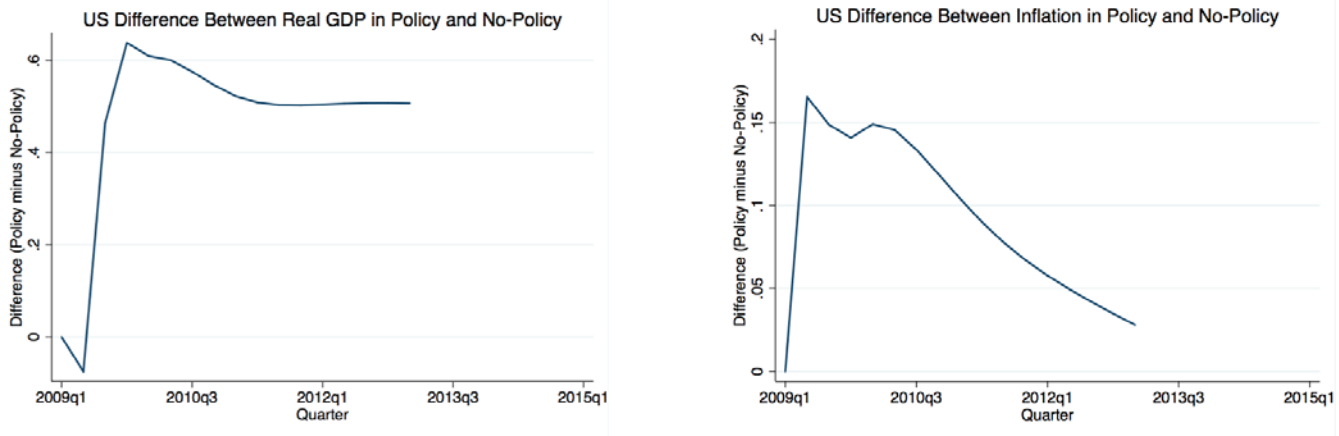


Figure 4.1.2 shows the difference between the policy and no-policy paths of the *rgdp_rate* and *inf*.

Figure 4.1.2: Difference Between Policy and No-policy Counterfactual Paths for Real GDP Growth and Inflation in US[2]



[1] Data source in Appendix 1.2.
[2] Data source in Appendix 1.2.

The difference in the level of real GDP growth (*rgdp_rate*) between the policy and no-policy scenarios decreased slightly in the first period following QE, and increases to a maximum of a little over 0.6 percent, before settling around 0.5 percent in the long run. For *inf*, the difference in levels are positive following the start of QE, reaching a peak of 0.15 percent, before diminishing.

Results for UK: Similar to the US, we first estimate *VAR 1* for the period of 1991Q3 – 2008Q4. The results of this VAR are also in Appendix 3. We see that the coefficient for lag 1 of *bspread* on *rgdp_rate* is negative, lag 2 is positive, but neither are statistically significant. The coefficient of *bspread* on *inf* for lag 1 is positive, lag 2 is negative, but neither are statistically significant. Looking at the fit of the VAR, the R^2 for *rgdp_rate* is low ($R^2 = 0.6623$) compared to that for *inf* ($R^2 = 0.9292$). Figure 4.1.3 shows the path of the counterfactual results, along with the actual paths of *rgdp_rate* and *inf*.

Figure 4.1.3: Counterfactual Paths (Policy and No-policy) of Real GDP Growth and Inflation in UK[1]

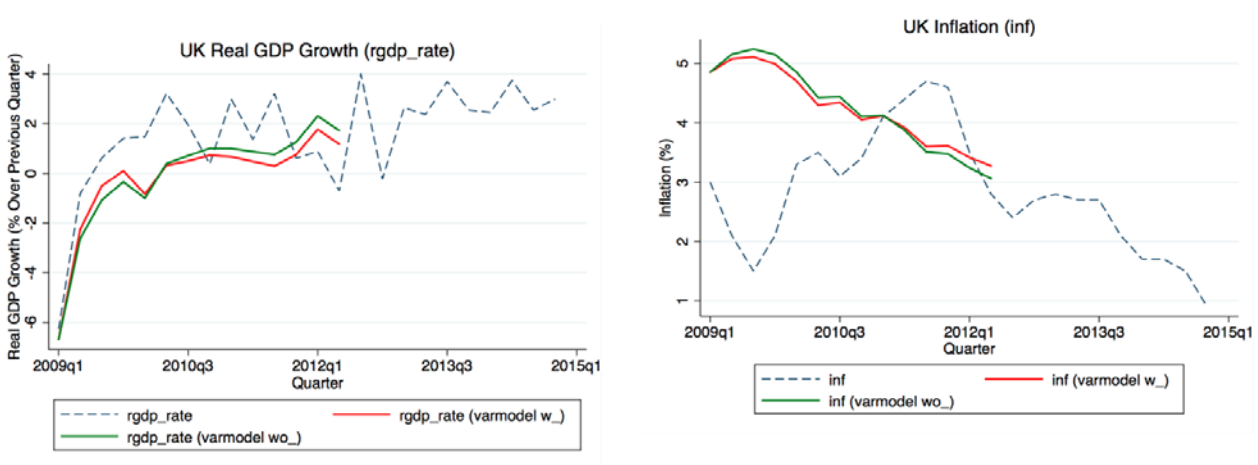


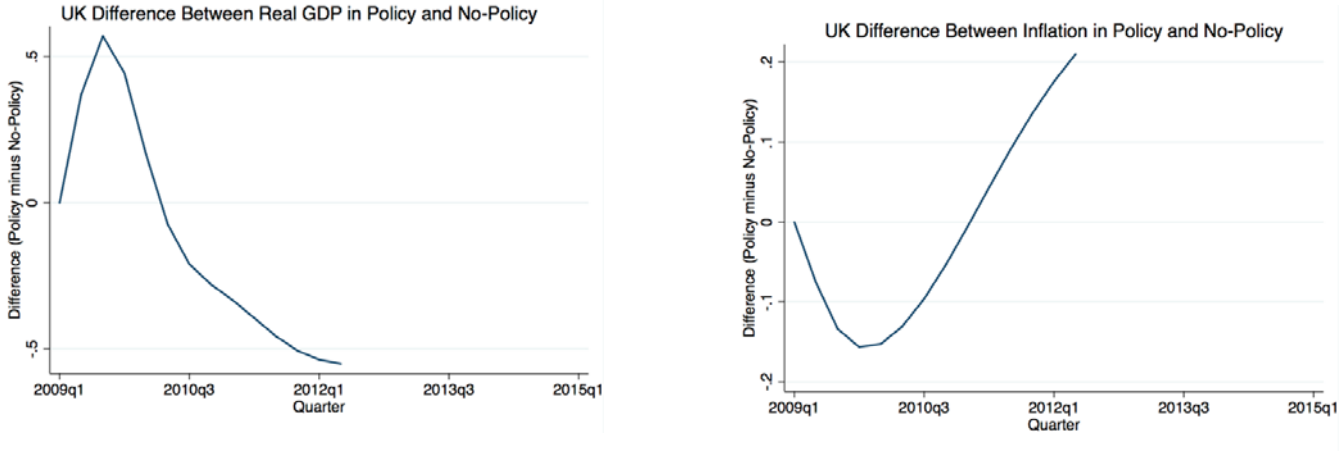
Figure 4.1.4 shows the difference between the policy and no-policy paths of the *rgdp_rate* and *inf* . The difference between the policy and no-policy *rgdp_rate* peaks at slightly over 0.5 percent 3 periods after implementation, before falling off rapidly. By these results, it seems the UK QE had a similar effect to the US program in the short run. For *inf*, the difference in levels reaches a low point of about 0.15 percent three periods after implementation, before steadily increasing.

Shortcomings: Compared to the results of BB, our results for the US *rgdp_rate* are similar in direction, but smaller in magnitude (peak of 0.6 percent compared to a peak of 1.9 percent in BB). For *inf*, the results from BB (peak of 1.1 percent after 3 periods), are again larger in magnitude compared to our results (peak of just over 0.15 percent). While the direction of our results appear to match those of other studies, the differences in magnitude and duration of the impacts leave something to be desired. According to BB, the "results for other countries are quantitatively slightly different [from the US] but

[1] Data source in Appendix 1.2.

exhibit, overall, the same order of magnitude" (Baumeister and Benati 2010). Our results for the UK again match the direction of the BB results (both positive) but are smaller in magnitude (peak of 0.5 percent compared to peak of 1.9 percent). For *inf*, the results move in the opposite direction as those in BB. The results for *rgdp_rate* are similar to the BB results in direction, but fail when it comes to the magnitude of the effects, while the results for our *inf* counterfactual do not line up with their results in terms of magnitude or direction.

Figure 4.1.4: Difference Between Policy and No-policy Counterfactual Paths for Real GDP Growth and Inflation in UK[1]



4.2 Testing Hypothesis 2: Relationship Between Exchange Rate and Term Premium Strengthens During QE

Theory suggests the relationship between short-term interest rates and exchange rates diminished as short-term interest rates reach their lower bound. As speculators look for different ways to analyze trading opportunities, they look at longer term interest rates for insight. In order to test the hypothesis that the relationship between exchange rates and term premium (*bspread*) strengthened during the QE period, *VAR 1* was used with the exchange rate as an endogenous variable, instead of exogenous. Two separate VAR models were run for each country. The first VAR (VAR_{pre}) is run for the period before the financial crisis, before 2006Q2, when symptoms of the financial crisis first began to surface, and the FED began to lower the federal funds rate. This was done because the recession and QE may have affected the relationship between our variables of interest. The second VAR (VAR_{post}) was run for the period during financial crisis, that is 2006Q3 and 2012Q4.

Results for the US: To study the strength of the relationship between interest rates and term premiums, the coefficients and p-values between the two were analyzed. VAR_{post}

[1] Data source in Appendix 1.2.

had a higher R^2 and better Final Prediction Error (FPE) than VAR_{pre}. Looking at the coefficient in VAR_{pre} to determine the direction of the effect on exchange rates, we see that coefficients for both lags 1 and 2 have a negative sign, with lag 1 being significant at the 10 percent level and lag 2 not significant. Neither target rate lags had a significant effect on the dollar index. In VAR_{post}, there was an increase in the significance level across most variables. As well, in $VAR_{post,}$ the coefficients' directions stayed the same and the level of the effects became greater, suggesting the relationship strengthened during the period of QE. This is in line with Hypothesis 2.

Results for the UK: In the UK, VAR_{post} had a much higher R^2 and FPE than VAR_{pre}. In VAR_{pre}, the coefficient for the effect of *bspread* on the dollar index is positive for lag 1 and negative for lag 2, with a p-value showing the coefficients are not significantly different from zero. The sign on these coefficients remained the same for VAR_{post} as they had for VAR_{pre}. However, the coefficients' significance were greater during the QE period than before it.

Shortcomings: It was surprising that the VAR model for the pre-QE period showed insignificant coefficients between the exchange rate index and key macroeconomic variables, such as current account and target rate, in both the US and UK. This finding, combined with the R^2 on dollar exchange being low (0.45 for UK and 0.55 for US) suggests that the VAR model specification of variables was insufficient in explaining exchange rate movements. This is contrary to theory, which suggests that the fundamental drivers of exchange rates are short-term interest rates and the movement of goods between countries, as explained in Section 2.2.

Furthermore, the significance of variables between VAR_{pre} and VAR_{post} showed that the hypothesis may be incorrect. In the US VAR_{pre}, only three of the 22 coefficients were significant in determining the dollar index, but in the VAR_{post} seven were significant. The results were similar for the UK. One possible explanation could be that during the financial crisis, variables moved together because the general fear in the public shifted all behaviour of agents in the economy negatively. The negative behaviour means more cautious spending and investing behaviour, which is not in line with the fundamental drivers of exchange rates.

4.3 Testing Hypothesis 3: QE Depreciates Domestic Currency

Theory suggests QE depreciates domestic currency, as it depresses the domestic interest rate and increases money supply. To test this hypothesis, *VAR 1* was modified so that the exchange rate variable was changed from exogenous to endogenous.[1] The VAR was then estimated up to when QE was introduced, 2008Q4. A counterfactual study was then conducted. The VAR estimates were used to forecast from 2009Q1 onwards as the *without-QE* scenario (prefix wo_). Another forecast was run as the *with-QE* scenario, where QE was proxied as a 60 basis points decrease in *bspread* (prefix w_). The exchange rate variable was analyzed in both forecasts to understand the effects of QE on currency.

[1] The variable is an effective dollar index from US (twusdi) and UK (seri).

Results in the US: The VAR model with *d_l_twusdi* as endogenous changed the significance and fit of the model. By R^2 and Final Prediction Error (FPE) measures, the results were a better fit than the original counterfactual model.

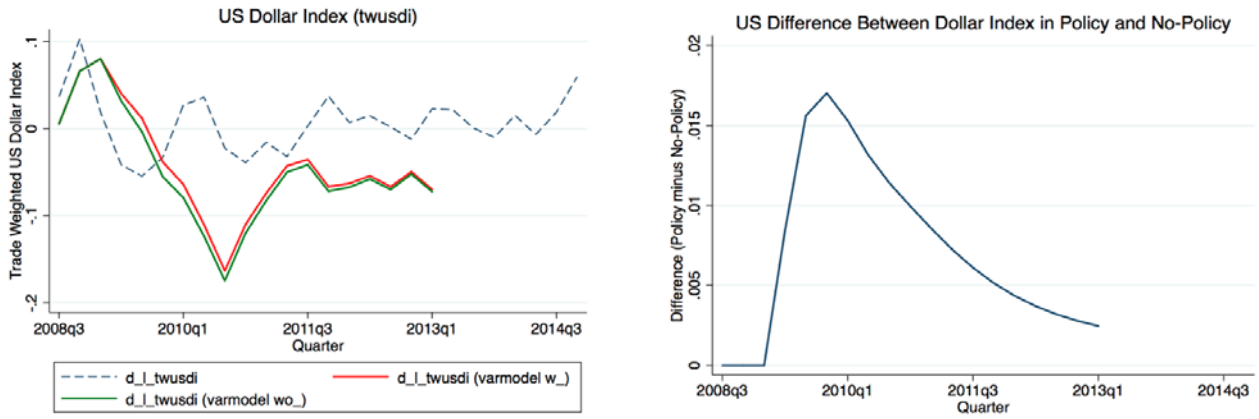
```
Vector autoregression

Sample:  1994q1 - 2008q4                        No. of obs      =         60
Log likelihood =  16.05334                      AIC             =   3.131555
FPE            =  .0000189                      HQIC            =   4.633446
Det(Sigma_ml)  =  4.03e-07                      SBIC            =   6.971187

Equation           Parms      RMSE     R-sq      chi2     P>chi2
------------------------------------------------------------------
rgdp_rate             22   1.31045   0.8360    305.87     0.0000
inf                   22   .625393   0.6366   105.1036    0.0000
target_rate           22   .344253   0.9767   2520.511    0.0000
d_l_twusdi            22    .02536   0.5480   72.73234    0.0000
bspread               22   .393579   0.9268   759.8873    0.0000
------------------------------------------------------------------
```

The results above for US were different from the hypothesis. Figure 4.3.1 below shows that the VAR forecast of dollar index with QE is actually higher than the VAR forecast without QE.

Figure 4.3.1: Counterfactual Path (Policy and No-policy) of US Dollar Index (Left) and Difference Between Policy and No-policy Counterfactual Paths for the US Dollar Index (Right)[1]

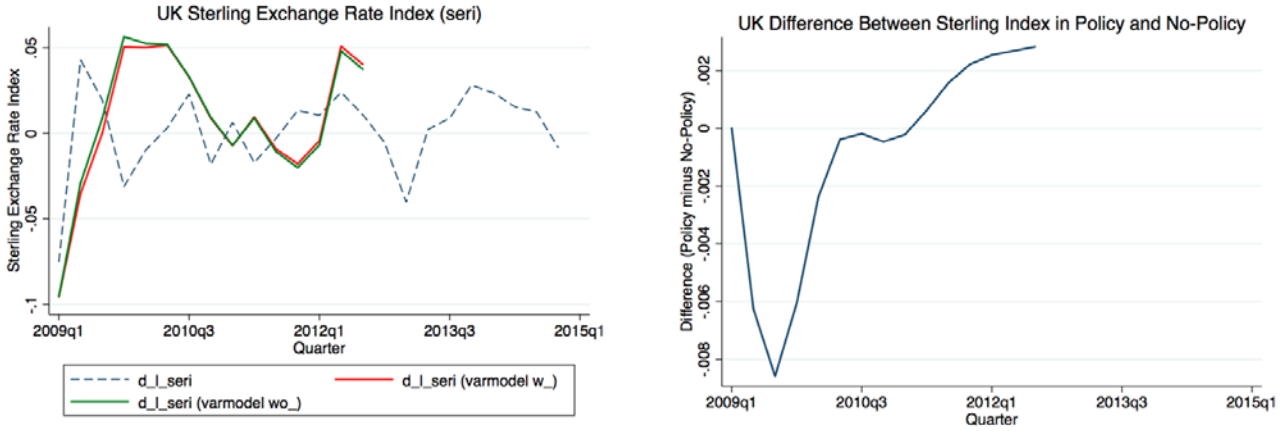


Results in the UK: The UK VAR model with *d_l_seri* as endogenous rather than exogenous increases the R^2 and decreases FPE of the model. Figure 4.3.2 below shows that the results of the counterfactual study are in line with hypothesis 3. QE decreased the Pound index.

[1] Data source in Appendix 1.2.

Figure 4.3.2 below shows that the results of the counterfactual study are in line with hypothesis 3. QE decreased the Pound index.

Figure 4.3.2: Counterfactual Path (Policy and No-policy) of UK Sterling Index (Left) and Difference Between Policy and No-policy Counterfactual Paths for the UK Sterling Index (Right)[1]



Findings: The results from the empirical analysis for Hypothesis 3 suggest differences between the US and UK QE policy, as well as in the market structure. While the introduction of QE depreciated the currency value in the UK, it appreciated the currency in the US. However, a low R^2 in the initial model could mean that there are many other factors that our VAR did not account for. Further analysis will need to be performed. Exchange rate indicators using different weighting methods, as well as using actual QE data, which measures the effects of increasing money supply rather than what the interest rate effect has on exchange rates, could prove useful.

5. Discussion of Results, Policy, Theory and Implications

5.1 Macroeconomic Comparison

The main goal of QE was to help improve economic performance and encourage inflation due to the recession. In order to do so, QE worked through 5 main channels (Figure 2.2.1), the most important of which was the portfolio balance channel.

In Section 4.1, Figures 4.1.2 and 4.1.3 show that the US program had a longer lasting impact on real GDP growth than that of the UK. For inflation, the results from the UK seem to suggest that its program was more effective in encouraging inflation in the short run, compared to the US. Nonetheless, it appears that in the long run, the US program was more capable in boosting inflation than in the UK. While neither program is perfect, the US program seems to have had a more positive effect on real GDP growth and

[1] Data source in Appendix 1.2.

inflation in the long run, while the UK program had a more desirable effect in terms of short-run inflation. The basic results for the estimation described in Section 4.1, along with those of our alternative methods (Section 5.3), are summarized in Appendix 4, for both the US and UK.

Depending on the government's main concern, whether it is improving the economy as quickly as possible or a long-term recovery, the different QE programs studied in this paper may be of interest. Certain aspects could be changed or modified, and findings such as these could serve to better understand how QE functions, as well as its overall effectiveness, for countries in similar situations to the US and UK.

5.2 Exchange Rate and QE

Exchange rates in US and UK are driven primarily by market forces. The FED and BOE did very little intervention in the currency exchange market over the past 20 years. Theories in exchange rates suggest QE would depreciate the exchange rate. As well, at the zero lower-bound, speculators would look to other indicators, especially long-term bonds, in making their buy or sell decision.

The results from our empirical analysis are surprising and give further insights into what moves the currency rate during the financial crisis. In Section 4.2, the possibility arises that even though the hypothesis was correct, it may not be because the relationship between the exchange rate and term premium strengthened, but rather that during QE, traders were in a general panic, and all assets moved in sync with economic indicators. In Section 4.3, we looked at a counterfactual analysis of QE on exchange rates and saw it had different effects in the US and UK, suggesting it was not through the mechanisms of decreasing bond spread. One explanation might be that during a global economic crisis such as the one in 2008, the US dollar is seen as more of a "safe haven" currency.

Exchange rates are important to many sectors of the economy in both the US and UK. Understanding how the implementation of QE can affect exchange rates will ultimately affect the decisions and design of the policy in QE. Both the FED and BOE needed to boost aggregate demand in order to stimulate the economy and get it back on track. Depreciating the currency could boost the exports of the economy. However, with the interconnectedness of global markets, it becomes much more difficult to account for exchange rate fluctuations. With other countries in distress at the same time, analyzing currency must be done in conjunction with the rest of the world, which was not done in this paper.

5.3 Alternative Methods and Findings

There were a few alternative methods that were attempted in order to evaluate the robustness of our model regarding the impact of QE. First, we ran a VAR for all time periods (1991Q1-2014Q4) for the US and UK, rather than our sample to the end of 2008. We also tried using *bspread* as an exogenous, rather than endogenous, variable in our *VAR 1* model. We found that in the US, *bspread* was positively correlated with GDP, so

when QE was implemented through downward *bspread* shock in the counterfactual analysis, there was a decrease in GDP, although this relationship was not significant. However, in the UK, the relationship was negative, which is what theory has expected.

We also tried to use an alternate measure for QE. Instead of using *bspread*, we tried to input a proxy for the amount of QE, central bank assets, directly into *VAR 1*. We found the results for this VAR were meaningless and insignificant.

In general, while there were some minor similarities, we found for these alternative iterations, the effects of *bspread* on macroeconomic variables were very different for the US and UK. The effects of *bspread* on macroeconomic variables in the US were found to be more erratic, while in the UK, the effects were more along the lines of what we anticipated. This could be a result of the differences in the design of the programs. For example, in the US, QE1 was effective in achieving its goal, but QE2 and QE3 are generally believed to have been less successful in raising GDP and lowering inflation, as there was a diminishing effectiveness of the QE program. Meanwhile, in the UK, they only ran "one" program that was continually renewed, rather than what the US did in having multiple programs with different designs. This contrast could be an explanation for the differences in the effect of *bspread* on our variables of interest.

Additionally, forward guidance, expectations that result from the announcement of monetary policy, was more effective in the UK in that when they announced QE, the effects were seen more immediately. This is seen by the positive effect on real GDP growth in the period following the QE announcement in the UK (Figure 4.1.3), while in the US, there was an initially negative response, before becoming positive (Figure 4.1.2). The reason we believe forward guidance is less effective in the US is because its financial system is more complex and speculative by nature, as it is a larger and more open economy than the UK. Also, in the US, the Federal Reserve System, with the way it is organized with 12 districts and 7 board members that must pass monetary policy by a majority vote, is much less clear and straightforward with monetary policy for businesses and investors to act on compared to the more simple system in place in the UK.

The results for the alternative methods described above can be seen in Appendix 4. It details the results for all the variations of our VAR model that were estimated, describing the basic results for the first and second lags of *rgdp_rate* and *inf*, their respective p-values and the R^2 in both the US and UK.

Finally, a sensitivity analysis was done to vary the *bspread* variable to see whether a change in the magnitude away from the original 60 basis point assumption would cause different inferencing in the analysis of QE using the counterfactual. The general direction of the effect of QE on macroeconomic variables did not change. Varying *bspread* simply affected the magnitude of the change in *rgdp_rate* and *inf* in the counterfactual estimation.

5.4 Time-Varying Parameters

Based on the models presented in this paper, we have found that when analyzing QE on macroeconomic variables, time-varying parameters should have been used. This is in contrast to Lenza et al. (2010), who did not use time-varying parameters in their analysis, and claimed that this omission would not significantly affect the results. Through the course of our research, we found that they should be included, because the relationships between important macroeconomic variables change during the financial crisis compared to their relationship beforehand, and in many cases, this change is significant.

6. Conclusion

Using empirical analysis, we decided to focus on the macroeconomic and currency market effects of QE. This paper focuses on comparison of the macroeconomic results between the US and UK, and looks into the effects of QE on exchange rates and currency markets. A literature survey was conducted to look at the current research done on analysis of QE. After the analysis of the theory, we came to 3 hypotheses:

1: Macroeconomic variables improved due to QE
2: Relationship between exchange rates and term premium strengthened during QE
3: QE depreciated exchange rates

We estimated the coefficients of a VAR, forecasting out the macroeconomic variables without QE. We forecasted out the macro variables with QE by artificially depressing the bond spread by 60 basis points. The analysis was done by comparing the sets of forecasted variables. We found that both programs had nearly the same directional effect on macroeconomic variables in the short run, with the US outperforming the UK in the long run. For inflation, the UK program appears to have had the effect of decreasing inflation, compared to the no-policy scenario, in the short run. Meanwhile, in the US, inflation increased relative to the no-policy scenario in the short run, before steadily decreasing in subsequent periods.

The findings on exchange rates differ from the original hypotheses. The relationship between exchange rates and the bond spread strengthened during QE. The results were similar between the US and UK. The effects of QE on exchange rates were different for the two countries. Our empirical study suggests that QE appreciated the dollar index in US, while depreciating the UK Sterling index.

Comparing the two countries, the UK seems to have had the more desirable effects with their program than the US, as it was able to decrease inflation and exchange rates. On the other hand, the US' QE policy was more successful in improving the GDP growth rate. It ultimately depends on which variable was of greater importance to the country. In the US, the FED had the mandate to improve the unemployment rate as well as decreasing the amount of toxic assets in the financial system. On the other hand, the UK was solely focused on controlling inflation. This explains some of the differences between the implementation and ultimate results of the two countries' programs.

Our paper found that depending on how the model was specified, the effects and results of QE could tell different stories. A change in the time period or changing the transmission mechanism can greatly vary the estimated results.

Further research should be done on how QE affects even more specific variables such as income levels, bankruptcy rates, unemployment, and so forth. Moreover, most of the research done so far has used a decrease in *bspread* as a proxy for QE. Other transmission mechanisms of QE such as liquidity premium or consumer confidence should be studied as well because the effects can be complex in large open economies like the US and UK. As well, we find that there also needs to be further research done to study the recovery of financial crisis after the implementation of QE. Data showed a much longer recovery period in this recession compared to past recessions. All in all, QE is a tool that is effective under specific situations and has very specific goals. The design needs to carefully thought out and modelled to increase the success of its implementation.

References

Aldrick, Philip. 2012. "Economists Call Time On Quantitative Easing After Bank Votes To Hold." *Telegraph.Co.Uk*. http://www.telegraph.co.uk/finance/economics/9663744/Economists-call-time-on-quantitative-easing-after-Bank-votes-to-hold.html#disqus_thread.

Annunziata, Marco. 2011. *The Economics Of The Financial Crisis*. Houndmills, Basingstoke: Palgrave Macmillan.

Applebaum, Binyamin. 2014. "Federal Reserve Caps Its Bond Purchases; Focus Turns To Interest Rates." *Nytimes.Com*. http://www.nytimes.com/2014/10/30/business/federal-reserve-janet-yellen-qe-announcement.html?_r=0.

Bank of England. 2011. *The United Kingdom's Quantitative Easing Policy: Design, Operation And Impact*.

Bank of England. 2015. *The Bank Of England's Sterling Monetary Framework*. http://www.bankofengland.co.uk/markets/Documents/money/publications/redbook.pdf.

Bank of International Settlements. 2013. *Triennial Central Bank Survey: Foreign Exchange Turnover in April 2013: Preliminary Global Results*.

Baumeister, Christiane, and Luca Benati. 2010. "Unconventional Monetary Policy And The Great Recession." *European Central Bank Working Paper Series* 1258. https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1258.pdf.

Baily, Martin Neil and John B. Taylor. 2014. *Across The Great Divide*. Stanford, California: Hoover Institution Press.

Coenen, Gunter and Volker Wieland. 2003. "The Zero-interest-rate Bound and the Role of the Exchange Rate for Monetary Policy in Japan." *Journal of Monetary Economics.*

Dornbusch, Rudiger. 1976. “Exchange Rate Expectations and Monetary Policy.” *Journal of International Economics*.

Federal Reserve. 2008. *November 25Th Press Release*. http://www.federalreserve.gov/newsevents/press/monetary/20081125b.htm.

Federal Reserve. 2012. *Monetary Policy Since The Onset Of The Crisis*. Jackson Hole, Wyoming.

Federal Reserve Bank of St. Louis. 2016. "Trade Weighted U.S. Dollar Index: Broad (DTWEXB)." FRED. Fred Economic Data, n.d. Web. 01 Feb. 2016.

Gagnon, Joseph, Matthew Raskin, Julie Remache, and Brian Sack. 2010. “Large-Scale Asset Purchases by the Federal Reserve: Did They Work?.” Peterson Institute for International Economics and Federal Reserve Bank of New York.

Giannone, Domenico, Michele Lenza, Huw Pill, and Lucrezia Reichlin. 2012. “The ECB And The Interbank Market.” *The Economic Journal* 122 (564): F467-F486. doi:10.1111/j.1468-0297.2012.02553.x.

Giudice, Gabriele, Robert Kuenzel, and Tom Springbett. 2012. *UK Economy: The Crisis in Perspective*. London: Routledge.

Grilli, Vittorio and Graciela Kaminsky. 1990. “Nominal Exchange Rate Regimes and the Real Exchange Rate: Evidence from the United States and Great Britain.” *Journal of Monetary Economics* 27(2): 191-212.

Hnatkovska, Viktoria, Amaryta Lahiri, and Carlos Vegh. 2012. “Interest Rate and Exchange Rate: A Non-Monotonic Tale”. *European Economic Review* 63: 68-93. doi:10.1016/j.euroecorev.2013.06.001.

Joyce, Michael, Ana Lasaosa, Ibrahim Stevens, and Matthew Tong. 2011. “The Financial Market Impact Of Quantitative Easing.” *SSRN Electronic Journal*. doi:10.2139/ssrn.1638986.

Joyce, Michael, David Miles, Andrew Scott, and Dimitri Vayanos. 2012. “Quantitative Easing And Unconventional Monetary Policy - An Introduction.” *The Economic Journal* 122 (564): F271-F288. doi:10.1111/j.1468-0297.2012.02551.x.

Joyce, Michael, Matthew Tong, and Robert Woods. 2011. “The United Kingdom’s Quantitative Easing Policy: Design, Operation And Impact.” *Bank Of England Quarterly Bulletin* 51 (3).

Kapetanios, George, Haroon Mumtaz, Ibrahim Stevens, and Konstantinos Theodoridis. 2012. “Assessing The Economy-Wide Effects Of Quantitative Easing.” *The Economic Journal* 122 (564): F316-F347. doi:10.1111/j.1468-0297.2012.02555.x.

Lenza, Michele, Huw Pill, and Lucrezia Reichlin. 2010. “Monetary Policy In Exceptional Times.” *Economic Policy* 25 (62): 295-339. doi:10.1111/j.1468-0327.2010.00240.x.

Meier, André. 2009. "Panacea, Curse, or Non-Event? Unconventional Monetary Policy in the United Kingdom." *CEPR Working Paper N.7669,* International Monetary Fund.

Appendix

Appendix 1.1: Variable List

Variable	Description	Transformation
rgdp_rate*	Real GDP growth in percentage	Levels
inf*	Inflation (CPI) in percentage	Levels
gfcf	Gross Fixed Capital Formation, proxy for investment	Levels
unemp	Unemployment rate	Log-levels
stocks	Stock index value, S&P 500 or FTSE	Log-levels
tenyear	10-year maturity government bond yield	Levels
threemonth	3-month maturity government bond yield	Levels
bspread*	Difference between 10 year and 3 months	Levels
target_rate*	Central bank target overnight rate	Levels
savings	Net savings, not chained, ratio of income	Log-levels
bus_bankruptcy	Total number of business liquidations	Levels
ind_insol	Sum of bankruptcies, DROs an IVAs	Levels
ca	Export-Import, Total Current Account Balance	Log-levels
gov_exp	Government Final Consumption Expenditure	Log-levels
consum	Private Final Consumption Expenditure	Log-levels
manu	Manufacturing Production	Levels
housing	Real Residential Housing Prices	Log-levels
gbpusd*	British Pound per US Dollar	Levels
usdgpb*	US Dollar per British Pound	Levels
seri*	Sterling Exchange Rate Index	Log-levels

twusdi*	Trade Weighted US Dollar Index	Log-levels

* indicates endogenous variable

Appendix 1.2: Variable Source List

Variable	US Source	UK Source
rgdp_rate*	OECD Quartly GDP	OECD Quartly GDP
inf*	OECD CPI Inflation	OECD CPI Inflation
gfcf	FRED of St. Louis FED	FRED of St. Louis FED
unemp	OECD stats	OECD STAT stats
stocks	Investing.com	Investing.com
tenyear	Bloomberg Terminal	Bloomberg Terminal
threemonth	Bloomberg Terminal	OECD
bspread*	Calculated	Calculated
target_rate*	FRED of St. Louis FED	Bank of England
savings	Bureau of Eocnomics Table 5.1	Office for National Statistics, UK
bus_bankruptcy	American Bankruptcy Institute	Gov.uk Statistics
ind_insol	American Bankruptcy Institute	Gov.uk Statistics
ca	OECD Current Account Balance	FRED of St. Louis FED
gov_exp	Bureau of Eocnomics Table 3.9.3	FRED of St. Louis FED
consum	Bureau of Eocnomics Table 2.3.3	FRED of St. Louis FED
manu	FRED of St. Louis FED	FRED of St. Louis FED
housing	FRED of St. Louis FED	FRED of St. Louis FED
gbpusd*	Bloomberg Terminal	Bloomberg Terminal
usdgpb*	FRED of St. Louis FED	FRED of St. Louis FED
seri*		Bank of England
twusdi*	FRED of St. Louis FED	

Appendix 2: Data Summary

US Summary Statistics[1]

US	Count	Mean	Std. Dev	Min	Max
Country	96	2.000	0.000	2.000	2.000
rgdp_rate	96	2.495	2.478	-8.450	7.554
inf	96	2.514	1.101	-1.623	5.303
gfcf	94	0.044	0.066	-0.266	0.145
unemp	96	6.148	1.608	3.900	9.933
stocks	101	1113.822	453.152	371.160	2067.890
tenyear	96	4.739	1.681	1.634	8.227
threemonth	96	2.857	2.163	0.005	6.210
bspread	96	1.883	1.171	-0.783	3.789
target_rate	99	2.960	2.275	0.070	6.530
savings	99	304.436	244.134	-364.500	675.400
bus_bankru~y	94	11363.620	3443.232	4086.000	19566.000
ind_insolv	82	312720.200	87348.990	112685.000	654633.000
ca	92	-93.591	59.046	-214.501	9.957
gov_exp	97	444.837	144.455	249.100	654.050
consum	89	7715.291	1432.623	5284.400	9726.200
manu	97	0.584	1.507	-6.592	2.738
housing	95	102.426	21.155	79.000	152.300
usdgbp	100	0.613	0.052	0.489	0.704
twusdi	100	86.812	10.325	69.528	111.575
qe	52	2154.876	1361.760	725.019	4497.660
quarter	96	171.500	27.857	124.000	219.000
l_unemp	96	1.784	0.251	1.361	2.296
min_ca	101	-214.501	0.000	-214.501	-214.501
l_ca	92	4.594	0.832	0.000	5.418
l_stocks	101	6.917	0.473	5.917	7.634
min_savings	101	-364.500	0.000	-364.500	-364.500
l_savings	99	6.342	0.872	0.000	6.948
l_gov_exp	97	6.043	0.337	5.518	6.483
l_consum	89	8.933	0.195	8.573	9.183
l_housing	95	4.609	0.197	4.369	5.026
l_twusdi	100	4.457	0.118	4.242	4.715
d_l_twusdi	99	0.001	0.030	-0.059	0.103

[1] l_ indicates log, d_ indicates first difference.

UK Summary Statistics[1]

UK	Count	Mean	Std. Dev	Min	Max
Country	96	1.000	0.000	1.000	1.000
rgdp_rate	96	2.090	2.356	-9.012	6.426
inf	96	2.471	1.493	0.600	8.400
gfcf	94	0.032	0.115	-0.236	0.297
unemp	96	6.841	1.688	4.600	10.400
stocks	101	4985.432	1322.243	2313.000	6984.400
tenyear	96	5.279	2.199	1.727	10.500
threemonth	96	4.356	2.784	0.236	12.290
bspread	96	0.923	1.417	-2.229	3.778
target_rate	99	4.383	2.877	0.500	12.375
ind_insolv	96	15827.450	10213.590	5436.000	35682.000
liquidation	92	3923.554	826.037	2900.000	6473.000
ca	93	-5.686	5.032	-23.919	1.154
savings	96	10.244	3.369	4.500	17.000
gov_exp	96	57.938	20.885	29.311	89.195
consum	88	192.836	35.003	134.242	238.143
manu	96	0.056	1.191	-5.666	2.232
housing	97	76.005	25.637	41.500	114.600
gbpusd	100	1.644	0.150	1.421	2.044
seri	100	91.936	8.345	77.899	104.725
qe	33	248708.200	120877.800	78509.000	413029.000
quarter	96	171.500	27.857	124.000	219.000
l_unemp	96	1.893	0.245	1.526	2.342
min_ca	101	-23.919	0.000	-23.919	-23.919
l_ca	93	2.886	0.489	0.000	3.261
l_stocks	101	8.473	0.301	7.746	8.851
l_savings	96	2.271	0.340	1.504	2.833
l_gov_exp	96	3.991	0.376	3.378	4.491
l_consum	88	5.244	0.191	4.900	5.473
l_housing	97	4.267	0.369	3.726	4.741
l_seri	100	4.517	0.092	4.355	4.651
d_l_seri	99	-0.001	0.026	-0.131	0.064

Appendix 3: Output Summary of Base VAR Model

US VAR Model

[1] l_ indicates log, d_ indicates first difference.

Vector autoregression

Sample: 1994q1 - 2008q4		No. of obs	= 60
Log likelihood = -137.6174		AIC	= 7.387246
FPE = .0214783		HQIC	= 8.534144
Det(Sigma_ml) = .0011543		SBIC	= 10.31933

Equation	Parms	RMSE	R-sq	chi2	P>chi2
rgdp_rate	21	1.32777	0.8272	287.2481	0.0000
inf	21	.631557	0.6196	97.74566	0.0000
target_rate	21	.328492	0.9783	2701.407	0.0000
bspread	21	.391284	0.9258	748.2636	0.0000

	(1)	(2)	(3)	(4)
VARIABLES	rgdp_rate	inf	target_rate	bspread
L.rgdp_rate	-0.438***	0.0911*	-0.00960	0.0443
	(0.111)	(0.0529)	(0.0275)	(0.0328)
L2.rgdp_rate	0.0237	0.0466	-0.00768	0.00509
	(0.105)	(0.0500)	(0.0260)	(0.0310)
L.inf	-0.384	0.688***	0.00820	0.324**
	(0.436)	(0.207)	(0.108)	(0.128)
L2.inf	0.903**	0.141	0.0725	-0.0739
	(0.400)	(0.190)	(0.0989)	(0.118)
L.target_rate	-0.367	-0.295	1.154***	-0.838***
	(0.542)	(0.258)	(0.134)	(0.160)
L2.target_rate	-0.378	0.410	-0.277**	0.252
	(0.560)	(0.266)	(0.138)	(0.165)
L.bspread	0.125	-0.275	0.0775	0.333**
	(0.460)	(0.219)	(0.114)	(0.136)
L2.bspread	-0.964**	0.320	0.0697	-0.0493
	(0.442)	(0.210)	(0.109)	(0.130)
D.l_unemp	-4.975	0.777	-2.957*	5.628***

	(6.513)	(3.098)	(1.611)	(1.919)
gfcf	16.83***	1.233	2.802**	-3.381**
	(5.475)	(2.604)	(1.355)	(1.613)
l_ca	1.194***	-0.107	-0.0542	0.279**
	(0.383)	(0.182)	(0.0948)	(0.113)
D.l_stocks	4.420**	-0.262	-0.578	0.896
	(2.117)	(1.007)	(0.524)	(0.624)
manu	1.270***	0.0912	0.0587	0.101
	(0.252)	(0.120)	(0.0623)	(0.0742)
l_savings	0.190	-0.805	0.612*	0.483
	(1.386)	(0.659)	(0.343)	(0.408)
bus_bankruptcy	-0.000182*	-7.95e-05	-2.68e-05	-1.51e-06
	(0.000105)	(4.98e-05)	(2.59e-05)	(3.09e-05)
ind_insolv	2.03e-06	2.06e-06*	-7.52e-08	-9.46e-07
	(2.57e-06)	(1.22e-06)	(6.35e-07)	(7.56e-07)
D.l_gov_exp	39.32*	32.39***	8.281	25.39***
	(23.82)	(11.33)	(5.892)	(7.019)
l_consum	-2.008	-1.269	-1.171	-2.731***
	(3.335)	(1.586)	(0.825)	(0.983)

D.l_housing	-8.816	-5.016	-9.715**	-9.360*
	(17.35)	(8.250)	(4.291)	(5.111)
d_l_twusdi	1.845	-3.858	3.597**	0.725
	(6.689)	(3.182)	(1.655)	(1.971)
Constant	17.31	16.24	6.828	22.69**
	(33.99)	(16.17)	(8.410)	(10.02)
Observations	60	60	60	60

Standard errors in parentheses

*** p<0.01, ** p<0.05, *p<0.1

UK VAR Model

```
Vector autoregression

Sample:  1991q3 - 2008q4                        No. of obs      =         70
Log likelihood = -156.8028                      AIC             =   6.880079
FPE            =  .0123355                      HQIC            =   7.951835
Det(Sigma_ml)  =   .001037                      SBIC            =   9.578274

Equation           Parms      RMSE     R-sq      chi2     P>chi2
------------------------------------------------------------------
rgdp_rate             21   1.63319   0.6623   137.3076   0.0000
inf                   21    .42458   0.9292   918.7356   0.0000
bspread               21   .397999   0.9267   885.4714   0.0000
target_rate           21   .310707   0.9731   2530.357   0.0000
------------------------------------------------------------------
```

	(1)	(2)	(3)	(4)
VARIABLES	rgdp_rate	inf	bspread	target_rate
L.rgdp_rate	0.499***	-0.0377	-0.00371	0.0108
	(0.136)	(0.0353)	(0.0331)	(0.0259)
L2.rgdp_rate	-0.147	-0.0122	0.0106	0.0746***
	(0.139)	(0.0360)	(0.0338)	(0.0264)

L.inf	-0.728*	0.862***	0.153	-0.0512
	(0.422)	(0.110)	(0.103)	(0.0803)
L2.inf	0.464	-0.131	0.119	0.0175
	(0.410)	(0.107)	(0.0999)	(0.0780)
L.bspread	-0.617	0.126	0.480***	0.492***
	(0.473)	(0.123)	(0.115)	(0.0900)
L2.bspread	0.606	-0.0446	0.0944	-0.260***
	(0.499)	(0.130)	(0.122)	(0.0949)
L.target_rate	-0.496	-0.105	-1.149***	1.680***
	(0.643)	(0.167)	(0.157)	(0.122)
L2.target_rate	0.540	0.170	0.597***	-0.469***
	(0.762)	(0.198)	(0.186)	(0.145)
D.l_unemp	-8.419	-1.441	-6.262***	-2.685
	(9.958)	(2.589)	(2.427)	(1.894)
gfcf	-0.366	0.932**	0.0145	0.241
	(1.633)	(0.425)	(0.398)	(0.311)
l_ca	-0.761	0.155	-0.356	-0.196
	(1.597)	(0.415)	(0.389)	(0.304)
D.l_stocks	0.710	1.193*	0.514	0.244
	(2.599)	(0.676)	(0.633)	(0.494)
manu	0.626***	-0.0654	-0.0192	0.100**
	(0.218)	(0.0566)	(0.0531)	(0.0414)
D.l_savings	-0.664	-0.264	0.284	-0.341
	(1.319)	(0.343)	(0.322)	(0.251)
D.liquidation	-0.000734	0.000135	-0.000180	0.000302***
	(0.000541)	(0.000141)	(0.000132)	(0.000103)

D.ind_insolv	9.70e-06	8.59e-05	4.50e-05	1.02e-05
	(0.000204)	(5.29e-05)	(4.96e-05)	(3.87e-05)
D.l_gov_exp	12.64	-6.686**	-2.913	0.346
	(12.35)	(3.212)	(3.010)	(2.350)
l_consum	-1.164	0.921	-3.326***	1.951***
	(3.569)	(0.928)	(0.870)	(0.679)
D.l_housing	10.65	-8.430***	-0.494	0.458
	(8.463)	(2.200)	(2.062)	(1.610)
d_l_seri	-0.132	2.761	-10.76***	7.879***
	(7.925)	(2.060)	(1.931)	(1.508)
Constant	9.775	-4.918	21.12***	-11.17***
	(22.07)	(5.737)	(5.378)	(4.199)
Observations	70	70	70	70

Standard errors in parentheses

*** p<0.01, ** p<0.05, *p<0.1

Appendix 4: Alternative Model Result Summary

US Model Output

	Models	1	2	3	4	5
rgdp_rate	**Coef-1 lag**	**0.1246**	**2.5111**	**0.1498**	**-0.1304**	**-0.0018**
	p-value	0.7870	0.0000	0.7250	0.6950	0.0830
	Coef - 2 lag	**0.9636**	**1.0043**	**-0.2672**		
	p-value	0.0290	0.0250	0.4670		
			-			
inf	**Coef-1 lag**	**0.2754**	**1.4369**	**-0.0425**	**0.4870**	**-0.0008**
	p-value	0.2080	0.0000	0.8260	0.7260	0.1400
	Coef - 2 lag	**0.3205**	**1.2094**	**0.2660**		
	p-value	0.1280	0.0000	0.1110		
R^2	**rgdp_rate**	**0.8272**	**0.9671**	**0.7661**	**0.7651**	**0.8579**
	inf	**0.6196**	**0.9425**	**0.7245**	**0.7144**	**0.8164**

Models
1) Base model: 1991 to 2008, bspread as endogenous
2) 2007-2013: bspread as endogenous
3) All data: 1991 to 2014, bspread as endogenous
4) All data: 1991 to 2014, bspread as exogenous
5) All data: 1991 to 2014, qe as exogenous

UK Model Results

	Model	1	2	3	4	5
rgdp_rate	**Coef-1 lag**	**-0.6169**	**-0.6392**	**-0.6470**	**-0.4601**	**0.0000**
	p-value	0.1920	0.4510	0.1110	0.0560	0.0470
	Coef - 2 lag	**0.6065**	**3.3021**	**0.6131**		
	p-value	0.2240	0.0010	0.1520		
Inf	**Coef-1 lag**	**0.1263**	**-0.3947**	**0.1580**	**-0.0284**	**0.0000**
	p-value	0.3050	0.0000	0.1520	0.6680	0.0320
	Coef - 2 lag	**-0.0446**	**-0.1523**	**-0.0994**		
	p-value	0.7310	0.1670	0.3930		
R^2	**rgdp_rate**	**0.6623**	**0.9090**	**0.6612**	**0.6649**	**0.8860**
	inf	**0.9292**	**0.9851**	**0.9170**	**0.9151**	**0.9753**

Models

1) Base model: 1991 to 2008, bspread as endogenous
2) 2006-2013: bspread as endogenous
3) All data: 1991 to 2012, bspread as endogenous
4) All data: 1991 to 2012, bspread as exogenous
5) All data: 1991 to 2012, qe as exogenous