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Master Thesis

What are the effects of Large Scale Asset Purchases on asset prices in the US?

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Abstract

In this thesis we research the effects of the Federal Reserve's Large Scale Asset Purchase programs on asset prices in the United States, mainly stock prices and long term interest rates. First, an event study is employed to capture the effects of the announcements regarding LSAP, which gives an indication on what effects the LSAP programs had on asset prices. In addition, we employ a Vector Autoregression and a Vector Error-Correction model to analyse the actual effects of the asset purchases done through the LSAP.

From the event study we find that LSAP announcements have a statistically significant negative impact on five, ten and thirty year treasury yields. The results indicate a downward shift of around 0.4% for these yields. These findings are in line with what other studies have found, as well as what is expected from theory. The effects of LSAP announcements on the S&P500 index are not significant, which could be due to the fact that LSAP programs are not directly affecting the S&P500 index, and thus it is not captured in the short estimation window in the event study.

From the Vector Autoregression we find that an one-standard deviation shock to the Securities held outright by the Federal Reserve (measure of LSAP) has a positive effect on the S&P500 index of about 1.5% in the first few months, before the effect declines back towards equilibrium after about a year. For ten year treasury yields we find that an one-standard deviation shock to Securities held outright by the Federal Reserve results in a positive response of about 0.10%, before it moves back to equilibrium after around a year.

The results from the Vector Error-Correction model is similar to the results from the Vector Autoregression model, with the most noteworthy difference being that the effects appears to be more permanent.

The positive reaction on the ten year treasury yields due to a shock in Securities is not in line with what we would expect, and what other studies have found.

The reason for this could be that we have somehow misspecified our models, or that a more complex model that opens up for structural restrictions is better suited for this analysis.

1.0 Introduction

1.1 Research Question

In the wake of the financial crisis of 2007-2008 the federal reserve exhausted one of their most effective monetary policy tools by decreasing the federal funds rate target to the range of 0 to 0.25 in December 2008. A few weeks prior, on November 25th, the federal reserve had announced their new unconventional monetary policy tool to deal with the deteriorating situation in the US economy. The Large Scale Asset Purchase (LSAP) programs was introduced as a new form of Open Market Operations (OMOs). In this master thesis, we aim to research how these programs affect asset prices in the US.

Thus, our research question is the following:
What are the effects of large scale asset purchases on asset prices in the US?

1.2 Motivation

Being able to accurately estimate the effects of LSAP on asset prices can be greatly beneficial to several parties. For the policy makers, being able to predict the outcome of the policy is critical when formulating the policy. After the fact, knowing the effects of the LSAP programs will lead to better informed policy making in the future. From an investor’s point of view, having more reliable estimates for changes in asset prices can lead to better investment decisions. For firms, having better estimates for their own value can have great importance.
It can lead to better stability and more informed decision making.
We find this topic interesting in itself, and it also very useful to have an understanding of how monetary policy in the world's largest economy affect asset prices.

1.3 About the LSAP programs

First off, it is important to understand the difference between the traditional OMOs and LSAP. Traditional OMO's focus primarily on contracting or expanding the Fed's balance sheet by either selling or buying treasury bonds to manipulate the Federal funds rate (an overnight rate at which depository institutions and banks lend to each other). The aim of manipulating the Federal funds rate is to achieve stability in the economy by increasing the Federal funds rate when the economy is doing well, and vice versa.
Because the federal funds rate has been in a near-zero target range since late 2008 and that interest rates can not theoretically be lower than zero, the traditional OMO's have not been a suitable tool to affect the economy these last years.

This is where the Large Scale Asset Purchase program, also known as Quantitative Easing(QE) come into the picture. We will use these terms interchangeably.
QE can be viewed as a more expansive OMO. In contrast to traditional OMO's, which focus primarily on short-term interest rates and buying or selling treasury bonds, QE focus more on medium and long-term interest rates, while they also operate with more variety in the assets being bought.
The aim is to decrease the cost of borrowing by putting a downward pressure on the yield-curve as stated on the Federal Reserve homepage as of June 15th 2016. The scale at which assets are being bought is much larger than with traditional OMO's, as is implied by the name "Quantitative Easing". With QE, the Fed injects large amounts of money into the market through the large scale asset purchase programs, which helps to increase liquidity in the market and put a downward pressure on interest rates. This, in turn, boosts economic activity as it leads to more investments and higher aggregate demand.
To get a better perspective on the size of the QE rounds from 2008 to 2014, we need only to look at the balance sheet of the Fed. In late November 2008, the Fed held between $700 billion and $800 billion in assets, while when QE3 halted on 29 October 2014, the size of the Fed balance sheet had more than quadrupled to $4.5 trillion in assets.

Numerous earlier studies have concluded that traditional monetary policy has significant impact on asset prices, and vice versa. Bjørnland and Leitemo (2009) examined the interdependence between US monetary policy and the stock market and found a strong interdependence between the two. In their paper they mainly focus on the effect of interest rate setting, while in our thesis, we will examine the effect of the LSAP programs on US asset prices in the period from 2008 to 2016. These LSAP programs were designed to impact the rates of return of assets being purchased as well as on other assets with similar characteristics (Gagnon et al. 2010). Other relevant studies will be discussed further in the literature review section, and further details about the methodology will be discussed in the methodology section.

2.0 Literature review

In this section we review earlier relevant studies on similar subjects. We have looked at earlier articles that mainly focus on the impact of changes in the discount rate and/or changes in the federal funds rate target zone. The more recent articles we have looked at have focused more on the effects of LSAP.

2.1 Pre financial crisis

Estimating the effects of monetary policy has been perhaps one of the most researched topics in economic theory. Many later studies base their research on an article by Thorbecke (1997). He found that expansive monetary policy leads to an increase in equity prices, especially for smaller firms. His explanation for this was that perhaps the increased liquidity matters more for smaller firms.

Rigobon and Sack (2004) builds upon Thorbecke's results. They try to estimate the effect of monetary policy on asset prices, specifically what affects policy shocks on FOMC meeting days have on asset prices and market interest rates. They found that the stock markets have a significant negative reaction to monetary policy shocks, with an estimated reduction in stock prices of 1.9% as a reaction to a 25 basis point increase short term interest rates. They also found a strong reaction in short term market interest rates.

In an earlier article Rigobon and Sack (2001) tried to measure the reverse effect, how monetary policy reacts to changes in asset prices. With the use of a VAR model, they found significant results supporting their hypothesis. They found that for an increase in stock prices of 5%, the probability of a 25 basis point tightening by the Federal Reserve increased by about 50%.

Bjørnland and Leitemo (2009) follows in the footsteps of Rigobon and Sack in examining the interdependence between the S&P 500 and US monetary policy. They find strong interdependence between the interest rate setting and real stock prices. Real stock prices immediately fall by seven to nine percent due to a monetary policy shock that raises the federal funds rate by 1%. A stock price shock increasing real stock prices by one percent leads to an increase in the interest rate of close to 0,04%. These results are consistent with what Rigobon and Sack found earlier.
In contrast to earlier studies on the subject, they take simultaneity problem into consideration in order to better capture the interdependence between stock prices and monetary policy. They solve the simultaneity problem by using a combination of short-run and long-run restrictions that maintains the qualitative properties of a monetary policy shock found in the established literature.

Bernanke and Kuttner (2005) take a different approach, they try to explain stock market's reaction to federal reserve policy using a more traditional event study. In contrast to Rigobon and Sack (2001) and Bjørnland and Leitemo (2009), Bernanke and Kuttner found no evidence that changes in equity prices lead to interest rate changes by the FOMC. On the other hand their results show that stock prices react to changes in the federal funds rate. They estimated that an unexpected 25 basis point reduction in the rate would typically lead to a 1% increase in stock prices.

Gurkaynak, Sack, and Swanson (2004) does a similar study to Bernanke and Kuttner (2005), but find that a single factor analysis with the Federal Funds rate is not adequate to capture the effects of US monetary policy on asset prices.

Instead, they advocate a two-factor approach in which they also include a factor capturing the statements from the FOMC. They found that between 1990 and 2004, FOMC releases accounted for more than three-fourths of the explainable variation in the movements of five- and ten-year Treasury yields around FOMC meetings.

Harvey and Huang (2001) use previously unavailable data on open market operations from 1982 to 1988 to examine the effects of the Fed's trading on both foreign currencies and fixed income securities. They found that there is a dramatic increase in volatility during Fed Time (a thirty minute time window in which the Fed trades in the market), which is consistent with market expectations of the Fed intervening in this time interval. However, they found that the volatility is independent of whether the Fed actually trades in the market. Also, they found some evidence for that volatility is lower when the Fed actually trades, compared to when it does not. This indicates that market participants may be confused about the purpose of open market operations in this period.

2.2 Post financial crisis

Gagnon et al. (2010) examine in their article whether the Large-Scale Asset Purchases of the Fed had a significant and long-lasting effect on the economy in the US. They focus on the effects after November 2008, when the Fed started with QE. They found that the LSAP programs that were implemented led to economically meaningful and long-lasting reductions in longer-term interest rates on a range of securities, including securities that were not included in the purchase programs. The reason for this is that the LSAP programs reduced the net supply of assets with long duration, and hence reduced the term premium. Therefore, the reductions in interest rates primarily reflect lower risk premiums, including term premiums, rather than lower expectations of future short-term interest rates.
From their tests, they found that the overall size of reduction in 10-year term premium appears to be somewhere between 30 and 100 basis points.

Joyce et al. (2011) did a similar study, examining the impact of the quantitative easing programs on the financial markets in the UK. They identify three main channels through which QE could affect asset prices: Announcement effects, portfolio rebalancing, and through increased liquidity. The study found through an event-study that as a reaction to the news about QE purchases, the long term bond yields were about 1% lower than they would otherwise have been.

A working paper by Thornton (2014) follows up on the article of Gagnon et al. (2010) and other articles that use event-studies to examine the LSAP announcement effects on long-term yields. In his article, Thornton focus his attention on whether the announcement effects used in these articles are identified, i.e.; the announcement effects must be due solely to the LSAP news, and the announcement effects must be statistically significant. Thornton finds that of the 53 LSAP announcements considered in the literature none meet the strict requirements for identification. Hence, the event-study evidence from existing literature can be considered inconclusive.

In a working paper by Bhattarai and Chatterjee (2015), they examine the effects of US LSAP on asset prices in the US, as well as the spillover effects on emerging market economies.

They employ a Structural Vector Autoregression methodology, in where they identify the US LSAP shock with non-recursive identifying restrictions. They then use the identified US LSAP shock in a Bayesian panel VAR for emerging market economies. For the US, they find that the LSAP shocks have strong and robust macroeconomic and financial impacts on US consumer prices, output, long-term yields and asset prices. For the emerging market economies, they find that LSAP shocks have lead to exchange rate appreciation, a stock market boom, a reduction in long-term bond yields, and an increase in capital inflows to these countries.

In a paper by Olawale, Olusegun and Taofik (2014), they examine the relationships between the S&P500 index, short-term yields, and other variables, as well as unconventional monetary policy (QE) in the US and UK. They employ a vector error-correction model, where they also include a dummy for the financial crisis to capture structural breaks inherent in the data. They find that there is statistically significant long-run and short-run causal relationships between macroeconomic variables and S&P500, and that QE has a positive on the S&P500 in the US.

From the studies we have looked at it is clear that the earlier studies have focused more on the effect of changes in the federal funds rate target, and the discount rate. While this made sense earlier, both of these rates have been been constant at near zero percent since 2009. Because of this, the Fed was forced to use other measures, most notably the QE programs, a series of large scale asset purchases. Newer studies have tried to measure the effect these have had on asset prices, this is similar to what we want to research.

3.0 Theory

When examining what can potentially affect the value of assets it is beneficial to first know what theories say about value. We can start with the most basic model, the discounted cash flow valuation model. Irving Fisher's book from 1930 *The Theory Of Interest* and John Burr Williams' book from 1938 *The Theory Of Investment Value* are widely considered to be the first to formally lay the groundwork for the model in modern economic terms. The models states that the value of a firm or project should equal the sum of all future cash flows discounted at some discount factor. If we find that asset prices change because of LSAP, then for classical valuation theory to hold, LSAP must impact either the cash flows or the discount factor.

$$\text{DCF} = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1+r)^3} + \ldots\ldots + \frac{CF_n}{(1+r)^n}$$

Where CF = Cash flow and (1+r) = Discount rate.

Building on the classical valuation theory, Gordon (1959) developed what we now call the Gordon growth model. This model states that the price of a stock should equal the future discounted dividends on that stock. Similar to the classical valuation theory, if we see a change in stock prices, it has to be due to a change in the discount factor or the dividend yield.

The formula for the Gordon growth model is given by

Valuation = $\frac{D_1}{r - g}$

, and is derived from the following formula:

$$\text{Valuation} = \frac{D_1}{(1+r)^1} + \frac{D_1(1+g)}{(1+r)^2} + \frac{D_1(1+g)^2}{(1+r)^3} + \frac{D_1(1+g)^3}{(1+r)^4} + \ldots + \frac{D_1(1+g)^{n-1}}{(1+r)^n}$$

Where D_1 = Dividend at the end of the current year, g = growth rate on dividends, n = number of years, and r = discount rate.

The classical Gordon growth model assumes that the expected returns are constant, however, this does not hold in reality. If we compare returns over years and decades we see that they differ vastly. Campbell & Shiller (1988a & 1988b) introduced an alternative "dynamic" Gordon growth model with the use of moving average return variables.

Another theory which is important for understanding the effects of QE on stock prices, as well as the inflationary effects of QE, is The Quantity Theory of Money. The theory descends from Nicolaus Copernicus, and was further developed by Simon Newcomb, Irving Fisher, Ludwig von Mises, and others in the late 19th and early 20th century. It revolves around the connection between money supply and the price level in the economy. The model itself can be stated as:

MV=PY, where M is money, V is the velocity of money, P is the price level, and Y is the aggregate output (GDP or other similar benchmarks).

In order to analyse the effects of QE on asset prices, it is necessary to take into consideration the increased inflation due to the increased money supply. Therefore, this theory is useful when evaluating the inflation effects of QE on asset prices.

This brings us over to an important concept, money illusion also referred to as inflation illusion. The concept was popularized by Modigliani and Cohn (1979) when they hypothesized that stock markets suffers from money illusion, discounting real cash flows at nominal discount rates. They claim that only stock

market investors are subject to this illusion, while bond market investors are not. Stock market investors fail to understand the effect of inflation on nominal dividend growth rates. Hence when inflation rises, bond market participants increase nominal interest rates which are used by stock market participants to discount unchanged expectations of future nominal dividends. Stock market investors irrationally fail to adjust the nominal growth rate to match the discount rate, and so, for rational investors this would imply that stock prices are undervalued when inflation is high and vice versa.
Hence, when evaluating the effects of QE on stock prices in particular, it is important to take the money illusion hypothesis into consideration and identify whether the effects on stock prices are real, or due to mispricing because of the money illusion.

Since one of the methods we will employ in this thesis is an event-study, we must assume that the efficient market hypothesis (EMH) holds. Introduced by Fama (1970), the hypothesis states that asset prices fully reflect all available information, and that if new information becomes available, the prices will adjust immediately after the market participants adjust their expectations. In our analysis we should, according to EMH see asset prices adjust immediately after news and announcements of LSAP. The EMH is not without critics, others have tried to explain the market's reaction to news with behavioral finance. Bondt and Thaler (1985) found using psychology that most people tend to overreact to unexpected or dramatic news, suggesting that EMH might not hold.

A very relevant theory in relation to bond yields is the Expectations Theory of the Term Structure. Since Macaulay published his book *The Movements of Interest Rates* in 1938, it has been in the center of both theoretical and empirical research on fixed income securities. The expectations hypothesis has to do with the evolution of yields, which is highly relevant for bond prices. The hypothesis is that long-term interest rates contain a prediction of future short-term interest rates.

Another theory that tries to explain differences in the bond yields is the Liquidity Preference Theory. The theory was first introduced in Keynes book from 1936 *The General Theory of Employment, Interest and Money*. The theory states that investors require a higher rate of return on investments in longer maturity bonds.

For the Fed, it is particularly important to know how their QE programs affect bond yields, since the main goal of the QE programs is to lower the medium to long-term market interest rates, and so, the theories described above is useful for this purpose

4.0 Data

4.1 Data Collection

The data we used in our event study was collected from the Federal Reserve of St. Louis homepage. We went through all statements from the Federal Reserve Open Market Committee and included only the statements with new information regarding QE in our dataset. We then downloaded daily data for one, five, ten, and thirty-year treasury yields. Lastly, we used daily data on the S&P500 index.

For the Vector autoregression and Vector error-correction models we also employ, we use monthly data from January 2008 to March 2016. The variables we use are S&P500 index for stock prices, ten-year treasury yields for bond prices, Private Consumption Expenditures price index (PCEPI) as a deflator, and Industrial Production (Indpro) as a measure of output. Lastly, we use securities held outright by the Federal Reserve as a measure of LSAP/QE. This is a measure of the asset side of the Fed balance sheet, and consists of the holdings of mortgage-backed securities, US Treasury securities and Federal agency debt securities. These holdings are mainly due to outright purchases by the Fed, which is an important component of QE, and thus this is a precise measure of QE. For the purpose of modelling, we log all the variables except Ten year treasury yields. All the data we used in our VAR analyses came from the Federal Reserve Economic database (FRED).

4.2 Data description

Before running any of the models it can be useful and insightful to examine the date we have at hand. Looking at the data we can see some interesting points. Figure 2.1 - 2.5 in *Appendix B* shows the level of the five variables used in the VAR and VEC model from January 2008 until March 2016. Looking at the securities held outright by the FED we can easily point out the three LSAP programs by the sharp increases in the level.

Looking at the different variables in relation to the securities held outright is where things get interesting. The industrial production index fell sharply during the financial crisis and reached its' lowest point a little after the first LSAP program started, it since increased steadily until leveling off at about the same level as before the crisis at the same time as the last LSAP program had finished. The PCE Price Index had a smaller dip during the financial crisis and quickly recovered, increasing until it also seems to have leveled off after the last LSAP program ended. The S&P500 index follows the same pattern, with the largest growth during the LSAP programs, and then leveling off after they ended. The 10 year yield has been very volatile over the period, with several dips and spikes of up to 1.50% in the span of just a few months. However, the overall trend has been downward, with the yield going from between 3.50% and 4.00% to about 2.00%.

Overall, by just looking at the graphs it looks as though the FED has been successful in achieving their desired results from the LSAP programs. The buying of longer term treasuries and other securities has pushed the long term interest rates down, which in turn has boosted production and economic activity with a moderate increase in the price level.

5.0 Methodology

In order to measure the effects of the fed's LSAP programs we will use an event study to measure the effects of the announcements, as well as a Vector autoregression and a Vector error-correction model to measure the effects of the asset purchases.

5.1 Event study

To measure the immediate effects of the LSAP announcements we employ a simple event study. If the LSAP programs have an effect on treasury yields and/or stock prices, we should according to the efficient market hypothesis see an immediate effect right after the announcements.

5.1.1 The Event study model

The model we use for the event study is based roughly on the same framework as established by Gagnon et al. (2010) and Thornton (2013). We will follow the same basic assumptions: (1) the event set captures all relevant events, (2) The LSAP expectations are not captured by anything other than these events, (3) The time span tested around each event must be long enough to capture long-run effects, but short enough that other news do not impact the results, (4) Assume that Market Efficiency Hypothesis hold, i.e., effects on yields occur when market participants update their expectations.

In the model we will test the effects on stock prices (S&P500), and short-, medium-, and long-term interest rates (1, 5, 10, and 30 year treasury yields). The events we use are announcements and the corresponding minutes from the FOMC which contain new information about the LSAP programs. In addition we use speeches and statements from the chairman in which he/she talks about the LSAP programs. The events we use are listed in *Appendix A* (Figure 1.1 & 1.2).

We use the following models:

(1) $\Delta i_t = \alpha + \beta^{imp} Dum_t^{imp} + \beta^{Limp} Dum_t^{min} + \beta^{min} Dum_t^{speech} + \varepsilon_t$

(2) $\Delta s_t = \alpha + \beta^{imp} Dum_t^{imp} + \beta^{Limp} Dum_t^{min} + \beta^{min} Dum_t^{speech} + \varepsilon_t$

In (1) we measure the announcement effects on interest rates, in (2) we measure the effects on stock prices. Dum_t^{imp} is a dummy variable for LSAP announcements, it is 1 for buy announcements and -1 for sell announcements. Dum_t^{min} is a dummy variable for FOMC minutes, the value is the same as for its corresponding announcement. Dum_t^{speech} is a dummy variable which is equal to 1 on dates with a chairman speech. The estimation window is on the date and the next day.

5.1.2 Event study shortcomings

There are some flaws with this kind of event study. First of all the model treats all the events as equal, either 1 or -1, but we know that they are not all equal, the information in the announcements can be vastly different. However, there is no real way to quantify the events. Another inherent flaw in event studies is that they are not designed to measure long run effects, The longer window you use for the events the more “noise” is captured.

Another weakness with event studies are pre announcement drifts. Pre announcement drifts are when leaks and expectations lead the market to react prior to the official announcement (Lucca & Moench, 2015).

Our event study only measures the effects of the announcements and not the actual asset purchases. To measure the effects of the asset purchases we turn to vector autoregression and vector error-correction models.

5.2 Vector Autoregression Model

The basic Vector Autoregression model is a model used to capture the linear interdependencies among multiple time series. In comparison to the standard univariate autoregressive model, the VAR allows for more than one evolving variable, which is incredibly useful for examining the effects of QE on different macroeconomic and financial factors.

A basic VAR model is generally expressed in the following form:

$y_t = v + A_1 y_{t-1} + \cdots + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \varepsilon_t,$

where y_t is an *k x 1* vector of endogenous variables, *v* is a *k x 1* vector of constraints, A_k is a time invariant *k x k* matrix, and *et* is a *k x 1* vector of error terms satisfying the following assumptions:

1. $E(e_t) = 0$, that is, every error term has mean zero
2. $E(e_t e'_t) = \Omega$, that is, the contemporaneous covariance matrix of error terms is Ω (a *k x k* positive-semidefinite matrix)
3. $E(e_t e'_{t-k}) = 0$ for any non-zero k, that is, there is no correlation across time and no serial correlation in the individual error terms.

5.2.1 Specifying the VAR model

For our basic VAR model, we use a five variable setup. The variables we use are securities held outright by the Federal Reserve as a measure of QE as a measure of QE, S&P500 index for stock prices, ten-year treasury yields for bond prices, Private consumption expenditures price index (PCEPI) as a deflator, and Industrial production (Indpro) as a measure of economic output. All the variables are logged with the exception of the ten year treasury yield, as mentioned in the data section.

Stationarity is an important concern for econometric models in general. Non-stationarity (unit root) in the variables can impair a consistent estimation of the VAR. A remedy for non-stationarity is to difference the variables to induce stationarity. However, many proponents of the VAR approach to examining macroeconomic factors recommend that differencing should not be done, due to the purpose of VAR estimation is to examine the relationships between variables, and differencing will throw away information on any long-run relationships between the series away (Brooks, 2008).

In any case, the first step in specifying the model is to check for stationarity. To do this, we used the Dickey-Fuller test, and found that all our variables are non-stationary. After this, we checked for cointegration between the variables, that is, two or more variables have a fixed relationship in the long run.
There are two ways to check for cointegration, but the Johansen test is the prominent one in this setting, as discussed later on.
According to the Johansen test, we had three cointegrating relationships between our variables. From here, things get more advanced. After finding cointegration between two or more variables the correct next step is to run a Vector Error-Correction model. However, for the purpose of comparing results, we first run a VAR in levels with nonstationarity, before we later on run a VEC on the same specifications. Firstly, we will continue to describe the VAR specification, before we later on discuss and describe our VEC model.

The next step in the VAR specification is to find out the appropriate number of lags. According to the lag-selection test (see *Appendix D, Figure 4.1)*, the likelihood ratio (LR) test, Prediction Error Criterion (FPE) and Akaike information criterion (AIC), 6 lags should be appropriate for our model. In order to confirm that the chosen lag-length was optimal, we ran a Lagrange-multiplier test for serial autocorrelation in the residuals. This test showed that we had serial autocorrelation in the lags, and thus we decided to include another lag to eliminate the serial autocorrelation.

After deciding on the appropriate lag length, we ran the model in STATA. After running the model, we checked for normality on the residuals of our model. From the Jarque-Bera normality test we find that we do not have normal distribution in the residuals. In addition, we find that the residuals are kurtotic, but not skewed.

The rejection of normality in residuals could come from the our small sample size, but in any case, non-normally distributed residuals is not a necessary condition for the validity of VAR models (Belsley & Erricos Chpt.8, 2009).

Lastly we ran a eigenvalue test for stability conditions. According to the test, all the eigenvalues lie inside the unit circle, and thus, our VAR model satisfies the stability condition.

5.2.2 VAR shortcomings

Though VAR models are very useful for examining the effects of monetary policy on financial and macroeconomic factors, it is not without flaws.
There are numerous weaknesses pointed out by different studies (see, Cooley and Leroy 1985) which questions the eligibility of VAR results.
One weakness is that a VAR model has to be estimated to low order system, which causes all the effects of omitted variables to be reflected in the residuals. This can lead to major distortions in the impulse response functions, making them of little use for structural interpretations. To make things worse, all measurement errors or misspecification of the VAR model will also cause unexplained information left in the disturbance terms, which makes impulse response even more difficult to interpret. Because of this, special concern should therefore be given to check against dynamic misspecifications in VAR models.

Another criticism of VAR models is *Ad Hoc specification,* that is, VAR models do not shed any light on the underlying structure of the economy. This is not important when the objective of the VAR is forecasting, but it is a serious flaw when the objective of the VAR model is to find causal relations among macroeconomic variables, which is the case in this thesis.

One last criticism against VAR models worth mentioning is the fact that they are *A-theoretical.* In other words, they have little basis from economic theory. Thus, it can be troublesome to verify the results from VAR models.
A remedy for this is to impose restrictions. This is known as a structural VAR.

However, the atheoretical nature of VARs can also be viewed as a strength. Christopher Sims (1980) advocated VAR models due to it's a-theoretical nature, as a means to estimate economic relationships without the identification restrictions in structural models.

5.3 Vector Error-Correction Model

As mentioned earlier, we found that all our variables are non-stationary and that we have cointegration between some of the variables, that is, some of our series move together in the long run. Thus, in addition to the VAR model in levels discussed earlier, we run a Vector Error-Correction model.
This is basically a VAR, but in a VEC, the non-stationary variables are differenced automatically, and a lagged error-correction term(s) is added, which measures the previous period's deviation from long-run equilibrium.

The problem with a VAR with cointegrated variables is that it would only express the short-run responses of the variables to innovations in each variable.
A VEC model however, allows us to interpret both long-run and short-run relationships between the variables.
Below we present notation and some of the steps of how we get from a VAR model to a VEC model, based on the online STATA manual on Vector-Error Correction models.
Given the following m-variable VAR with p lags described earlier:

$$y_t = v + A_1 y_{t-1} + \cdots + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \varepsilon_t$$

we can rewrite it as a VECM:

$$\Delta y_t = v + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t ,$$

where $\Pi = \sum_{j=1}^{j=p} A_j - I_k$ and $\Gamma_i = -\sum_{j=i+1}^{j=p} A_j$

If the rank of Π is larger than 0, we have cointegration, and it can be expressed as $\Pi = \alpha\beta'$, where α and β are *(m x r)* matrices of rank r.

This can be further rewritten into:

$$\Delta y_t = \alpha(\beta' y_{t-1} + \mu + \rho t) + \sum_{i=1}^{p-1} \Gamma \Delta y_{t-i} + \gamma + \tau t + \varepsilon_t \ ,$$

Where γ and τ are *m x 1* vectors of parameters, and μ and ρ are *r x 1* vectors of parameters.

5.3.1 Specifying the VEC Model

There are two prominent procedures in checking for cointegration.

The first method is the Engle and Granger 2-step approach. This approach starts off with Dickey-Fuller tests to check whether our data are non-stationary. As mentioned earlier, we have found that all our variables are non-stationary on all significance levels according to the Dickey-Fuller test.

If two variables are to be cointegrated, then a linear combination of them have to be stationary:

$y_t - \beta x_t = u_t$, where u_t is stationary.

Since we do not know, we must estimate this, usually by using ordinary least squares, and then test for stationarity on the estimated u_t series, denoted $\hat{u}_t$.

Then a second regression is run on the first differenced variables from the first regression, and the lagged residuals $\hat{u}_{t-1}$ is included as a regressor.

However, this method suffers from a few weaknesses. The two most prominent weaknesses in our case is that: (1) it is restricted to only a single equation with one variable designated as the dependent variable, explained by another variable that is assumed to be weakly exogenous for the parameters of interest (Enders, 2004), and (2) at most one cointegration relationship can be examined.

Since we have a model with five non-stationary variables, it is not unlikely that we have more than one cointegration relationship.

Thus, a better method to decide the number of cointegration relationships is the Johansen method.

The Johansen method address the weaknesses of the Engle-Granger two step procedure, in that numerous cointegrating relationships is possible, variables are treated as endogenous, and tests relating to the long-run parameters are possible.

After running the Johansen-test to decide on the correct number of cointegration relationships, the cointegrating relationships are added to the underlying VAR as error correction parameters. This is known as the Vector-Error Correction model (VEC).
In our case, the Johansen-test found three cointegration relationships (see *Appendix E, Figure 5.1)*, which are all statistically significant
Thus, we run a VEC model with seven lags and three cointegrating relationships.

After running the model with these specifications, we took a closer look at the cointegration equations from our model, and put some restrictions in place on the variables which either had coefficients ~ 0 or were not statistically significant. With the restrictions in place, we did the same tests as with the VAR model discussed earlier, namely the Lagrange multiplier test for serial autocorrelation in the residuals, as well as Jarque-Bera test for normality in residuals.
We find no evidence of autocorrelation in the residuals, but we once again find that the residuals are not normally distributed.
Lastly, we check the stability conditions of our VEC model through the eigenvalue stability conditions, and find that our model appear to be stable.

6.0 Analysis and results

In this section we will analyse and discuss the results from our different models. The event study results are pretty forward, as we just look at the immediate reaction in the S&P500 index and different maturity yields on announcements and information regarding QE. Since we can not quantify the size of these announcements, the results from the event study itself is not to be taken as real results, but rather an indication on what we should expect the results from the VAR model in levels and the VEC model.
When it comes to the VAR and VEC model we will mainly be comparing and focusing on the impulse response functions, but we will also look at the forecast error variance decompositions from both models. The FEVD graphs can be seen in *Appendix C* (Figure 3.1-3.10).

A forecast error variance decomposition (FEVD) gives an indication on the amount of information each variable in the autoregression contributes to the other variables. That is, it determines the amount of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables (Lütkepohl, 2007).

Impulse response functions (IRFs) show us the reaction of any dynamic system in response to some external change (Lütkepohl, 2008). In the context of QE, impulse response functions can show us how our different endogenous variables reacts to a shock in the Fed's balance sheet (QE). From the IRFs we can see how the variables respond at the time of the shock, as well as over time.

For the purpose of our analysis, we choose a timeframe of 24 months from the shock for both our FEVDs and IRFs to see the long run effects of QE on the other variables.

In addition to IRFs and FEVDs we will also investigate whether the variables Granger-Cause each other. The concept of Granger-causality was introduced by Clive Granger (1969), and is used to explain the direction of possible causality between pairs of variables. It can be defined as when past values of *x* aid in the prediction of *yt,* conditional on having already accounted for the effects of *yt* of past values of *y.* This concept can be tied together with impulse response functions, in that an innovation in for example Securities has no effect on the other variables in our model if Securities does not Granger-cause the set of the other variables. If there is no Granger-causality, the impulse responses are zero.

6.1 Event study

The results from the event study are in line with what could be expected. The important QE announcements significantly impacted medium and long-term yields.

Asset	QE announcement	FOMC Minutes	Chairman speech
S&P500	-0.0484%	-0.01133%	0.0318%
1 Year yield	0.0271%	0.0407%	-0.0098%
5 Year yield	**-0.4299%*** **	**-0.2253%** **	0.0272%
10 Year yield	**-0.3534%** **	-0.1815%	0.1483%
30 Year yield	**-0.4019%*** **	-0.1510%	0.1111%

Table 1: Results from the event study. Results are marked with ***, **, and * correspond to significance on the 99%, 95%, and 90% level respectively.

We see from Table 1 that the chairman speeches have no significant effects on any of the assets, this is logical as the speeches rarely contain any new information. The same can be said for the FOMC minutes, we see that it only significantly impacts the five year treasury yield, but to a lesser extent than the announcements.

The effects of the QE announcements are strongly significant for 5, 10, and 30 year yields, with a downward shift of the yields of around 0.4% for all of them. These results are very much in line with what we would expect as the LSAP programs were designed specifically to lower the medium and long-term yields.

6.2 VAR

As mentioned earlier, it is best to focus on the IRFs, and to a lesser degree the FEVDs of the different variables when interpreting the results from a VAR. Below we show the graphed impulse response functions. In each graph Securities act as the impulse, such that we can see the responses on the different variables to a shock in QE.

6.2.1 The Orthogonalized Impulse Response Functions

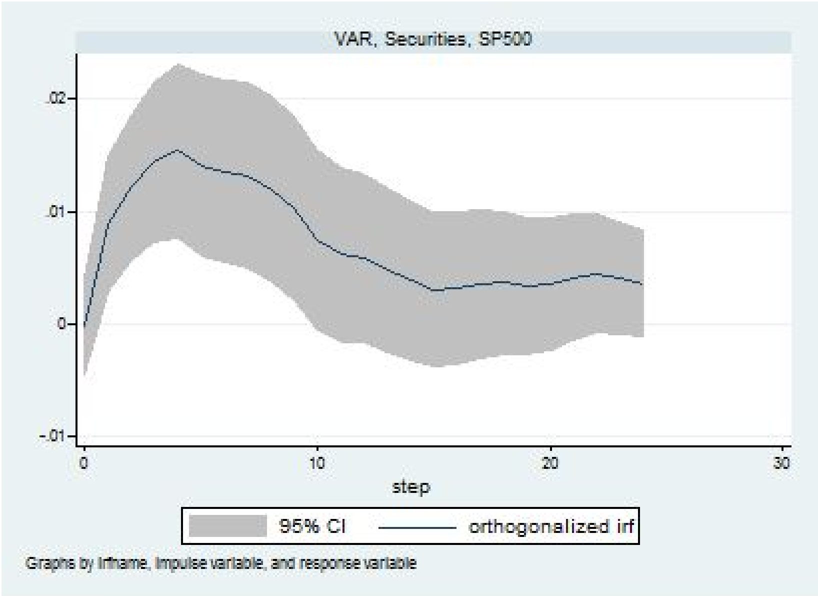

Figure 1.1: VAR Impulse response function. Securities held outright impulse, S&P500 response

Figure 1.1 Shows the IRF of the S&P500's reaction to an one-standard deviation shock to Securities. We see that there is a strong positive initial reaction up to about 1.50%, after the peak it moves slowly back towards normal. This result is as expected, as one of the goals of QE was to boost economic activity which in turn would result in increased stock prices.

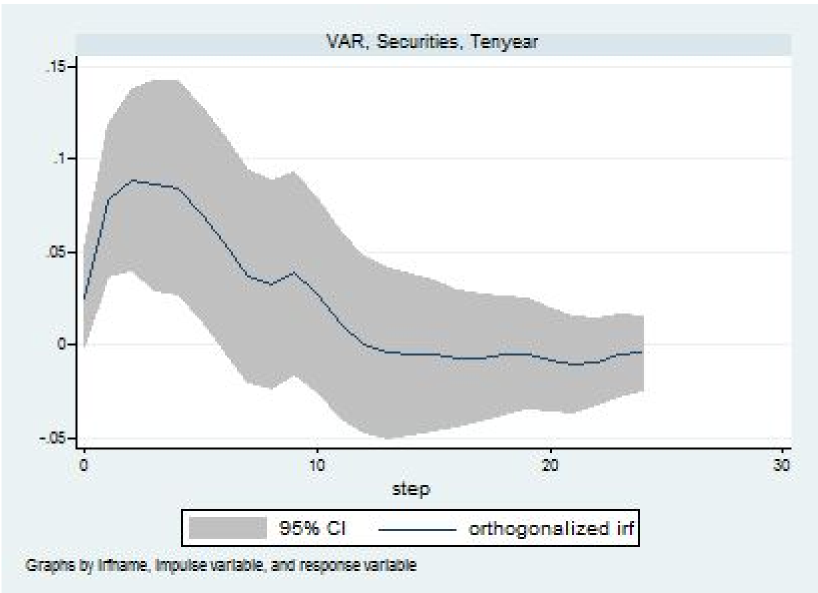

Figure 1.2: VAR Impulse response function. Securities held outright impulse, Ten Year Treasury Yield response

Figure 1.2 Shows the IRF of the Ten year treasury yield's reaction to an one-standard deviation shock to Securities. The IRF shows a strong positive initial reaction of about 0.10% before moving back towards zero. This result is surprising as the main goal of the QE programs were to lower the yield curve. We suspect that this result may be the result of some misspecification in the model, but we cannot say for certain.

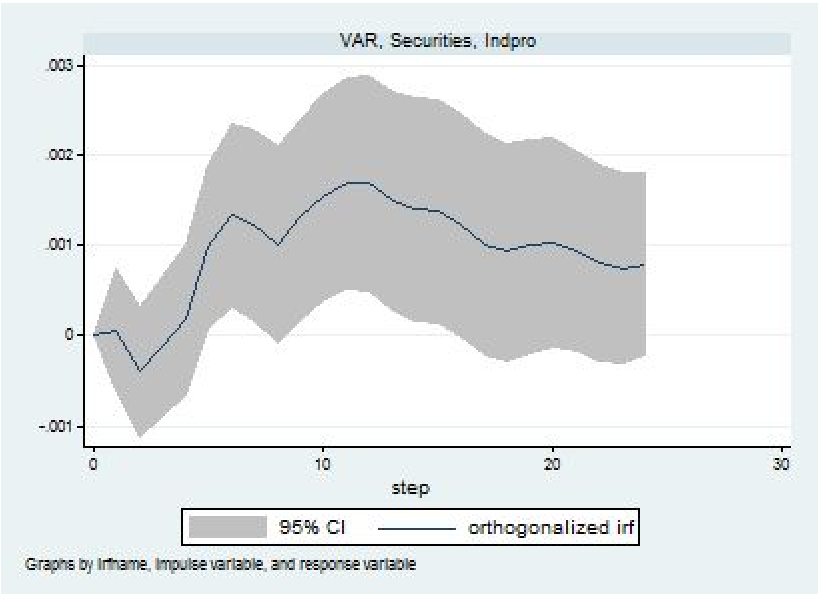

Figure 1.3: VAR Impulse response function. Securities held outright impulse, Industrial Production Index response

Figure 1.3 Shows the IRF of the Industrial Production index's reaction to an one-standard deviation shock to Securities. Industrial production is slower to react to an increase in the securities held outright, peaking at 0.15% after about 11 months. This result is as expected, industrial production is slower to react to news in the market

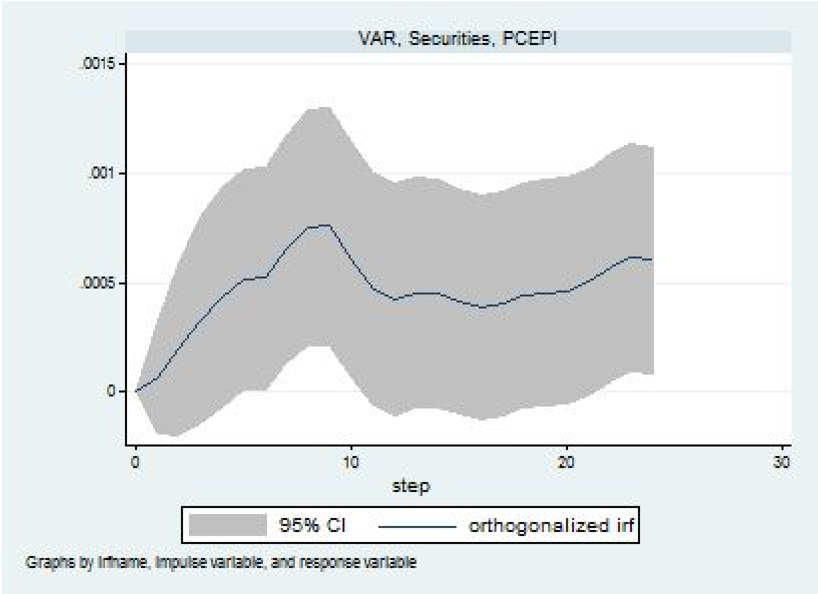

Figure 1.4: VAR Impulse response function. Securities held outright impulse, PCE Price Index response

Figure 1.4 shows the IRF of the PCE Price Index's reaction to an one-standard deviation shock to Securities. The IRF shows that similar to industrial production the PCE Price Index is slower to react than the previous variables. This result is also not surprising, as prices is traditionally a slow moving variable.

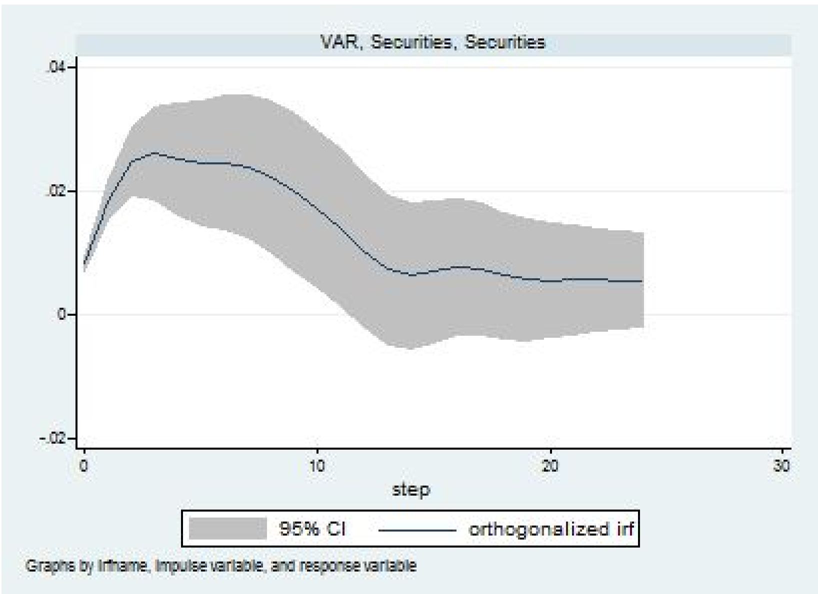

Figure 1.5: VAR Impulse response function. Securities held outright impulse, Securities held outright response.

Figure 1.5 shows the IRF of Securities' reaction to an one-standard deviation shock to itself. As is expected, the securities held outright reacts strongly and positively to its' own shocks, with a strong initial positive reaction of about 2.50% before moving back towards zero in the long-run.

6.2.2 Forecast error variance decomposition

The graphed FEVDs for the VAR can be seen in the *Appendix C* (Figure 3.1-3.5)

For industrial production we see that initially, a shock to Securities have no impact on the forecast error variance the first few months. After around 6 months, the forecast error variance explained by a shock to Securities rises and stabilizes at around 20-25% after around 15 months.

For PCEPI we see that a shock to Securities have an impact on the forecast error variance, starting after around 4 months. After around 10 months it evens out at around 20%. That is, after 10 months, 20% of the forecast error variance of PCEPI can be explained by a shock to Securities.

For Securities, not surprisingly, we can see that initially almost 100% of the forecast error variance is explained by itself. After the initial response, the forecast error variance decreases at a steady pace before it stabilizes around 70% after about 15 months.

For the S&P500 index the initial response for the first two months is zero, before it starts increasing and stabilizing at around 40% after 10 months. That is, after 10 months, 40% of the forecast error variance of the S&P500 index can be explained by a shock to Securities.

For ten year treasury yields we see that Securities have an immediate impact on the forecast error variance, which stabilizes at about 26-28% after around 7 months. Thus, a shock to securities explains about 26-28% of the forecast error variance of the ten year treasury yields.

6.3 VEC

The impulse response functions from a vector error-correction model does not always die out over time, as the IRFs from a stationary VAR. Models with non-stationary variables, like our VEC model, are not mean reverting, and unit moduli from the companion matrix imply that the effects of some shocks will not die out over time. Thus, in our IRFs we can see one of two types of shocks. The first type is transitory shocks, which dies out over time, and the second type is permanent shocks, which does not die out over time ("vec intro")

6.3.1 The Orthogonalized Impulse response functions

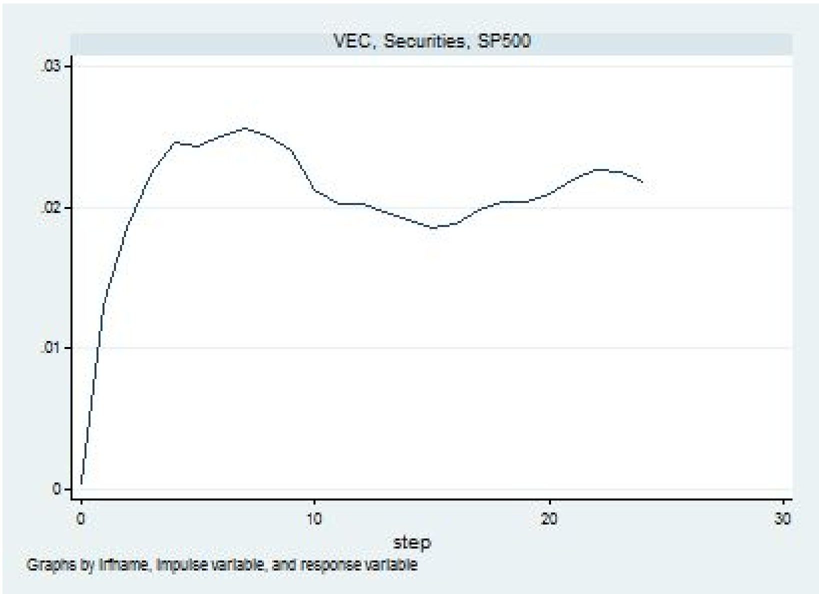

Figure 2.1: VEC Impulse response function. Securities held outright impulse, S&P500 response.

Figure 2.1 shows the IRF of S&P500's reaction to an one-standard deviation shock to Securities. It shows a strong initial positive reaction of around 2.50% before leveling off around 2.00%. This result is in line with what other studies have found. That is, QE have a positive effect on stock prices.

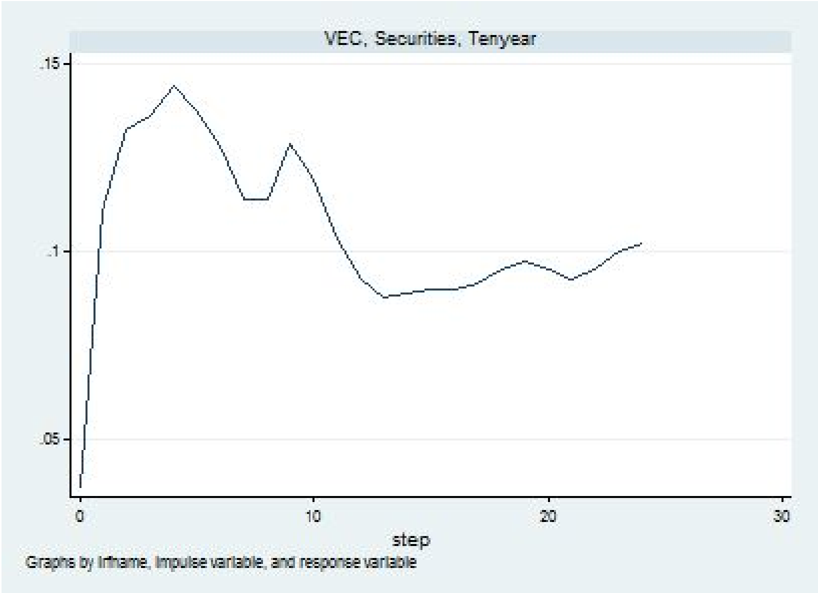

Figure 2.2: VEC Impulse response function. Securities held outright impulse, Ten Year Treasury Yield response.

Figure 2.2 shows the IRF of the Ten year treasury yield's reaction to an one-standard deviation shock to Securities. It shows a strong initial positive reaction of around 0.14% before leveling off around 0.10%. This result is similar to the result from the VAR and is as surprising.

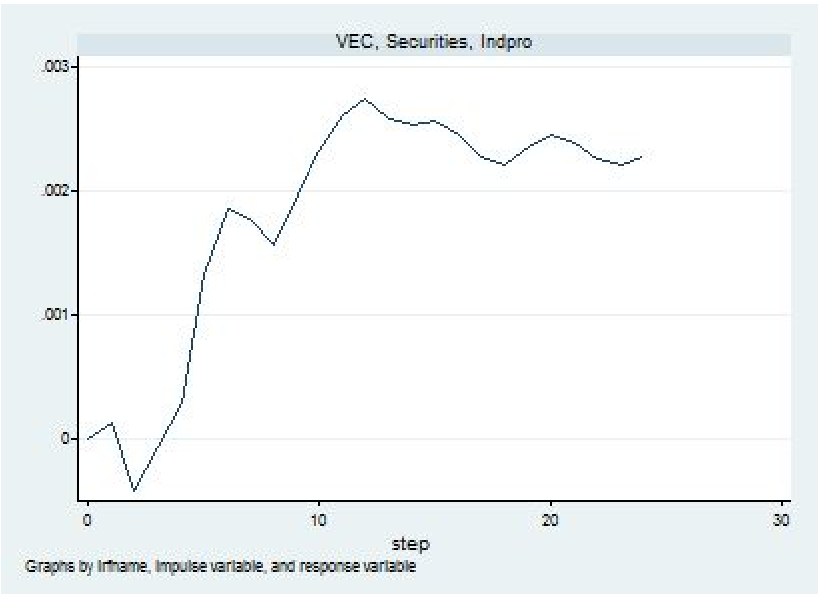

Figure 2.3: VEC Impulse response function. Securities held outright impulse, Industrial Production Index response.

Figure 2.3 shows the IRF of the Industrial production index's reaction to an one-standard deviation shock to Securities
It shows a delayed positive reaction after about 3-4 months, which peaks at around 0.27% and then levels off around 0.23% after 24 months.

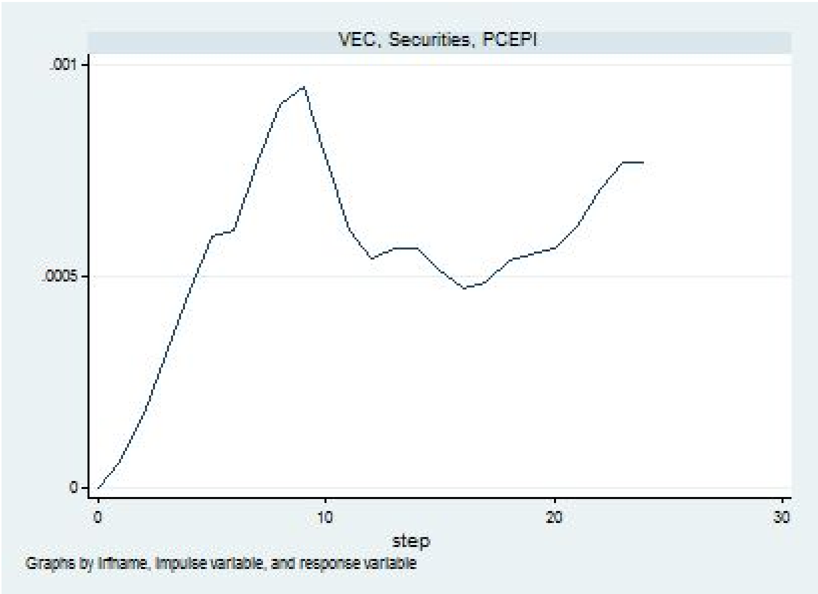

Figure 2.4: VEC Impulse response function. Securities held outright impulse, PCE Price Index response.

Figure 2.4 shows the IRF of Private consumer expenditures price index's reaction to an one-standard deviation shock to Securities
It shows a slower positive reaction which peaks at around 0.09% after 10 months and then levels off between 0.05% and 0.075% after 18-24 months.

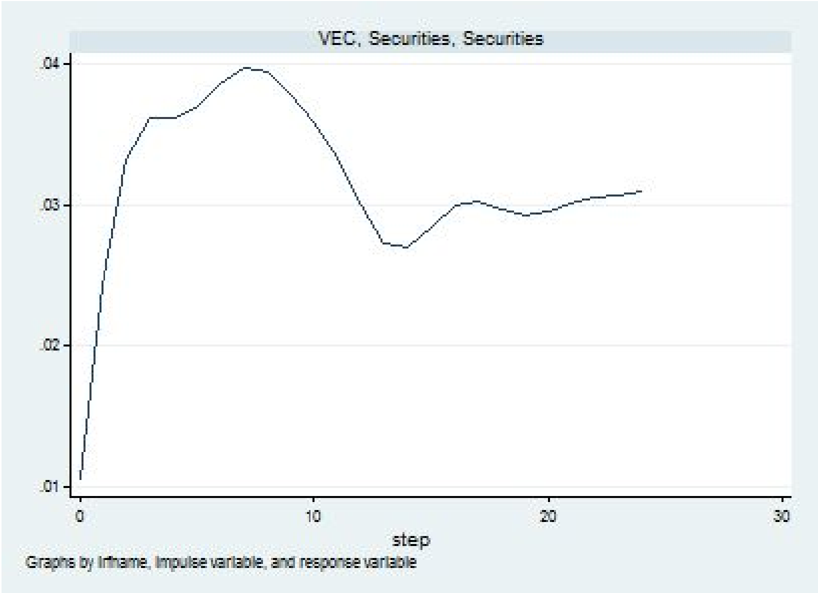

Figure 2.5: VEC Impulse response function. Securities held outright impulse, Securities held outright response.

Figure 2.5 shows the IRF of Securities's reaction to an one-standard deviation shock to itself. It shows that Securities reacts strongly to its own shocks, with a peak at about 4.00% before leveling off at around 3.00%.

6.3.2 Forecast error variance decomposition

The graphed FEVDs for the VEC model can be found in the *Appendix C* (Figure 3.6-3.9)

For Industrial production we see that a shock to Securities has no initial effect on the forecast error variance. However, after around 5 months, the amount of forecast error variance due to Securities increases rapidly up to around 25% after around 15 months, and stabilizes at around 23%.

For PCEPI we see that a shock to Securities has little immediate effect on forecast error variance, but that it starts increasing after about 3 months. It keeps increasing until around 12 months, where a shock to securities amounts to about 9% of the forecast error variance for PCEPI. After this, it falls down steadily to around 5% after 24 months. This differs greatly from the forecast error variance of PCEPI in the VAR model.

The forecast error variance for Securities is identical to what we found from the VAR model. The initial response to a shock in Securities amounts to about 95% of the forecast error variance of Securities. After this, it decreases and stabilizes at around 60% after 20 months.

For the S&P500 index the initial response in forecast error variance is zero the two first months, before it starts to increase rapidly and stabilize around 55% after 13 months. That is, after 13 months, a shock to Securities amounts to about 55% of the forecast error variance of the S&P500 index.

For Ten year treasury yields, the forecast error variance due to a shock in Securities starts increasing immediately, and stabilizes around 35-37% after about 11 months. Thus, a shock to securities amounts to about 35% of the forecast error variance of ten year treasury yields.

Thus, as we can see from both the FEVDs from the VAR and VEC model, an one-standard deviation shock to Securities have an impact on all the variables. That is, a shock to Securities contributes to the forecast error variance of all the other variables, some more than others.

6.4 Causality

In figure 6.1 in *Appendix F*, we can see the results from the Granger-causality test. The null hypothesis in this test is that variable x does not Granger-cause y.
In our setting, for the first row in the table, the null hypothesis is that PCEPI does not Granger-cause Industrial production.
As we can see from the table, there is definitely Granger-causality between our variables. In total, the test only finds the following four cases where a variable does not Granger-cause another:
(1) & (2) PCEPI does not Granger-cause Ten year treasury yields, and vice versa, (3) Industrial production does not Granger-Cause Ten year treasury yields, and (4) the S&P500 index does not Granger-cause Ten year treasury yields.

Aside from the four cases described above, we see that Granger-causality is present. Most importantly, we see that for all five variables in our model, the variables jointly Granger-cause each other. That is, even though PCEPI, S&P500 and Indpro does not Granger-cause Ten year treasury yields, they jointly(including Securities) Granger-cause Ten year treasury yields.
To conclude, we can reject the null hypothesis of no Granger-causality for all variables in our model. The fact that Securities Granger-cause all the other variables is already apparent, as we can see from the impulse response functions (they are not zero).

6.5 VAR versus VEC discussion

Basic VAR models are useful to describe relationships when applied to covariance-stationary time series. They do however encounter difficulties when applied to non-stationary variables, which all the variables used in our model are. The reason we still conducted and included the basic VAR model, was to have a benchmark to which we could compare the results from the VEC model.
For this purpose, we ran the VAR model with non-stationarity in all variables, without differencing. Thereafter, we ran the VEC model with the same underlying specification and ordering of the variables. In the VEC model the variables are differenced automatically, and error-correction term(s) are added to the equation, depending on the number of cointegrating relationships.
As mentioned earlier, when checking for cointegration with the Johansen-test before running the VEC model, we found three cointegration relationships. According to the VEC model output, after adding constraints on nonsignificant cointegration relationships, the three cointegration equations are as follows: (1) Industrial production normalized to 1, cointegrating with Ten year yields and S&P500 index, (2) PCEPI normalized to 1, cointegrating with Ten year yields and S&P500 index, (3) Securities normalized to 1, cointegrating with S&P500 index. The output of these cointegration equations can be seen in Figure 5.8 in *Appendix E*.
The error-correction coefficients resulting from the cointegration equations (See *Appendix E* Figure 5.3-5.7) is the main difference between the VAR and VEC

models, and thus, is likely the prominent factor that causes the difference in the results.

Although the cointegration relationships make economic sense, not all of the error-correction coefficients make sense, as can be seen from the VEC output for Ten year treasury yields and S&P500 in *Appendix E* (Figure 5.6-5.7).

The second cointegration equation on the Ten year output has a error-correction coefficient of -4.9646, and the first and second cointegration equations on the S&P500 output has an error-correction coefficient of 1.8246 and -2.8001 respectively. These coefficients do not make sense, as an error-correction coefficient should lie between -1 and 0. A coefficient of -1 would mean that the variable will be fully corrected back to equilibrium after one period. Thus, having a coefficient of -4.9646 would mean that the variable is corrected towards equilibrium at a rate of 496% each period.

These odd error-correction coefficient could indicate that our model is somehow mis-specified.

When comparing the IRFs from the VAR and VEC model, we see that they are quite similar, especially the initial responses. The most noteworthy differences is that the IRFs from the VEC model tends to have a marginally stronger reaction to an one-standard deviation shock to Securities, as well as that the effects tends to be permanent, rather than transitory, which is the case for the VAR IRFs.

The differences are likely due to the added error-correction terms in the VEC, as well as the fact that the VEC is differenced to induce stationarity.

7.0 Conclusion

In this thesis we have aimed to measure the effects of the large scale asset purchase programs conducted by the Federal Reserve Bank. In doing so we have run three different models, first a simple event study, and second and third, a Vector Autoregression model and a Vector Error-Correction model.

The aim of the event study was to measure the immediate effects of the QE, building on the fundamental belief that any effect should be reflected in the prices immediately after the news hit the market. The goals of the VAR and VEC models were to measure the effects of the programs as they were conducted.

When it comes to the effect of QE on the S&P500 index, we found non-significant results in the event study. While in the VAR and VEC models we find evidence supporting the general conception of QE leading to an increase in the S&P500 index.

The effect of QE on treasury yields from the event study are as intended, with the effect being negative and the result being stronger on the medium and longer term yields. Our results from the VAR and VEC models on ten year treasury yields are a bit more obscure. In contrast to most other studies, as well as theory, we find evidence from both the VAR and VEC model supporting that QE lead to a small increase in ten year treasury yields.

7.1 The validity of the results

Although a large portion of our results give economic meaning, we find some results that are a little concerning. As previously mentioned we find from the VAR and the VEC models that QE has a positive impact on long term yields. We know that the main goal of the QE programs were to lower the yield curve by buying large quantities of longer term securities thereby making them less desirable investment objects and lowering the rate of return.

There can be several reasons for this concerning result. As we have previously mentioned the basic VAR and VEC models are not optimal for describing structural relationships. Therefore we might get more correct results if we introduce structural restrictions on the variables, as is done in several other similar studies, like for example Bhattarai and Chatterjee (2015).

Another reason might be as simple as a misspecification of the model. We can not be blind to the fact that we might have done something wrong in our methodology.

In the event study we find a significant negative relationship between QE and long term yields. This suggests that much of the reaction might be from the QE announcements and not so much from the actual asset purchases.

On the other hand we have the S&P 500 where we have the opposite problem. The event study whos no significant relationship, while the VAR and VEC models show a significant positive relationship as we would expect. One reason we see for this is that stock prices are not directly affected by QE and therefore might react slower, hence the effect not being picked up in the days after, but rather in the monthly data.

Overall, there seems to be some limitations in this thesis. This is fairly apparent due to the fact that our results, specifically the results regarding the ten year treasury yield, contradict the aims of the Large Scale Asset Purchase Programs, as well as fundamental economic theory. Our suggestion for further studies is to employ a structural model, for example a structural VAR or a structural VEC.

8.0 Appendix

8.1 Appendix A - *Event study*

Important announcements		
date	minutes	type
25.11.2008		press release
01.12.2008		Bernanke statement
16.12.2008	06.01.2009	fomc statement
28.01.2009	18.02.2009	fomc statement
18.03.2009	08.04.2009	fomc statement
29.04.2009	20.05.2009	fomc statement
12.08.2009	02.09.2009	fomc statement
23.09.2009	14.10.2009	fomc statement
04.11.2009	24.11.2009	fomc statement
16.03.2010	06.04.2010	fomc statement
10.08.2010	31.08.2010	fomc statement
03.11.2010	23.11.2010	fomc statement
27.04.2011	18.05.2011	fomc statement
22.06.2011	12.07.2011	fomc statement
21.09.2011	12.10.2011	fomc statement
20.06.2012	11.07.2012	fomc statement
13.09.2012	04.10.2012	fomc statement
12.12.2012	03.01.2013	fomc statement
18.12.2013	08.01.2014	fomc statement
29.01.2014	19.02.2014	fomc statement
19.03.2014	09.04.2014	fomc statement
30.04.2014	21.05.2014	fomc statement
18.06.2014	09.07.2014	fomc statement
30.07.2014	20.08.2014	fomc statement
17.09.2014	08.10.2014	fomc statement
29.10.2014	19.11.2014	fomc statement

Figure 1.1: Important announcement dates and FOMC minutes for the event study

Bernanke speeches	
date	statement
04.12.2008	Bernanke speech
13.01.2009	Bernanke speech
10.02.2009	Bernanke speech
18.02.2009	Bernanke speech
24.02.2009	Bernanke speech
03.04.2009	Bernanke speech
21.07.2009	Bernanke speech
21.08.2009	Bernanke speech
08.10.2009	Bernanke speech
07.12.2009	Bernanke speech
24.02.2010	Bernanke speech
25.03.2010	Bernanke speech
07.04.2010	Bernanke speech
14.04.2010	Bernanke speech
21.07.2010	Bernanke speech
27.08.2010	Bernanke speech
15.10.2010	Bernanke speech
19.11.2010	Bernanke speech
07.01.2011	Bernanke speech
03.02.2011	Bernanke speech
09.02.2011	Bernanke speech
01.03.2011	Bernanke speech
27.04.2011	Bernanke speech
13.07.2011	Bernanke speech
04.10.2011	Bernanke speech
18.10.2011	Bernanke speech
29.02.2012	Bernanke speech
17.07.2012	Bernanke speech
31.08.2012	Bernanke speech
20.11.2012	Bernanke speech
26.02.2013	Bernanke speech
01.03.2013	Bernanke speech
22.05.2013	Bernanke speech
17.07.2013	Bernanke speech
03.01.2014	Bernanke speech

Figure 1.2: Dates of the chairman speeches

8.2 Appendix B - *VAR/VEC variable data plots*

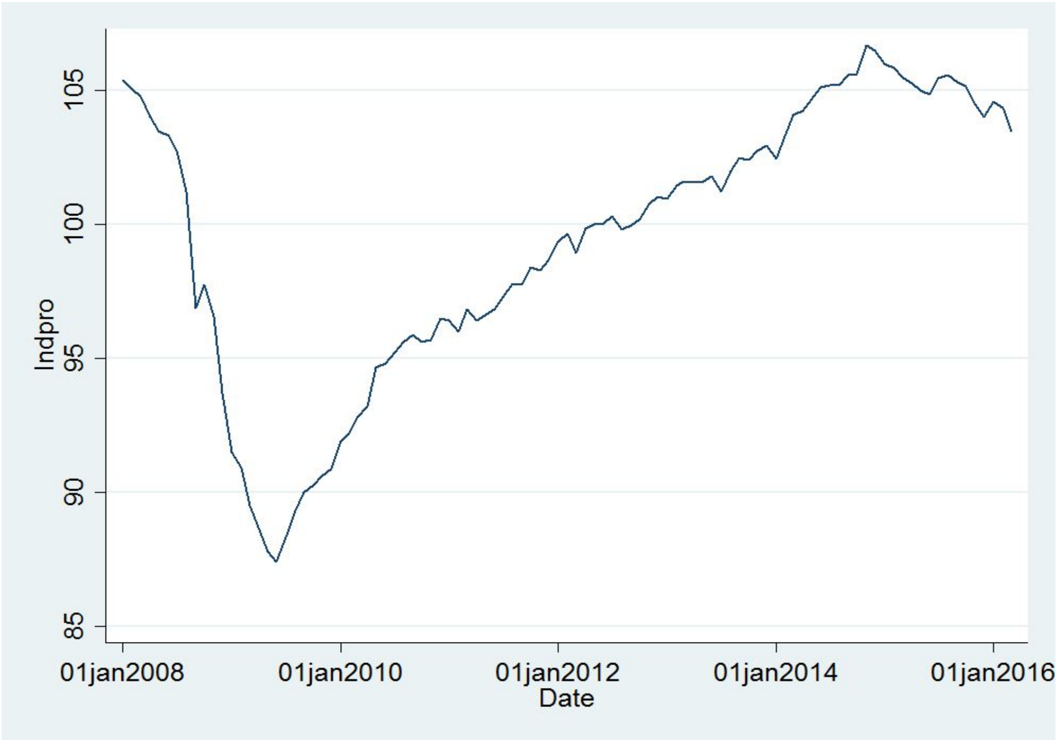

Figure 2.1: Industrial Production Index

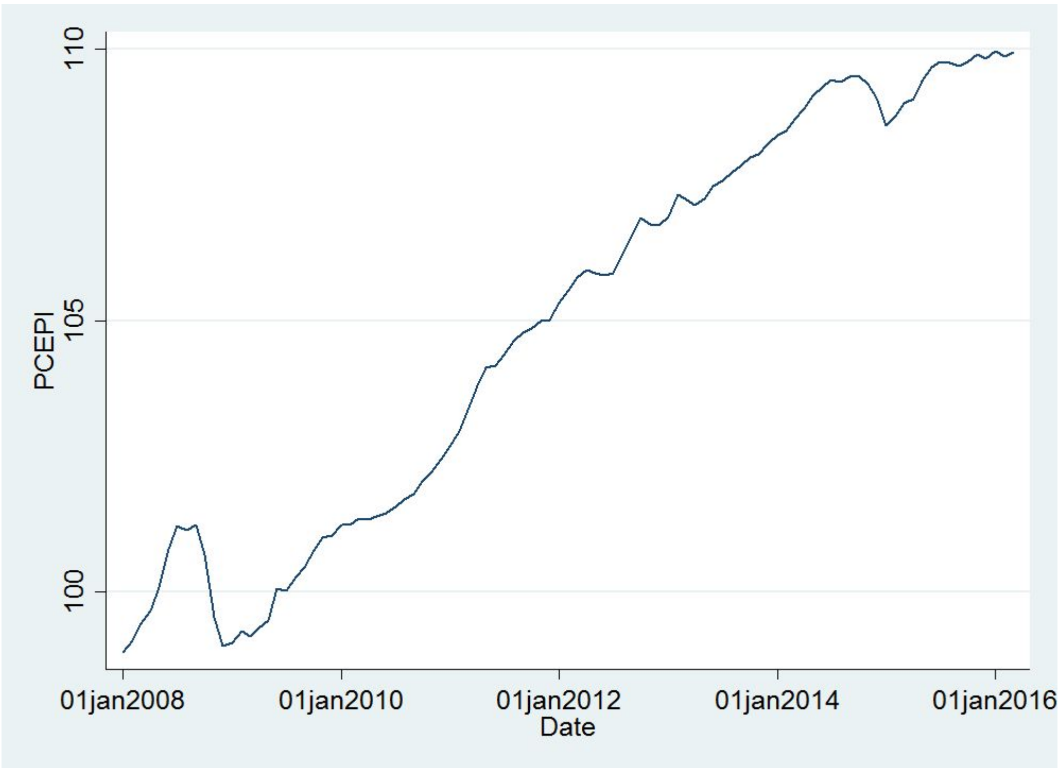

Figure 2.2: Private Consumption Expenditures Price Index

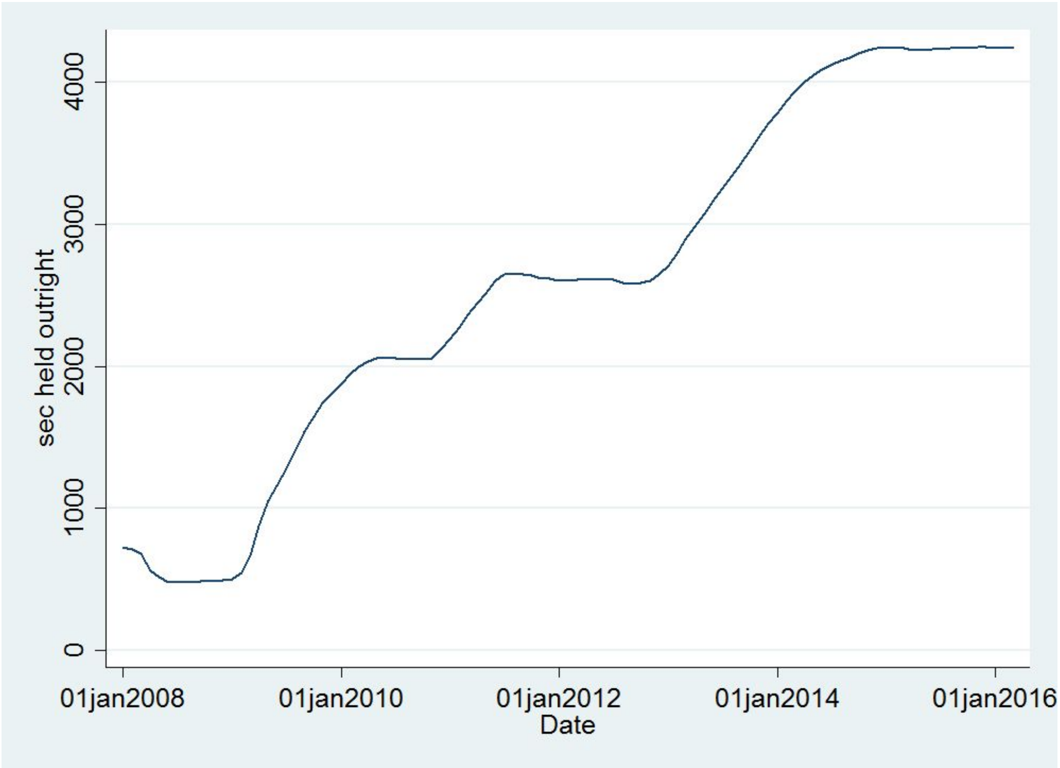

Figure 2.3: Securities held outright by the Federal Reserve (measure of QE)

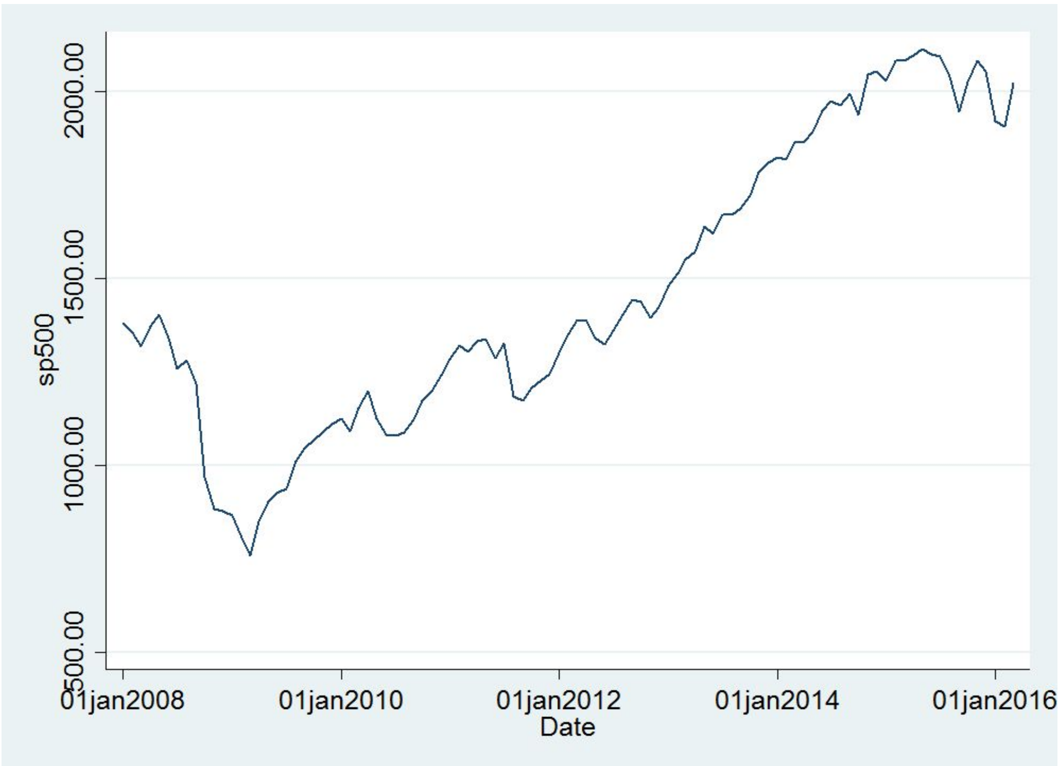

Figure 2.4: The S&P500 index

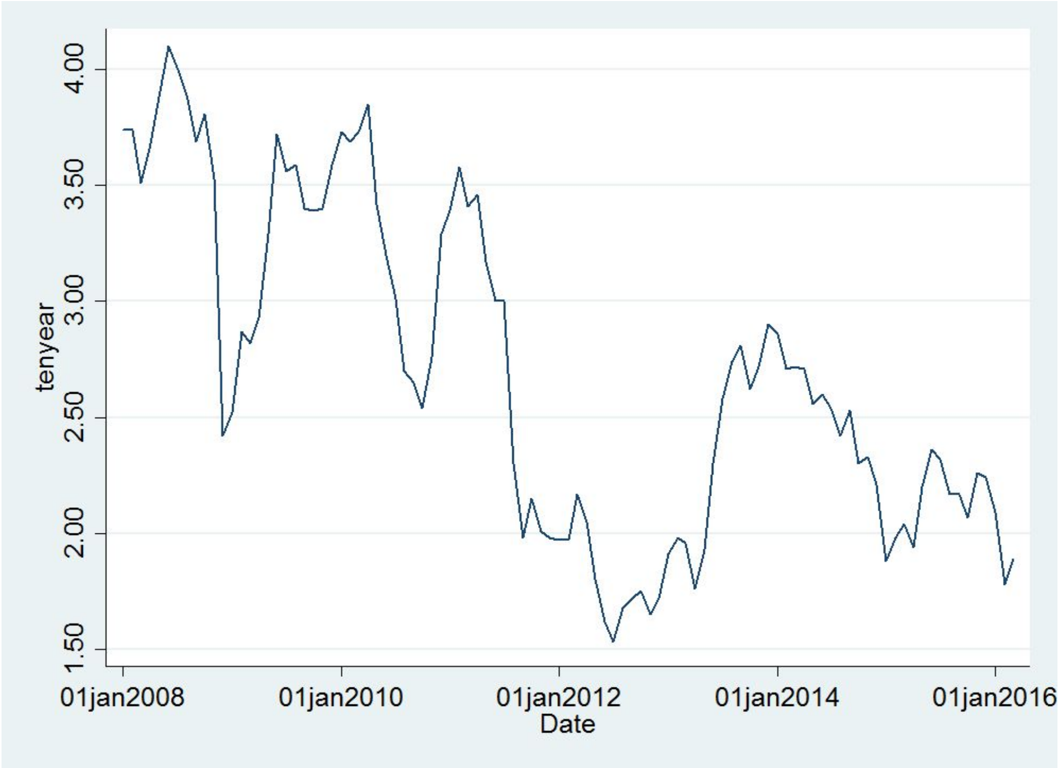

Figure 2.5: Ten year treasury yield

8.3 Appendix C - *Forecast error variance decompositions (FEVD)*

8.3.1 VAR:

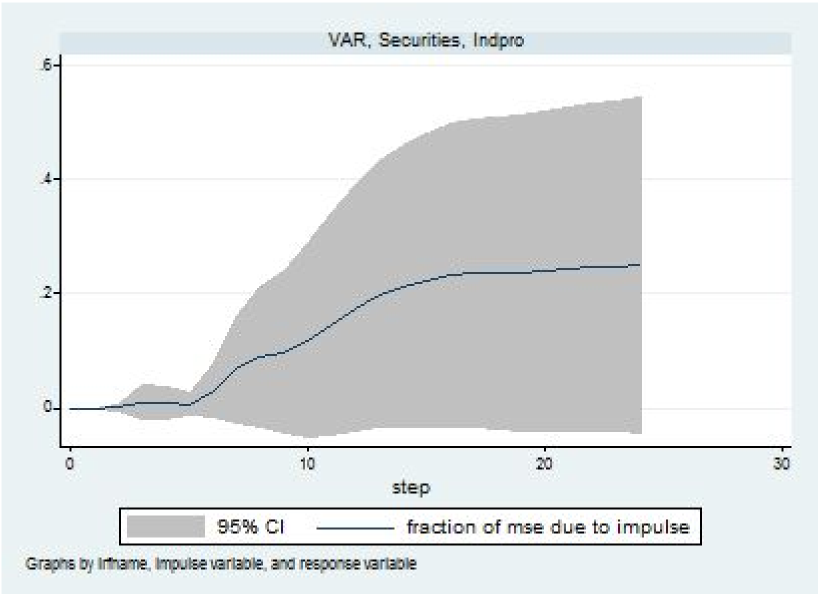

Figure 3.1: FEVD - Industrial production

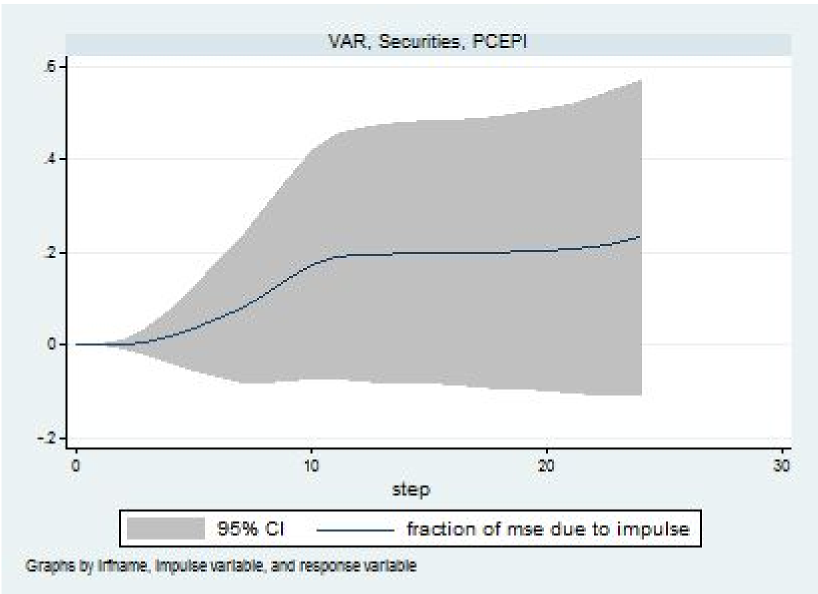

Figure 3.2: FEVD - Private consumer expenditure price index

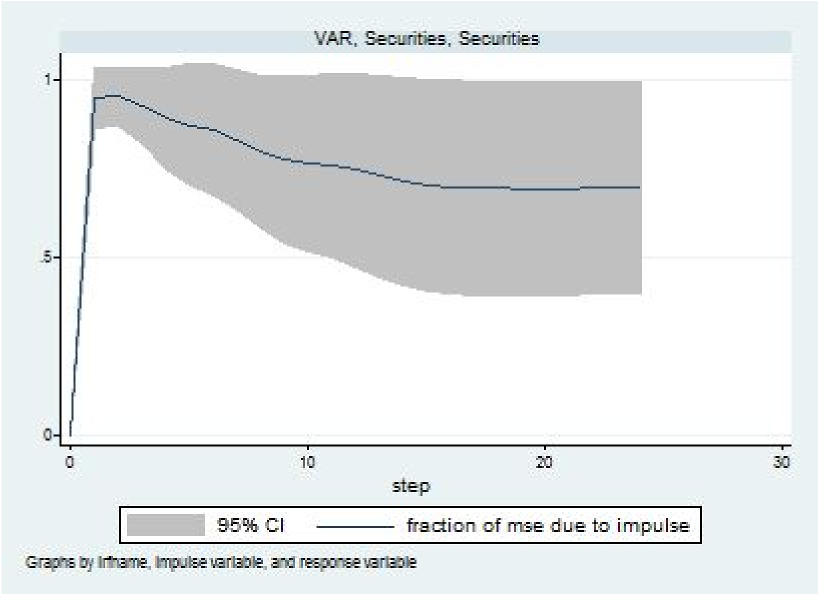

Figure 3.3: FEVD - Securities held outright by the Federal Reserve(QE)

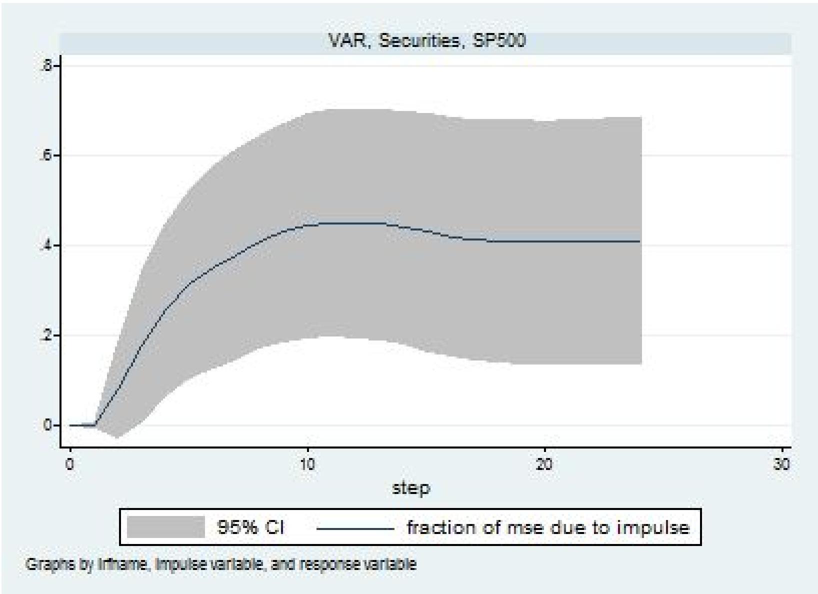

Figure 3.4: FEVD - S&P500 index

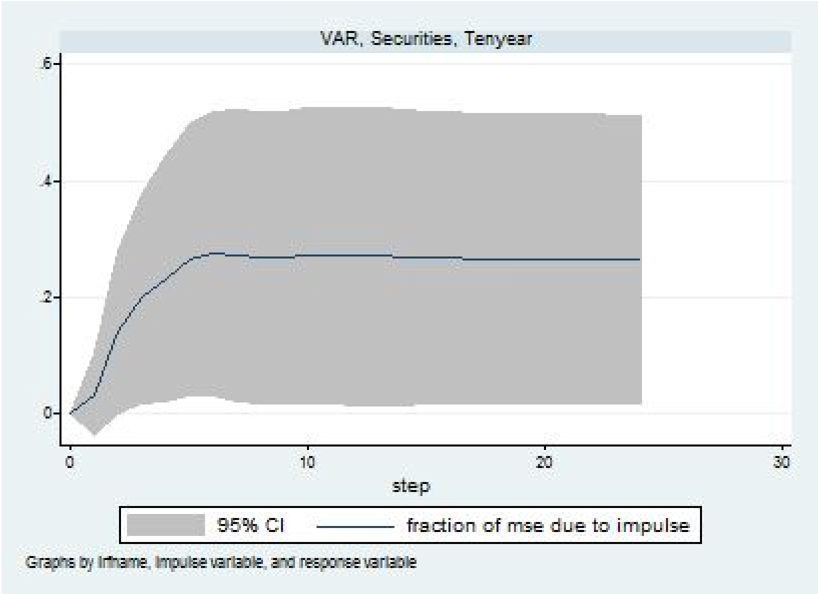

Figure 3.5: FEVD - Ten year treasury yields

VEC:

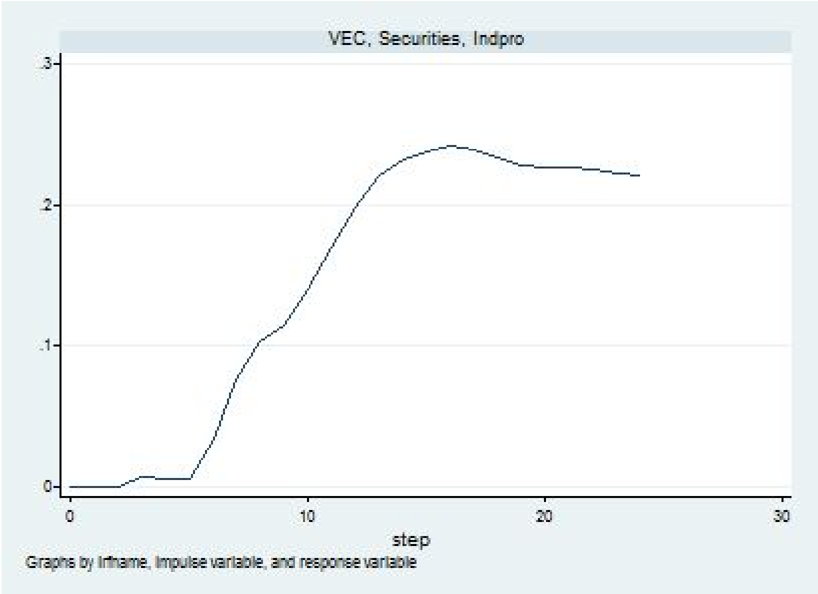

Figure 3.6: FEVD - Industrial Production

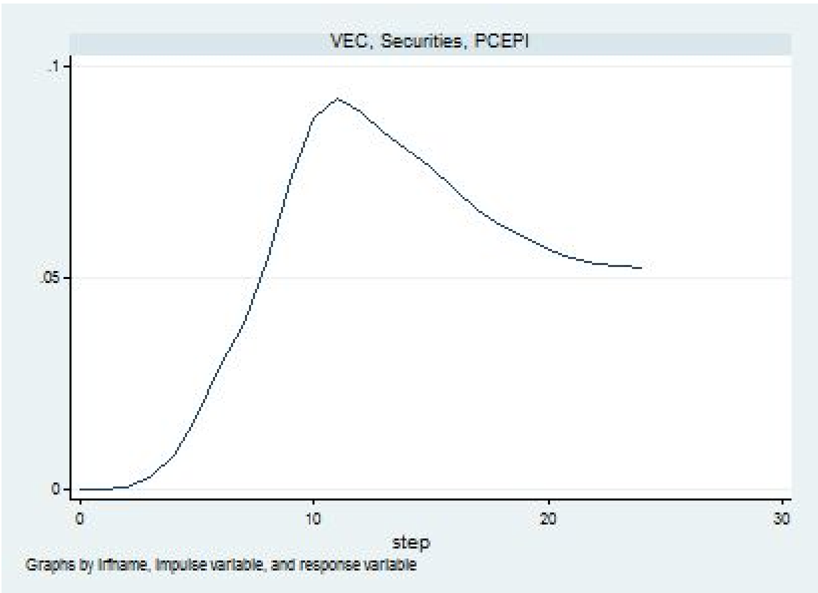

Figure 3.7: FEVD - Private consumer expenditures price index

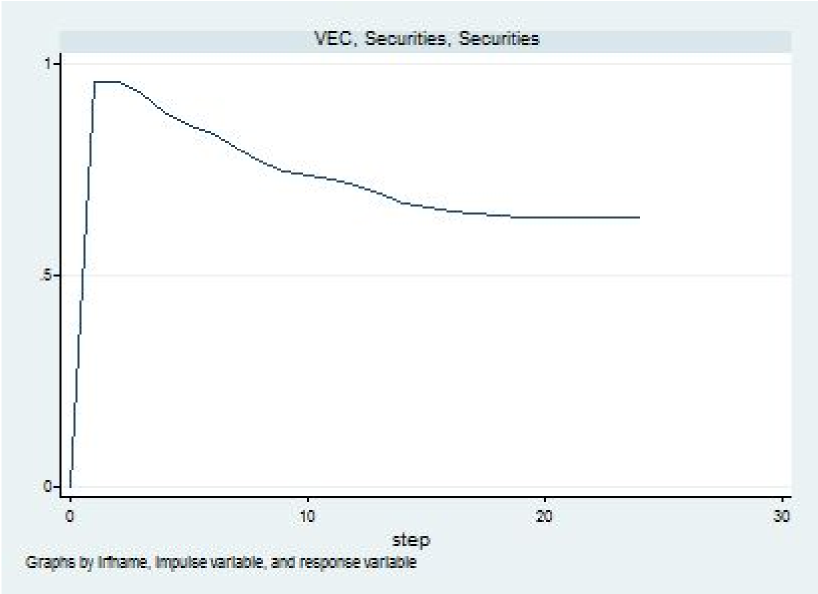

Figure 3.8: FEVD - Securities held outright by the federal reserve (QE)

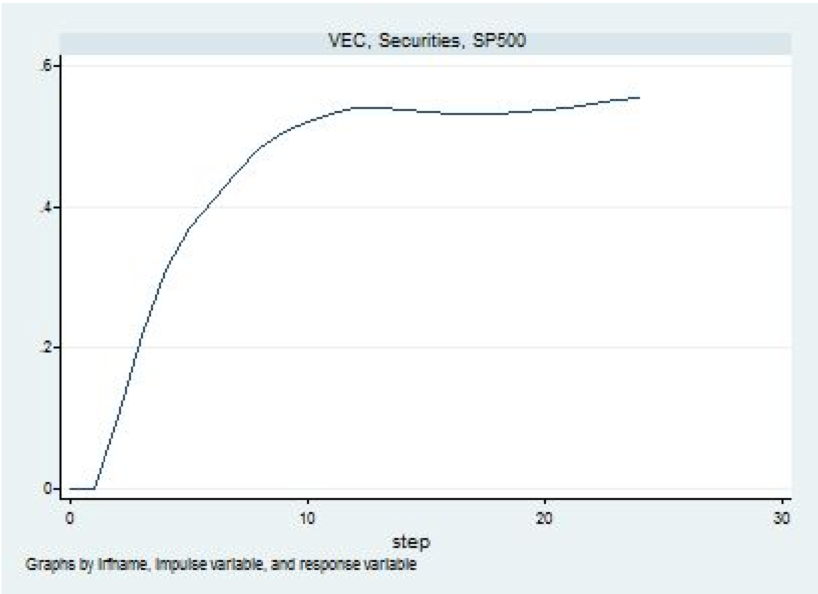

Figure 3.9: FEVD - S&P500 stock index

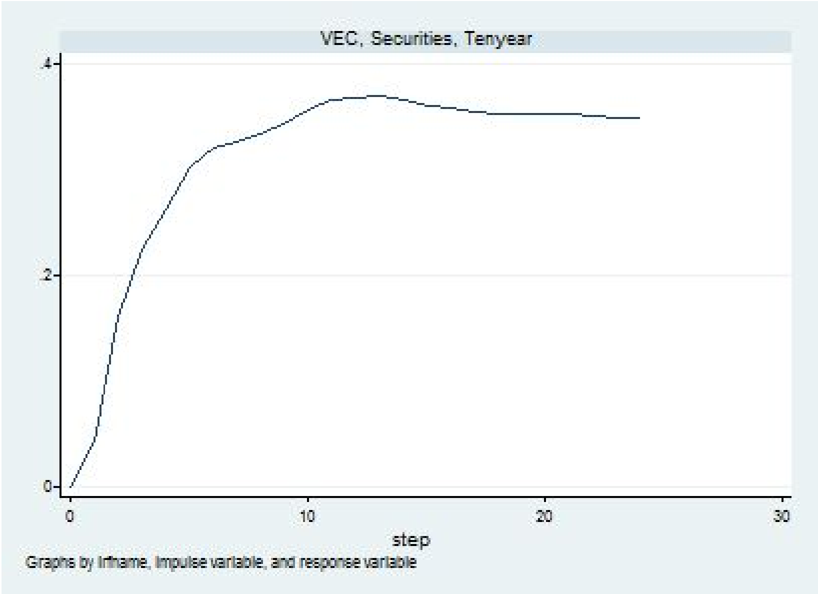

Figure 3.10: FEVD - Ten year treasury yields

8.4 Appendix D - *VAR specification and output*

Selection-order criteria
Sample: 2008m7 - 2016m3 Number of obs = 93

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	490.293				2.0e-11	-10.4364	-10.3814	-10.3002
1	1223.87	1467.1	25	0.000	4.9e-18	-25.6746	-25.3447	-24.8576
2	1304.95	162.17	25	0.000	1.5e-18	-26.8807	-26.2759	-25.3829*
3	1352.13	94.355	25	0.000	9.2e-19	-27.3576	-26.478	-25.1791
4	1401.59	98.911	25	0.000	5.6e-19	-27.8836	-26.729*	-25.0242
5	1431.62	60.075	25	0.000	5.2e-19	-27.9919	-26.5625	-24.4517
6	1465.36	67.478*	25	0.000	4.5e-19*	-28.1798*	-26.4755	-23.9588

Endogenous: Indpro PCEPI Securities Tenyear SP500
Exogenous: _cons

Figure 4.1: Lag selection

Vector autoregression

Sample: 2008m8 - 2016m3 Number of obs = 92
Log likelihood = 1487.496 AIC = -28.42384
FPE = 3.88e-19 HQIC = -26.43246
Det(Sigma_ml) = 6.22e-21 SBIC = -23.4899

Equation	Parms	RMSE	R-sq	chi2	P>chi2
Indpro	36	.004145	0.9964	25386.36	0.0000
PCEPI	36	.001601	0.9987	68703.72	0.0000
Securities	36	.010839	0.9998	451255.5	0.0000
Tenyear	36	.178628	0.9548	1941.161	0.0000
SP500	36	.028372	0.9936	14339.05	0.0000

Figure 4.2 VAR model header

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Indpro						
Indpro						
L1.	.610565	.0929537	6.57	0.000	.428379	.7927509
L2.	.1719548	.103921	1.65	0.098	-.0317266	.3756362
L3.	.3687332	.1121747	3.29	0.001	.1488748	.5885917
L4.	-.1356793	.1257868	-1.08	0.281	-.382217	.1108583
L5.	-.2315146	.1019725	-2.27	0.023	-.431377	-.0316522
L6.	.147059	.1024529	1.44	0.151	-.0537449	.3478629
L7.	-.0983049	.0814834	-1.21	0.228	-.2580095	.0613997
PCEPI						
L1.	.1708718	.2719574	0.63	0.530	-.3621549	.7038984
L2.	.3786838	.4197451	0.90	0.367	-.4440015	1.201369
L3.	-.0598345	.4140053	-0.14	0.885	-.8712699	.7516009
L4.	.1114148	.4384702	0.25	0.799	-.747971	.9708005
L5.	-.3341938	.4491884	-0.74	0.457	-1.214587	.5461992
L6.	-.2065402	.4498257	-0.46	0.646	-1.088182	.6751021
L7.	.3738738	.2877783	1.30	0.194	-.1901612	.9379089
Securities						
L1.	-.0190244	.0400581	-0.47	0.635	-.0975368	.059488
L2.	-.0311016	.0926207	-0.34	0.737	-.2126347	.1504315
L3.	.1084051	.1014316	1.07	0.285	-.0903971	.3072073
L4.	-.1231883	.0675283	-1.82	0.068	-.2555413	.0091648
L5.	.2191664	.0391011	5.61	0.000	.1425297	.2958032
L6.	-.2442739	.0382863	-6.38	0.000	-.3193136	-.1692342
L7.	.0946444	.0219389	4.31	0.000	.0516449	.1376438
Tenyear						
L1.	.0082796	.0027037	3.06	0.002	.0029803	.0135788
L2.	-.0062012	.0037382	-1.66	0.097	-.0135279	.0011256
L3.	.0041995	.0035853	1.17	0.241	-.0028276	.0112266
L4.	-.0042054	.0037134	-1.13	0.257	-.0114835	.0030727
L5.	.0009955	.0037927	0.26	0.793	-.006438	.008429
L6.	-.0001547	.0035433	-0.04	0.965	-.0070994	.0067901
L7.	.0021757	.002448	0.89	0.374	-.0026223	.0069737
SP500						
L1.	-.035803	.0171404	-2.09	0.037	-.0693976	-.0022083
L2.	.0317819	.0217234	1.46	0.143	-.0107952	.0743589
L3.	.0209175	.0213523	0.98	0.327	-.0209323	.0627672
L4.	-.0520211	.0210799	-2.47	0.014	-.0933369	-.0107054
L5.	.0164609	.0214523	0.77	0.443	-.0255848	.0585066
L6.	-.0018887	.0206766	-0.09	0.927	-.0424141	.0386368
L7.	-.0064241	.014674	-0.44	0.662	-.0351846	.0223365
_cons	-1.105989	.4178539	-2.65	0.008	-1.924967	-.28701

Fig 4.3: VAR output - Industrial Production

PCEPI						
Indpro						
L1.	-.0878631	.0359028	-2.45	0.014	-.1582313	-.0174949
L2.	.0855039	.0401389	2.13	0.033	.0068332	.1641746
L3.	-.0069513	.0433268	-0.16	0.873	-.0918703	.0779677
L4.	.040744	.0485844	0.84	0.402	-.0544797	.1359677
L5.	-.0507352	.0393863	-1.29	0.198	-.1279308	.0264605
L6.	.0365935	.0395718	0.92	0.355	-.0409658	.1141528
L7.	.02935	.0314725	0.93	0.351	-.0323349	.0910349
PCEPI						
L1.	1.152865	.1050419	10.98	0.000	.9469871	1.358744
L2.	-.1088549	.162124	-0.67	0.502	-.4266121	.2089023
L3.	-.2820988	.159907	-1.76	0.078	-.5955109	.0313132
L4.	.1604242	.1693565	0.95	0.344	-.1715083	.4923568
L5.	.0075127	.1734963	0.04	0.965	-.3325338	.3475593
L6.	-.0905109	.1737425	-0.52	0.602	-.4310399	.2500182
L7.	.0632048	.1111526	0.57	0.570	-.1546503	.28106
Securities						
L1.	.0112428	.0154722	0.73	0.467	-.0190821	.0415677
L2.	-.020867	.0357742	-0.58	0.560	-.0909831	.0492491
L3.	.0216406	.0391773	0.55	0.581	-.0551456	.0984267
L4.	-.0032263	.0260824	-0.12	0.902	-.0543469	.0478942
L5.	-.0163474	.0151026	-1.08	0.279	-.0459478	.0132531
L6.	.0374301	.0147878	2.53	0.011	.0084464	.0664137
L7.	-.0229959	.0084738	-2.71	0.007	-.0396041	-.0063876
Tenyear						
L1.	-.0008489	.0010443	-0.81	0.416	-.0028957	.0011979
L2.	.0012767	.0014439	0.88	0.377	-.0015532	.0041066
L3.	.0005046	.0013848	0.36	0.716	-.0022096	.0032187
L4.	-.0010396	.0014343	-0.72	0.469	-.0038507	.0017715
L5.	.0010955	.0014649	0.75	0.455	-.0017756	.0039667
L6.	-.0022292	.0013686	-1.63	0.103	-.0049116	.0004532
L7.	.0009844	.0009455	1.04	0.298	-.0008688	.0028375
SP500						
L1.	.0128124	.0066204	1.94	0.053	-.0001633	.0257881
L2.	-.0218387	.0083905	-2.60	0.009	-.0382838	-.0053936
L3.	.0004072	.0082472	0.05	0.961	-.015757	.0165714
L4.	.0126471	.008142	1.55	0.120	-.0033109	.028605
L5.	-.0168891	.0082858	-2.04	0.042	-.0331291	-.0006492
L6.	.0094874	.0079862	1.19	0.235	-.0061653	.0251401
L7.	-.0053588	.0056678	-0.95	0.344	-.0164674	.0057498
_cons	.2505528	.1613936	1.55	0.121	-.0657728	.5668784

Figure 4.4: VAR output - PCEPI

Securities						
Indpro						
L1.	-.9249169	.2430726	-3.81	0.000	-1.40133	-.4485033
L2.	.9459095	.2717519	3.48	0.000	.4132856	1.478533
L3.	-.6372773	.2933353	-2.17	0.030	-1.212204	-.0623507
L4.	.2909381	.3289307	0.88	0.376	-.3537543	.9356305
L5.	-.1530873	.2666566	-0.57	0.566	-.6757246	.3695499
L6.	-.106864	.2679128	-0.40	0.690	-.6319634	.4182354
L7.	.3612231	.213078	1.70	0.090	-.056402	.7788483
PCEPI						
L1.	1.057006	.7111646	1.49	0.137	-.3368509	2.450863
L2.	-1.706469	1.097627	-1.55	0.120	-3.857779	.4448414
L3.	1.40491	1.082618	1.30	0.194	-.7169815	3.526802
L4.	-2.039339	1.146593	-1.78	0.075	-4.286621	.2079419
L5.	.3971562	1.174621	0.34	0.735	-1.905059	2.699371
L6.	1.874812	1.176288	1.59	0.111	-.4306693	4.180294
L7.	-.1370331	.752536	-0.18	0.856	-1.611977	1.33791
Securities						
L1.	2.217369	.1047513	21.17	0.000	2.01206	2.422677
L2.	-2.04505	.2422017	-8.44	0.000	-2.519757	-1.570344
L3.	.940708	.2652421	3.55	0.000	.4208431	1.460573
L4.	-.0131317	.1765855	-0.07	0.941	-.3592329	.3329696
L5.	-.2378116	.1022488	-2.33	0.020	-.4382155	-.0374078
L6.	.1973789	.100118	1.97	0.049	.0011512	.3936066
L7.	-.063925	.0573699	-1.11	0.265	-.1763679	.0485179
Tenyear						
L1.	.0075639	.0070702	1.07	0.285	-.0062934	.0214213
L2.	.0082123	.0097754	0.84	0.401	-.0109472	.0273717
L3.	-.022858	.0093756	-2.44	0.015	-.0412338	-.0044823
L4.	.0237123	.0097104	2.44	0.015	.0046802	.0427443
L5.	.0095655	.0099178	0.96	0.335	-.0098731	.0290041
L6.	-.0151168	.0092657	-1.63	0.103	-.0332773	.0030438
L7.	-.0002662	.0064015	-0.04	0.967	-.0128129	.0122804
SP500						
L1.	-.0213088	.044822	-0.48	0.634	-.1091583	.0665407
L2.	.0376283	.0568063	0.66	0.508	-.07371	.1489666
L3.	.0447643	.0558359	0.80	0.423	-.0646721	.1542007
L4.	-.1245354	.0551235	-2.26	0.024	-.2325756	-.0164953
L5.	-.0162411	.0560975	-0.29	0.772	-.1261901	.0937079
L6.	-.002695	.0540691	-0.05	0.960	-.1086684	.1032785
L7.	.0149463	.0383724	0.39	0.697	-.0602622	.0901548
_cons	-2.421885	1.092682	-2.22	0.027	-4.563502	-.2802671

Figure 4.5: VAR output - Securities held outright

Tenyear						
Indpro						
L1.	-6.628959	4.005715	-1.65	0.098	-14.48002	1.222099
L2.	.9321523	4.478335	0.21	0.835	-7.845223	9.709527
L3.	12.00515	4.834019	2.48	0.013	2.530646	21.47965
L4.	-.9888553	5.420614	-0.18	0.855	-11.61306	9.635353
L5.	-8.816905	4.394367	-2.01	0.045	-17.42971	-.2041048
L6.	1.15838	4.415068	0.26	0.793	-7.494994	9.811755
L7.	.4119386	3.511418	0.12	0.907	-6.470315	7.294192
PCEPI						
L1.	-3.981193	11.71964	-0.34	0.734	-26.95126	18.98887
L2.	8.183346	18.08835	0.45	0.651	-27.26917	43.63586
L3.	-25.20735	17.841	-1.41	0.158	-60.17507	9.760363
L4.	23.05494	18.89528	1.22	0.222	-13.97913	60.08901
L5.	-11.59463	19.35717	-0.60	0.549	-49.53398	26.34472
L6.	13.27413	19.38463	0.68	0.493	-24.71906	51.26731
L7.	-11.43509	12.40142	-0.92	0.356	-35.74142	12.87124
Securities						
L1.	6.64431	1.726249	3.85	0.000	3.260923	10.0277
L2.	-13.73714	3.991362	-3.44	0.001	-21.56006	-5.914211
L3.	11.1468	4.371056	2.55	0.011	2.579691	19.71392
L4.	-4.775735	2.910041	-1.64	0.101	-10.47931	.9278403
L5.	.8614847	1.685008	0.51	0.609	-2.441071	4.16404
L6.	-.6462958	1.649895	-0.39	0.695	-3.88003	2.587438
L7.	.4602545	.9454271	0.49	0.626	-1.392749	2.313258
Tenyear						
L1.	.9069187	.1165136	7.78	0.000	.6785563	1.135281
L2.	-.1733449	.1610937	-1.08	0.282	-.4890827	.142393
L3.	.1539367	.1545046	1.00	0.319	-.1488868	.4567603
L4.	-.2519496	.1600227	-1.57	0.115	-.5655883	.061689
L5.	.1750208	.1634409	1.07	0.284	-.1453176	.4953591
L6.	-.3823599	.1526949	-2.50	0.012	-.6816364	-.0830834
L7.	.3290031	.105493	3.12	0.002	.1222406	.5357656
SP500						
L1.	1.560733	.7386443	2.11	0.035	.1130167	3.008449
L2.	-.9950288	.9361396	-1.06	0.288	-2.829829	.8397712
L3.	.6908743	.9201484	0.75	0.453	-1.112583	2.494332
L4.	-.258213	.9084083	-0.28	0.776	-2.03866	1.522234
L5.	.8578127	.924458	0.93	0.353	-.9540917	2.669717
L6.	-.0574508	.8910315	-0.06	0.949	-1.803841	1.688939
L7.	-.5684551	.6323577	-0.90	0.369	-1.807853	.6709431
_cons	36.68793	18.00685	2.04	0.042	1.395148	71.98071

Figure 4.6: VAR output - Ten year treasury yield

SP500						
Indpro						
L1.	.984949	.6362347	1.55	0.122	-.2620481	2.231946
L2.	1.491628	.7113017	2.10	0.036	.0975026	2.885754
L3.	-.1446175	.7677956	-0.19	0.851	-1.649469	1.360234
L4.	.2683685	.8609655	0.31	0.755	-1.419093	1.95583
L5.	-.9595809	.6979649	-1.37	0.169	-2.327567	.4084051
L6.	.3006089	.7012529	0.43	0.668	-1.073822	1.675039
L7.	-.1863457	.5577246	-0.33	0.738	-1.279466	.9067746
PCEPI						
L1.	-3.445306	1.86145	-1.85	0.064	-7.093681	.2030691
L2.	6.14749	2.873004	2.14	0.032	.5165061	11.77847
L3.	-8.175006	2.833717	-2.88	0.004	-13.72899	-2.621023
L4.	1.052673	3.00117	0.35	0.726	-4.829512	6.934859
L5.	5.736693	3.074533	1.87	0.062	-.2892802	11.76267
L6.	-4.764971	3.078895	-1.55	0.122	-10.79949	1.269552
L7.	1.019824	1.969738	0.52	0.605	-2.840792	4.880441
Securities						
L1.	1.069744	.2741832	3.90	0.000	.5323552	1.607133
L2.	-1.986688	.633955	-3.13	0.002	-3.229217	-.7441591
L3.	1.986335	.6942624	2.86	0.004	.6256056	3.347064
L4.	-1.050683	.4622068	-2.27	0.023	-1.956592	-.1447747
L5.	.0137406	.2676328	0.05	0.959	-.51081	.5382912
L6.	.4248093	.2620556	1.62	0.105	-.0888103	.9384289
L7.	-.3747701	.1501638	-2.50	0.013	-.6690858	-.0804544
Tenyear						
L1.	.0077952	.0185061	0.42	0.674	-.028476	.0440665
L2.	.0018626	.0255868	0.07	0.942	-.0482866	.0520118
L3.	.0112528	.0245402	0.46	0.647	-.0368452	.0593507
L4.	-.0538761	.0254167	-2.12	0.034	-.1036919	-.0040603
L5.	.0165759	.0259596	0.64	0.523	-.034304	.0674558
L6.	-.0389089	.0242528	-1.60	0.109	-.0864435	.0086257
L7.	.0251887	.0167556	1.50	0.133	-.0076517	.0580292
SP500						
L1.	.9310445	.1173201	7.94	0.000	.7011013	1.160988
L2.	-.417563	.1486887	-2.81	0.005	-.7089874	-.1261385
L3.	.1353212	.1461488	0.93	0.354	-.1511251	.4217675
L4.	.2350542	.1442841	1.63	0.103	-.0477373	.5178458
L5.	-.1110475	.1468333	-0.76	0.449	-.3988354	.1767404
L6.	-.0924376	.1415241	-0.65	0.514	-.3698197	.1849445
L7.	.1733402	.1004385	1.73	0.084	-.0235156	.370196
_cons	3.722863	2.86006	1.30	0.193	-1.882751	9.328476

Figure 4.7: VAR output - S&P500 Index

8.5 Appendix E - *VEC specification and output*

Johansen tests for cointegration

Trend: constant Number of obs = 92

Sample: 2008m8 - 2016m3 Lags = 7

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	155	1434.8597	.	105.2734	68.52
1	164	1454.4711	0.34710	66.0506	47.21
2	171	1468.187	0.25783	38.6189	29.68
3	176	1480.3751	0.23276	14.2426*	15.41
4	179	1485.1665	0.09892	4.6598	3.76
5	180	1487.4964	0.04939		

Figure 5.1: Johansen tests for cointegration

Vector error-correction model

Sample: 2008m8 - 2016m3 Number of obs = 92

AIC = -28.37503

Log likelihood = 1480.251 HQIC = -26.43897

Det(Sigma_ml) = 7.28e-21 SBIC = -23.57815

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_Indpro	34	.004115	0.8477	317.241	0.0000
D_PCEPI	34	.00162	0.7064	137.1321	0.0000
D_Securities	34	.010796	0.9700	1845.392	0.0000
D_Tenyear	34	.178853	0.6073	88.14396	0.0000
D_SP500	34	.028184	0.7305	154.5174	0.0000

Figure 5.2: VEC header

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_Indpro						
_ce1						
L1.	-.175345	.0817013	-2.15	0.032	-.3354765	-.0152135
_ce2						
L1.	.3199135	.1213386	2.64	0.008	.0820941	.5577328
_ce3						
L1.	.0067399	.0047677	1.41	0.157	-.0026046	.0160843
Indpro						
LD.	-.2088388	.1535318	-1.36	0.174	-.5097557	.092078
L2D.	-.0510584	.1398152	-0.37	0.715	-.3250912	.2229744
L3D.	.3051908	.1317178	2.32	0.021	.0470287	.5633529
L4D.	.1652146	.1076228	1.54	0.125	-.0457222	.3761514
L5D.	-.0616998	.1072643	-0.58	0.565	-.271934	.1485344
L6D.	.0885398	.1020215	0.87	0.385	-.1114186	.2884982
PCEPI						
LD.	-.2530055	.3608129	-0.70	0.483	-.9601857	.4541748
L2D.	.1570022	.3231666	0.49	0.627	-.4763928	.7903971
L3D.	.1097957	.349209	0.31	0.753	-.5746415	.7942329
L4D.	.2003021	.3515668	0.57	0.569	-.4887562	.8893603
L5D.	-.1159792	.3747933	-0.31	0.757	-.8505605	.6186021
L6D.	-.2963454	.3594048	-0.82	0.410	-1.000766	.4080751
Securities						
LD.	-.0206606	.0497611	-0.42	0.678	-.1181905	.0768693
L2D.	-.0553954	.0741882	-0.75	0.455	-.2008016	.0900107
L3D.	.0497557	.0612875	0.81	0.417	-.0703656	.169877
L4D.	-.0712231	.0361617	-1.97	0.049	-.1420988	-.0003474
L5D.	.1493127	.0287711	5.19	0.000	.0929225	.2057029
L6D.	-.0967434	.0280816	-3.45	0.001	-.1517824	-.0417044
Tenyear						
LD.	.0041175	.0034585	1.19	0.234	-.0026611	.0108961
L2D.	-.002426	.0035387	-0.69	0.493	-.0093618	.0045098
L3D.	.0017247	.0033614	0.51	0.608	-.0048636	.008313
L4D.	-.0024369	.0035706	-0.68	0.495	-.0094352	.0045613
L5D.	-.0015065	.0029757	-0.51	0.613	-.0073388	.0043258
L6D.	-.0014798	.0030249	-0.49	0.625	-.0074085	.004449
SP500						
LD.	-.015143	.0223373	-0.68	0.498	-.0589232	.0286373
L2D.	.020211	.021844	0.93	0.355	-.0226025	.0630246
L3D.	.0398558	.0214359	1.86	0.063	-.0021578	.0818695
L4D.	-.0127668	.022309	-0.57	0.567	-.0564916	.030958
L5D.	.0058905	.0204592	0.29	0.773	-.0342088	.0459899
L6D.	.0027088	.0185015	0.15	0.884	-.0335534	.0389711
_cons	-.001976	.0011702	-1.69	0.091	-.0042696	.0003175

Figure 5.3: VEC output - Industrial production

D_PCEPI						
_ce1						
L1.	.0508863	.0321636	1.58	0.114	-.0121532	.1139257
_ce2						
L1.	-.0220171	.0477677	-0.46	0.645	-.1156402	.0716059
_ce3						
L1.	.0053567	.0018769	2.85	0.004	.001678	.0090353
Indpro						
LD.	-.141924	.0604413	-2.35	0.019	-.2603868	-.0234611
L2D.	-.0477761	.0550415	-0.87	0.385	-.1556554	.0601032
L3D.	-.046119	.0518537	-0.89	0.374	-.1477504	.0555125
L4D.	-.0016714	.0423682	-0.04	0.969	-.0847115	.0813687
L5D.	-.0550647	.0422271	-1.30	0.192	-.1378282	.0276988
L6D.	-.0212095	.0401631	-0.53	0.597	-.0999277	.0575087
PCEPI						
LD.	.2452485	.1420423	1.73	0.084	-.0331493	.5236462
L2D.	.1153151	.127222	0.91	0.365	-.1340354	.3646656
L3D.	-.1759737	.1374742	-1.28	0.201	-.4454181	.0934707
L4D.	-.0020034	.1384024	-0.01	0.988	-.273267	.2692603
L5D.	-.0076129	.147546	-0.05	0.959	-.2967978	.2815719
L6D.	-.1176685	.141488	-0.83	0.406	-.3949798	.1596429
Securities						
LD.	.0017903	.0195896	0.09	0.927	-.0366046	.0401851
L2D.	-.0152627	.0292059	-0.52	0.601	-.0725051	.0419798
L3D.	.0075087	.0241272	0.31	0.756	-.0397798	.0547972
L4D.	.0029439	.0142359	0.21	0.836	-.0249579	.0308458
L5D.	-.0140948	.0113264	-1.24	0.213	-.0362941	.0081046
L6D.	.024438	.011055	2.21	0.027	.0027707	.0461054
Tenyear						
LD.	-.0011423	.0013615	-0.84	0.402	-.0038108	.0015263
L2D.	.0003674	.0013931	0.26	0.792	-.0023631	.0030978
L3D.	.0009113	.0013233	0.69	0.491	-.0016823	.003505
L4D.	-.0001575	.0014057	-0.11	0.911	-.0029125	.0025975
L5D.	.0009487	.0011715	0.81	0.418	-.0013473	.0032447
L6D.	-.0013924	.0011908	-1.17	0.242	-.0037264	.0009415
SP500						
LD.	.0254047	.0087936	2.89	0.004	.0081696	.0426398
L2D.	.0011835	.0085994	0.14	0.891	-.015671	.018038
L3D.	.0024156	.0084387	0.29	0.775	-.014124	.0189553
L4D.	.0155978	.0087824	1.78	0.076	-.0016155	.0328111
L5D.	-.0026893	.0080543	-0.33	0.738	-.0184753	.0130968
L6D.	.0077157	.0072835	1.06	0.289	-.0065598	.0219912
_cons	-.0000776	.0004607	-0.17	0.866	-.0009805	.0008253

Figure 5.4: VEC output - PCEPI

D_Securities						
_ce1						
L1.	-.1854791	.2143217	-0.87	0.387	-.605542	.2345838
_ce2						
L1.	.7777321	.3182999	2.44	0.015	.1538756	1.401589
_ce3						
L1.	.0017831	.0125067	0.14	0.887	-.0227297	.0262958
Indpro						
LD.	-.7472258	.4027504	-1.86	0.064	-1.536602	.0421504
L2D.	.2168193	.3667684	0.59	0.554	-.5020335	.9356722
L3D.	-.4428447	.3455269	-1.28	0.200	-1.120065	.2343756
L4D.	-.1881579	.2823201	-0.67	0.505	-.741495	.3651793
L5D.	-.3528045	.2813797	-1.25	0.210	-.9042985	.1986896
L6D.	-.4329577	.2676265	-1.62	0.106	-.9574959	.0915806
PCEPI						
LD.	.1438277	.9464975	0.15	0.879	-1.711273	1.998929
L2D.	-1.526553	.8477426	-1.80	0.072	-3.188098	.1349921
L3D.	-.0804104	.916058	-0.09	0.930	-1.875851	1.71503
L4D.	-2.123658	.9222429	-2.30	0.021	-3.931221	-.3160956
L5D.	-1.664682	.9831714	-1.69	0.090	-3.591663	.2622982
L6D.	.3147333	.9428039	0.33	0.739	-1.533128	2.162595
Securities						
LD.	1.246961	.1305351	9.55	0.000	.9911172	1.502805
L2D.	-.8550443	.1946131	-4.39	0.000	-1.236479	-.4736096
L3D.	.1227221	.1607716	0.76	0.445	-.1923844	.4378287
L4D.	.1064199	.0948608	1.12	0.262	-.0795038	.2923436
L5D.	-.138684	.0754733	-1.84	0.066	-.2866089	.0092409
L6D.	.0603619	.0736648	0.82	0.413	-.0840185	.2047422
Tenyear						
LD.	-.0050299	.0090726	-0.55	0.579	-.0228118	.0127521
L2D.	.0026893	.009283	0.29	0.772	-.015505	.0208836
L3D.	-.0204767	.0088179	-2.32	0.020	-.0377594	-.003194
L4D.	.003279	.0093665	0.35	0.726	-.0150791	.0216371
L5D.	.0140458	.007806	1.80	0.072	-.0012537	.0293452
L6D.	-.0012533	.0079351	-0.16	0.874	-.0168059	.0142992
SP500						
LD.	.053919	.0585959	0.92	0.357	-.0609268	.1687649
L2D.	.0948436	.0573021	1.66	0.098	-.0174664	.2071536
L3D.	.1393527	.0562315	2.48	0.013	.029141	.2495645
L4D.	.0091019	.0585218	0.16	0.876	-.1055987	.1238024
L5D.	-.0076952	.0536694	-0.14	0.886	-.1128854	.097495
L6D.	-.0137114	.0485338	-0.28	0.778	-.1088359	.0814131
_cons	.0022029	.0030697	0.72	0.473	-.0038137	.0082195

Figure 5.5: VEC output - Securities held outright

D_Tenyear						
_ce1						
L1.	-.9792981	3.550724	-0.28	0.783	-7.93859	5.979994
_ce2						
L1.	-4.96457	5.273359	-0.94	0.346	-15.30016	5.371024
_ce3						
L1.	-.012971	.2072022	-0.06	0.950	-.4190799	.3931379
Indpro						
LD.	-5.966991	6.672471	-0.89	0.371	-19.04479	7.110812
L2D.	-4.227821	6.076348	-0.70	0.487	-16.13724	7.681603
L3D.	7.829681	5.724435	1.37	0.171	-3.390006	19.04937
L4D.	6.368864	4.677271	1.36	0.173	-2.798419	15.53615
L5D.	-2.807335	4.661691	-0.60	0.547	-11.94408	6.329412
L6D.	-1.301712	4.433838	-0.29	0.769	-9.991875	7.388451
PCEPI						
LD.	2.294477	15.68087	0.15	0.884	-28.43947	33.02842
L2D.	10.00176	14.04477	0.71	0.476	-17.52549	37.52901
L3D.	-14.93951	15.17657	-0.98	0.325	-44.68505	14.80602
L4D.	8.779574	15.27904	0.57	0.566	-21.16679	38.72594
L5D.	-2.38041	16.28846	-0.15	0.884	-34.3052	29.54438
L6D.	11.77379	15.61968	0.75	0.451	-18.84022	42.3878
Securities						
LD.	7.017337	2.162609	3.24	0.001	2.778703	11.25597
L2D.	-7.570346	3.224207	-2.35	0.019	-13.88968	-1.251017
L3D.	4.326353	2.663545	1.62	0.104	-.8940996	9.546806
L4D.	-.581076	1.571584	-0.37	0.712	-3.661323	2.499171
L5D.	.1073505	1.250386	0.09	0.932	-2.34336	2.558061
L6D.	-.4480045	1.220424	-0.37	0.714	-2.839991	1.943983
Tenyear						
LD.	.0867048	.1503076	0.58	0.564	-.2078927	.3813023
L2D.	-.0831293	.1537935	-0.54	0.589	-.384559	.2183005
L3D.	.0672272	.1460879	0.46	0.645	-.2190998	.3535542
L4D.	-.1855079	.1551781	-1.20	0.232	-.4896513	.1186355
L5D.	.0124087	.129324	0.10	0.924	-.2410617	.265879
L6D.	-.3794255	.1314631	-2.89	0.004	-.6370884	-.1217626
SP500						
LD.	.6850252	.9707737	0.71	0.480	-1.217656	2.587707
L2D.	-.3783544	.9493386	-0.40	0.690	-2.239024	1.482315
L3D.	.3526492	.9316023	0.38	0.705	-1.473258	2.178556
L4D.	.0173694	.9695455	0.02	0.986	-1.882905	1.917644
L5D.	.7888231	.8891558	0.89	0.375	-.9538902	2.531536
L6D.	.7195863	.8040725	0.89	0.371	-.8563668	2.295539
_cons	.0001518	.050857	0.00	0.998	-.0995262	.0998297

Figure 5.6: VEC output - Ten year treasury yield

D_SP500						
_ce1						
L1.	1.824605	.5595378	3.26	0.001	.7279307	2.921278
_ce2						
L1.	-2.800138	.8309976	-3.37	0.001	-4.428863	-1.171412
_ce3						
L1.	.1000766	.0326518	3.06	0.002	.0360802	.1640729
Indpro						
LD.	-.8470544	1.051475	-0.81	0.420	-2.907908	1.2138
L2D.	.6582159	.957536	0.69	0.492	-1.21852	2.534952
L3D.	.4415009	.9020801	0.49	0.625	-1.326544	2.209545
L4D.	.6224603	.7370636	0.84	0.398	-.8221577	2.067078
L5D.	-.3539884	.7346085	-0.48	0.630	-1.793795	1.085818
L6D.	.0110525	.6987024	0.02	0.987	-1.358379	1.380484
PCEPI						
LD.	-1.133783	2.471057	-0.46	0.646	-5.976964	3.709399
L2D.	5.150572	2.213233	2.33	0.020	.8127146	9.48843
L3D.	-2.910748	2.391587	-1.22	0.224	-7.598172	1.776676
L4D.	-1.905181	2.407734	-0.79	0.429	-6.624253	2.813891
L5D.	4.000081	2.566802	1.56	0.119	-1.030759	9.030922
L6D.	-.4872815	2.461413	-0.20	0.843	-5.311563	4.337
Securities						
LD.	1.047873	.3407927	3.07	0.002	.3799313	1.715814
L2D.	-1.0704	.5080838	-2.11	0.035	-2.066226	-.0745736
L3D.	.9911976	.4197324	2.36	0.018	.1685371	1.813858
L4D.	-.0623658	.2476566	-0.25	0.801	-.5477638	.4230322
L5D.	-.0620913	.1970409	-0.32	0.753	-.4482844	.3241018
L6D.	.3630884	.1923194	1.89	0.059	-.0138508	.7400275
Tenyear						
LD.	.0357087	.0236861	1.51	0.132	-.0107152	.0821326
L2D.	.0358591	.0242354	1.48	0.139	-.0116415	.0833596
L3D.	.0463466	.0230211	2.01	0.044	.001226	.0914672
L4D.	-.0073537	.0244536	-0.30	0.764	-.0552819	.0405744
L5D.	.0117363	.0203794	0.58	0.565	-.0282066	.0516792
L6D.	-.027238	.0207165	-1.31	0.189	-.0678416	.0133656
SP500						
LD.	.0827641	.1529785	0.54	0.588	-.2170683	.3825964
L2D.	-.3209873	.1496007	-2.15	0.032	-.6141993	-.0277754
L3D.	-.1885714	.1468057	-1.28	0.199	-.4763053	.0991625
L4D.	.0328417	.152785	0.21	0.830	-.2666113	.3322948
L5D.	-.0753765	.1401168	-0.54	0.591	-.3500005	.1992474
L6D.	-.1774799	.1267091	-1.40	0.161	-.4258251	.0708653
_cons	.0001177	.0080143	0.01	0.988	-.01559	.0158253

Figure 5.7: VEC output - S&P500 Index

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
Indpro	1	.	.	.	.	.
PCEPI	0	(omitted)				
Securities	0	(omitted)				
Tenyear	.0215996	.0053872	4.01	0.000	.0110409	.0321584
SP500	-.197347	.0172876	-11.42	0.000	-.23123	-.163464
_cons	-3.199945	.	.	.	.	.
_ce2						
Indpro	0	(omitted)				
PCEPI	1	.	.	.	.	.
Securities	0	(omitted)				
Tenyear	.023233	.0036885	6.30	0.000	.0160037	.0304624
SP500	-.132576	.0098312	-13.49	0.000	-.1518448	-.1133071
_cons	-3.734095	.	.	.	.	.
_ce3						
Indpro	0	(omitted)				
PCEPI	0	(omitted)				
Securities	1	.	.	.	.	.
Tenyear	0	(omitted)				
SP500	-1.433613	.1503443	-9.54	0.000	-1.728283	-1.138944
_cons	2.644419	.	.	.	.	.

LR test of identifying restrictions: chi2(1) = .2473 Prob > chi2 = 0.619

Figure 5.8: VEC output - Cointegration equations

8.6 Appendix F - *Causality*

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
Indpro	PCEPI	21.933	7	0.003
Indpro	Securities	90.088	7	0.000
Indpro	Tenyear	15.227	7	0.033
Indpro	SP500	16.973	7	0.018
Indpro	ALL	311.52	28	0.000
PCEPI	Indpro	17.297	7	0.016
PCEPI	Securities	20.502	7	0.005
PCEPI	Tenyear	4.5665	7	0.713
PCEPI	SP500	14.137	7	0.049
PCEPI	ALL	108.25	28	0.000
Securities	Indpro	31.465	7	0.000
Securities	PCEPI	26.194	7	0.000
Securities	Tenyear	27.212	7	0.000
Securities	SP500	16.125	7	0.024
Securities	ALL	214.66	28	0.000
Tenyear	Indpro	13.373	7	0.064
Tenyear	PCEPI	5.5878	7	0.589
Tenyear	Securities	19.094	7	0.008
Tenyear	SP500	10.439	7	0.165
Tenyear	ALL	103.53	28	0.000
SP500	Indpro	27.168	7	0.000
SP500	PCEPI	24.806	7	0.001
SP500	Securities	33.171	7	0.000
SP500	Tenyear	16.421	7	0.022
SP500	ALL	163.17	28	0.000

Figure 6.1: Granger causality test

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Preliminary Thesis Report

What are the effects of Large Scale Asset Purchases on asset prices in the US?

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Master of Science in Business - Finance

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Abstract

This paper lays the groundwork for how we will research the effects of Open Market Operations by the Federal Reserve on asset prices in the US. According to classical valuation theory, asset prices are only determined by the firm's future discounted cash flows, Is this what we see in reality? If not, then we might have to look at other theories explaining valuation. Although the Federal Reserve bank has several monetary policy tools, we will focus on Open Market Operations. More specifically we will focus on the Large scale asset purchases, also known as Quantitative Easing, which have been a prevalent tool since the financial crisis in 2008. Through Quantitative Easing, the Federal Reserve aims to lower long-term yields and increase liquidity in the economy.

1.0 Introduction

In our master thesis we want to research how the Open Market Operations (OMO) of the Federal Reserve (Fed) affect asset prices in the US. OMO's have been a prevalent monetary policy tool for many years, especially since late 2008 in the form of Large Scale Asset Purchases (LSAP) also referred to as Quantitative Easing (QE). We will use these terms interchangeably.

Traditional OMO's focus primarily on contracting or expanding the Fed's balance sheet by either selling or buying treasury bonds to manipulate the Federal funds rate (an overnight rate at which depository institutions and banks lend to each other). The aim of manipulating the Federal funds rate is to achieve stability in the economy by increasing the Federal funds rate when the economy is doing well, and vice versa.

The federal funds rate has been in a near-zero target range since late 2008, and as a result of this, the traditional OMO's power to affect the economy has been drastically weakened due to the fact that interest rates can't theoretically be lower than zero.

QE can be viewed as a more expansive OMO. In contrast to traditional OMO's, which focus primarily on short-term interest rates and buying or selling treasury bonds, QE focus more on medium and long-term interest rates, while they also operate with more variety in the assets being bought.
The aim is to decrease the cost of borrowing by putting a downward pressure on the yield-curve. The scale at which assets are being bought is much larger than with traditional OMO's, as is implied by the name "Quantitative Easing". With QE, the Fed injects large amounts of money into the market through LSAP, which helps to increase liquidity in the market and put a downward pressure on interest rates. This, in turn, boosts economic activity as it leads to more investments and higher aggregate demand.
To get a better perspective on the size of the QE rounds from 2008 to 20014, we need only to look at the balance sheet of the Fed. In late November 2008, the Fed held between $700 billion and $800 billion in assets, while when QE3 halted on

29 October 2014, the size of the Fed balance sheet had more than quadrupled to $4,5 trillion in assets.

As we can see from numerous studies traditional monetary policy has significant effects on asset prices, and vice versa. Bjørnland and Leitemo (2009) examined the interdependence between US monetary policy and the stock market and found that there is in fact, a strong interdependence between the two.
In their paper they mainly focus on the effect of interest rate setting, while in our thesis, we will examine the effect of LSAP on US asset prices in the period from 2008 to 2014. These LSAP programs were designed to have a noticeable impact on the interest rates of the asset being purchased as well as on other assets with similar characteristics (Gagnon et al. 2010).

Being able to accurately estimate the effects of OMO's on asset prices can be greatly beneficial to several parties. For the policy makers, being able to predict the outcome of the policy is critical when formulating the policy. From an investor's point of view, having more reliable estimates for changes in asset prices can lead to better investment decisions. For firms, having better estimates for their own value can have great importance. It can lead to better stability and more informed decision making.

1.1 Research question

We will look at announcements about LSAP programs and use them in an event-study in order to answer our research question:

What are the effects of Large Scale Asset Purchases on asset prices in the US?

2.0 Literature review

In this section we review earlier relevant studies on similar subjects. We have looked at earlier articles that mainly focus on the impact of changes in the discount rate and/or changes in the federal funds rate target zone. The later articles we have looked at have focused more on the effects of LSAP.

Estimating the effects of monetary policy has been perhaps one of the most researched topics in economic theory. Many later studies base their research on an article by Thorbecke (1997). He found that expansive monetary policy leads to an increase in equity prices, especially for smaller firms. His explanation for this was that perhaps the increased liquidity matters more for smaller firms.

Rigobon and Sack (2004) builds upon Thorbecke's results. They try to estimate the effect of monetary policy on asset prices, specifically what affects policy shocks on FOMC meeting days have on asset prices and market interest rates. They found that the stock markets have a significant negative reaction to monetary policy shocks, with an estimated reduction in stock prices of 1.9% as a reaction to a 25 basis point increase short term interest rates. They also found a strong reaction in short term market interest rates.

In an earlier article Rigobon and Sack (2001) tried to measure the reverse effect, how monetary policy reacts to changes in asset prices. With the use of a VAR model, they found significant results supporting their hypothesis. They found that for an increase in stock prices of 5%, the probability of a 25 basis point tightening by the Federal Reserve increased by about 50%.

Bjørnland and Leitemo (2009) follows in the footsteps of Rigobon and Sack in examining the interdependence between the S&P 500 and US monetary policy. They find strong interdependence between the interest rate setting and real stock prices. Real stock prices immediately fall by seven to nine percent due to a monetary policy shock that raises the federal funds rate by 1%. A stock price shock increasing real stock prices by one percent leads to an increase in the

interest rate of close to 0,04%. These results are consistent with what Rigobon and Sack found earlier.
In contrast to earlier studies on the subject, they take simultaneity problem into consideration in order to better capture the interdependence between stock prices and monetary policy. They solve the simultaneity problem by using a combination of short-run and long-run restrictions that maintains the qualitative properties of a monetary policy shock found in the established literature.

Bernanke and Kuttner (2005) take a different approach, they try to explain stock market's reaction to federal reserve policy using a more traditional event study. In contrast to Rigobon and Sack (2001) and Bjørnland and Leitemo (2009), Bernanke and Kuttner found no evidence that changes in equity prices lead to interest rate changes by the FOMC. On the other hand their results show that stock prices react to changes in the federal funds rate, they estimated that an unexpected 25 basis point reduction in the rate would typically lead to a 1% increase in stock prices.

Gurkaynak, Sack, and Swanson (2004) does a similar study to Bernanke and Kuttner (2005), but find that a single factor analysis with the Federal Funds rate is not adequate to capture the effects of US monetary policy on asset prices. Instead, they advocate a two-factor approach in which they also include a factor capturing the statements from the FOMC. They find that between 1990 and 2004, FOMC releases accounted for more than three-fourths of the explainable variation in the movements of five- and ten-year Treasury yields around FOMC meetings.

Harvey and Huang (2001) use previously unavailable data on open market operations from 1982 to 1988 to examine the effects of the Fed's trading on both foreign currencies and fixed income securities. They find that there is a dramatic increase in volatility during Fed Time (a thirty minute time window in which the Fed trades in the market), which is consistent with market expectations of the Fed intervening in this time interval. However, they find that the volatility is independent of whether the Fed actually trades in the market. They find some evidence for that volatility is lower when the Fed actually trades, compared to when it does not. This indicates that market participants may be confused about the purpose of open market operations in this period.

Gagnon et al. (2010) examine in their article whether the Large-Scale Asset Purchases of the Fed had a significant and long-lasting effect on the economy in the US. They focus on the effects after November 2008, when the Fed started with QE. They found that the LSAP programs that were implemented led to economically meaningful and long-lasting reductions in longer-term interest rates on a range of securities, including securities that were not included in the purchase programs. The reason for this is that the LSAP programs reduced the net supply of assets with long duration, and hence reduced the term premium. Therefore, the reductions in interest rates primarily reflect lower risk premiums, including term premiums, rather than lower expectations of future short-term interest rates.
From their tests, they found that the overall size of reduction in 10-year term premium appears to be somewhere between 30 and 100 basis points..

Joyce et al. (2011) did a similar study, examining the impact of the quantitative easing programs on the financial markets in the UK. They identify three main channels through which QE could affect asset prices: Announcement effects, portfolio rebalancing, and through increased liquidity. The study found through an event-study that as a reaction to the news about QE purchases, the long term bond yields were about 1% lower than they would otherwise have been.

A working paper by Thornton (2014) follows up on the article of Gagnon et al. (2010) and other articles that use event-studies to examine the LSAP announcement effects on long-term yields. In his article, Thornton focus his attention on whether the announcement effects used in these articles are identified, i.e.; the announcement effects must be due solely to the LSAP news, and the announcement effects must be statistically significant. Thornton finds that of the 53 LSAP announcements considered in the literature none meet the strict requirements for identification. Hence, the event-study evidence from existing literature can be considered inconclusive.

From the studies we have looked at it is clear that the earlier studies have focused more on the effect of changes in the federal funds rate target, and the discount rate. While this made sense earlier, both of these rates have been been constant at near zero percent since 2009. Because of this, the Fed was forced to use other measures, most notably the QE programs, a series of large scale asset purchases. Newer studies have tried to measure the effect these have had on asset prices, this is similar to what we want to research.

3.0 Theory

When examining what can potentially affect the value of assets it is beneficial to first know what theories say about value. We can start with the most basic model, the discounted cash flow valuation model. Irving Fisher's book from 1930 *The Theory Of Interest* and John Burr Williams' book from 1938 *The Theory Of Investment Value* are widely considered to be the first to formally lay the groundwork for the model in modern economic terms. The models states that the value of a firm or project should equal the sum of all future cash flows discounted at some discount factor. If we find that asset prices change because of LSAP, then for classical valuation theory to hold, LSAP must impact either the cash flows or the discount factor.

Building on the classical valuation theory, Gordon (1959) developed what we now call the Gordon growth model. This model states that the price of a stock should equal the future discounted dividends on that stock. Similar to the classical valuation theory, if we see a change in stock prices, it has to be due to a change in the discount factor or the dividend yield.

Since we will be doing an event-study, we must assume that the efficient market hypothesis (EMH) holds. Introduced by Fama (1970), the hypothesis states that asset prices fully reflect all available information, and that if new information becomes available, the prices will adjust immediately after the market participants adjust their expectations. In our analysis we should, according to EMH see asset prices adjust immediately after news and announcements of LSAP. The EMH is not without critics, others have tried to explain the market's reaction to news with behavioral finance. Bondt and Thaler (1985) found using psychology that most people tend to overreact to unexpected or dramatic news, suggesting that EMH might not hold.

A very relevant theory in relation to bond yields is the Expectations Theory of the Term Structure. Since Macaulay published his book *The Movements of Interest Rates* in 1938, it has been in the center of both theoretical and empirical research on fixed income securities. The expectations hypothesis has to do with the evolution of yields, which is highly relevant for bond prices. The hypothesis is that long-term interest rates contain a prediction of future short-term interest rates.

Another theory that tries to explain differences in the bond yields is the Liquidity Preference Theory. The theory was first introduced in Keynes book from 1936 *The General Theory of Employment, Interest and Money*. The theory states that investors require a higher rate of return on investments in longer maturity bonds.

For the Fed, it is particularly important to know how their QE programs affect bond yields, since the main goal of the QE programs is to lower the medium to long-term market interest rates.

In order to get a better understanding of the inflation effects of QE, it is important to understand the Quantity Theory of Money. The theory descends from Nicolaus Copernicus, and was further developed by Simon Newcomb, Irving Fisher, Ludwig von Mises, and others in the late 19th and early 20th century. It revolves around the connection between money supply and the price level in the economy. It is a fairly simple model, which is useful in explaining the effect of an increase in the money supply on price levels in the economy. The model itself can be stated as:

$MV=PY$, where M is money, V is the velocity of money, P is the price level, and Y is the aggregate output (GDP or other similar benchmarks).

In order to analyse the effects of QE on asset prices, it is necessary to take into consideration the increased inflation due to a larger money supply. Therefore, this theory is useful when evaluating the inflation effects of QE on asset prices.

Another theory we will take into consideration is The Fed Model. It is a theory of equity valuation, and hence, is of importance when evaluating the effects of monetary policy on stock prices. The model hypothesizes a relationship between long-term treasury notes and the market return of equities. It states that if bond and stock markets are in equilibrium, then the one-year forward -looking earnings yield (E/P) equals the 10-year treasury note yield.

4.0 Data

The data we will need is mostly easily available. In order to properly analyse our research problem, we'll need data on asset prices, as well as data on the factors affecting asset prices. Most of the data can be found using datastream.

For stock prices we will use the S&P 500 index as a proxy. We feel the S&P 500 index will fit our needs better than the Dow Jones industrial average for example, because it captures a wider range of stocks and weighs the stocks according to their market value. Data on the S&P 500 index can be found on datastream.

For bond yields, we will need data on short, medium and long term treasury yields (for example 6 month, 12 month, 5 year, 10 year, and 30 year yields). We are also planning to use investment grade corporate bonds in our research. Data on bond yields can be found on datastream.

For an event study we will have to identify all the relevant events. The events we will use are; Official LSAP announcements from the FOMC, FOMC meeting statements, FOMC minutes, chairman speeches, and other impactful news. Details of the LSAP announcements can be found on the Fed of New York's website. The meeting schedule for the FOMC can be found on the Fed's official website along with FOMC statements and minutes. A list with all of chairman Bernanke's statements and speeches can be found on the Fed of St. Louis' website. Other impactful news we will have to find through relevant keyword searches around important dates.

In order to get correct estimates we will need to adjust asset prices for inflation, therefore we will need to gather data on CPI growth. Monthly data on CPI growth in the US can be found on the Bureau of Labor Statistics' website.

5.0 Methodology

In order to examine the effects of the Fed's LSAP (QE) programs we will take an event-study approach. We will measure the reaction to specific events related to the LSAP programs. The events will typically be, LSAP announcements, FOMC meeting statements, FOMC minutes, chairman speeches, and other major news related to the matter.

We will use roughly the same framework for testing as established by Gagnon et al. (2010) and Thornton (2013). We will follow the same basic assumptions: (1) the event set captures all relevant events, (2) The LSAP expectations are not captured by anything other than these events, (3) The time span tested around each event must be long enough to capture long-run effects, but short enough that other news do not impact the results, (4) Assume that Market Efficiency Hypothesis hold, i.e., effects on yields occur when market participants update their expectations.

As mentioned in the *Data* section, we will use data on stock returns, bond yields (different maturities and different types), CPI, and announcements by the Fed. We will run regressions on the variables in order to examine the effects of announcements on the different variables determining asset prices.

Thornton (2013) used the following model to estimate the change in bond yields

$$(1)\quad \Delta i_t = \alpha + \beta^{imp} Dum_t^{imp} + \beta^{Limp} Dum_t^{Limp} + \beta^{min} Dum_t^{min} + \varepsilon_t$$

where Dum_t^{imp} and Dum_t^{Limp} are dummy variables for important and less important days, and Dum_t^{min} is a dummy variable for days when FOMC minutes are released. FOMC minutes is treated as a standalone factor because it usually carries little new information about LSAP.

We want to use this model as a basis for our estimation, and will use a similar model for estimating the change is stock prices

$$(2)\ \Delta s_t = \alpha + \beta^{imp} Dum_t^{imp} + \beta^{Limp} Dum_t^{Limp} + \beta^{min} Dum_t^{min} + \varepsilon_t$$

Where Δs_t will be the change in the S&P 500 index, and the rest of the variables the same as in (1).

In order to get correct estimates we need to make sure that the model is robust, we will need to run a series of tests on the residuals, testing for heteroskedasticity, autocorrelation, etc. We will also have to make sure that the variables in the model are significant.

In addition to the event study we are checking the possibility of running a VAR model estimating the effects of the actual asset purchases, this can be done using transaction data available from the New York Fed. A VAR model is optimal for this as it assumes that the variables are endogenous, allowing for contemporaneous movements.

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